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Notice

City of Elmira Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

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Abstract

Together with the City of Elmira (Elmira), Booz Allen Hamilton has completed the feasibility study for a proposed community microgrid. This study summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is feasible, though not without challenges. The commercial and financial viability of the project are detailed in this document. The Elmira microgrid project faces the challenge of high capital costs, and requires subsidies to be commercially feasible. A new 4.4 megawatt (MW) combined heat and power (CHP) unit and a new 50 kilowatt (kW) solar photovoltaic (PV) array will provide reliable, low-emission electricity and thermal energy to customers while providing a proof of concept for a community microgrid in investor-owned utility (IOU) territory. Seven existing standby generators will also be interconnected to improve the resilience of the energy supply in island mode. Many of the takeaways of the feasibility study may be generalized across the spectrum of NY Prize and community microgrids.

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

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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
CHG&E	Central Hudson Gas and Electric
CHP	Combined Heat and Power
DC	Direct Current
DER	Distributed Energy Resources
DNP3	Distributed Network Protocol
DR	Demand Response
DSP	Distributed System Platform
EDRP	Emergency Demand Response Program
EE	Energy Efficiency
EMS	Energy Management System
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
Hz	Hertz
ICCP	Inter-Control Center Communications Protocol
IEc	Industrial Economics
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor-Owned Utility
ISM	Industrial Scientific and Medical
IT	Information Technology
ITC	Investment Tax Credit
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hour
LAN	Local Area Network
LBMP	Location-Based Marginal Price
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
NYSEG	New York State Electric and Gas Corporation
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
OPC	Open Platform Communication or OLE (Object Link Embedded) Process Control
OPF	Optimal Power Flow
PCC	Point of Common Coupling
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PV	Photovoltaic
RAID	Redundant Array of Independent Disks
REV	Reforming the Energy Vision
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCOPF	Security Constrained Optimal Power Flow
SOA	Service Oriented Architecture
SOW	Statement of Work
SPV	Special Purpose Vehicle
TCP/IP	Transmission Control Protocol/Internet Protocol
T&D	Transmission and Distribution
VAC	Volt Alternating Current

Executive Summary

Booz Allen Hamilton was awarded a contract by the New York State Energy Research and Development Authority (NYSERDA) through its New York Prize initiative to conduct a feasibility study of a community microgrid concept in the City of Elmira (Elmira). This deliverable presents the findings and recommendations from the previous four tasks, discusses the results and lessons learned from the project, and lays out the environmental and economic benefits for the project. The design demonstrates the City can improve energy resilience with intentional and emergency island mode capabilities, stabilize energy prices by relying on its own energy generation assets when statewide electricity demand is high, and comply with the greater New York REV (Reforming the Energy Vision) program by constructing 4.45 MW of energy generation capacity. The study concludes the technical design is feasible, but the project will require subsidies to be financially feasible.

The Elmira microgrid project will tie together a critical facility (per NYSERDA's definition), an important facility, and a residential load cluster into a community microgrid. According to the NY Prize definition, critical facilities are those facilities whose "disruption, incapacitation, or destruction… could jeopardize the health, safety, welfare or security of the state, its residents or its economy." The College can function as a shelter during emergency outages, and the Hilliard Corporation is an important part of the local economy. The Hilliard Corporation currently loses significant productivity and risks damage to equipment during long-term outages. Table ES-1 lists all the facilities under consideration for the microgrid concept at this time, and Figure ES- 1 shows their locations in the City of Elmira.

Table ES- 1. Prospective Microgrid Facilities

Table lists the facilities in the City of Elmira's proposed microgrid, including their economic classifications. The table also denotes critical and important facilities.

Name on Map	Property	Classification
F1	**Elmira College**	School*
F2	**Hilliard Corporation**	Industrial**
F3	**Load Cluster**	Residential**
		* Critical Facility ** Important Facility

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

Figure shows the proposed microgrid and the locations of facilities and DERs. DER locations are approximations and are not meant to reflect actual placement.

In order to meet the energy needs of connected facilities, the microgrid system will incorporate the following existing and proposed generation assets:

- Seven existing backup generators, including four diesel generators and three natural gas generators. These seven generators are split between the Hilliard Corporation and Elmira College, and have an aggregate generation capacity of 2.28 MW
- One proposed 4.4 MW natural gas-fired continuous duty reciprocating generator with combined heat and power capability at Elmira College
- One proposed 50 kW solar PV array at Elmira College

The existing and proposed generation assets will maintain power to connected facilities during emergency outages. The CHP unit and solar array are sized to easily meet the average microgrid load, but if Elmira College and the Hilliard Corporation simultaneously approach their 2014 peak demands, the CHP unit and solar array will require supplemental power from the existing backup generators. The backup power supplied by the microgrid will ensure essential services remain accessible to citizens of Elmira during long-term grid outages. In addition, the CHP unit will supply the college with hot water in the winter months and chilled water in the summer. Existing natural gas infrastructure in Elmira will support continuous operation of the CHP unit. With the addition of these generation assets, the City could experience reduced emissions during peak demand events and could benefit from a more resilient and redundant energy supply to critical services.

The Project Team envisions a hybrid ownership model for the Elmira microgrid, wherein one special purpose vehicle (SPV) owns the new DERs and the local utility, the New York State Electric and Gas Corporation (NYSEG), or a third party operator, owns and operates microgrid infrastructure, controls and software. If NYSEG elects to operate the system they can leverage their energy domain expertise to operate and maintain microgrid components and controls. Elmira College and the Hilliard Corporation will maintain ownership of existing generation assets. The Project Team believes this hybrid model offers the greatest benefits and flexibility to the utility and customer base within the City by bringing private capital into the energy arena and engaging the local investor-owned utility.

Given the high capital expenditures, the project will require NY Prize Phase III funding and possibly additional subsidies to produce a positive net value for SPV owners/investors. Private investors and possibly the local government will own the majority stake in the SPV. Revenue streams from electricity and thermal energy sales will accrue to SPV investors and will cover variable generation costs. SPV investors will remit a fixed payment per kilowatt hour (kWh) to NYSEG to compensate for operation costs associated with the microgrid infrastructure, controls and software.

The microgrid will incur initial capital costs of $9.6 million as well as yearly operation, maintenance, and fuel costs totaling $1.99 million per year. Overall revenue streams from the project are estimated at $2.17 million per year and will be captured primarily through the sale of electricity during grid-connected mode and the sale of thermal resources to the college. Other sources of revenue from the proposed microgrid may include tax credits, incentives, and participation in demand response (DR) programs.

The proposed microgrid's commercial feasibility will likely depend on NY Prize Phase III funding. While the Project Team forecasts yearly revenues that should reliably cover yearly generator operation and maintenance (O&M) costs, cash flows may not be high enough to recover initial investment costs. The project may require extra subsidies (i.e., NYSERDA NY Prize funding) to attract sufficient investor interest to fund the remaining capital costs.

The Elmira microgrid concept, which includes new sources of reliable and renewable energy as well as the integration of existing energy resources, provides the City with an energy resilience solution that is technically sound and, with NY Prize Phase III funding, financially viable. The ability to island two critical facilities and a residential load cluster improves the energy resilience and quality of life in the City during emergencies and extended grid outages.

1. Introduction

The City of Elmira is seeking to develop a community microgrid to improve energy service resilience, accommodate distributed energy resources (DERs), and stabilize energy prices. Working with the City of Elmira (Elmira) and NYSEG, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary microgrid concept that will connect two critical facilities and a residential load cluster with two new generation assets and seven existing standby generators. The design proposes a new 4.4 MW CHP unit at Elmira College, a new 50 kW solar PV array at Elmira College, and the incorporation of seven existing diesel and natural gas generators at Elmira College and the Hilliard Corporation. Section 2 of this document describes the configuration further. In this document, the Project Team discusses the observations, findings, and recommendations from the entirety of the analysis. Within the document, Booz Allen also explores avenues for further development, discusses project results, and shares lessons learned regarding configuration, capabilities, environmental and economic benefits, and implementation scenarios.

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

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

2. Microgrid Capabilities and Technical Design and Configuration

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

2.1 Project Purpose and Need

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

Elmira faces several challenges that could be resolved with a community microgrid:

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

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

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

The NYSERDA statement of work (SOW) 65753 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 Elmira microgrid will meet these criteria.

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

The following sections demonstrates how the design concept meets all of the required capabilities and select preferred capabilities.

[1] While the system will be technically capable of intentional islanding, doing so would cut power flow to other customers on the included feeders and thus will not be feasible for economic purposes.

[2] The microgrid could participate in DR programs by increasing output from the CHP unit or backup generators, but it will not intentionally enter island mode unless there is a forecasted disturbance or outage.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

At this stage of the study, the City of Elmira and the Booz Allen team have identified two critical facilities and one group of residential units that will be connected to the microgrid. Elmira College and the Hilliard Corporation will provide NYSERDA-defined critical services to the community in the case of an outage. The Project Team evaluated other critical facilities in Elmira, but they are located on different feeders, far away from each other. See Table 2 for a full list of prospective facilities to be tied into the microgrid.

Table 2. City of Elmira Critical and Important Facilities

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

Name of Facility	Address	Classification (Critical, Important)
Elmira College	1 Park Place	Critical
Hilliard Corporation	100 W Fourth St.	Important
Load Cluster	307 W 5^{th} St. – 653 N Main St.	Important

The proposed microgrid footprint occupies approximately 60 acres in Elmira. Loads will be interconnected via the existing medium-voltage NYSEG power line along West 5^{th} Street (Madison Avenue 090 distribution line). Distributed microgrid equipment and control software will communicate over NYSEG's WAN utilizing the existing IT fiber optic backbone. Utilizing industry standard protocols, such as Distributed Network Protocol (DNP3), Open Platform Communication (OPC), Modbus, 61850, and Inter-Control Center Communications Protocol (ICCP) (IEC 60870-6) will enable the remote monitoring and control of distributed devices, regardless of manufacturer. The microgrid design is flexible and scalable to accommodate future expansion and technologies.

2.2.2 Limited Use of Diesel Fueled Generators

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

The microgrid control system (MCS) will maximize the deployment of energy from the solar array whenever it is available, and will meet remaining facility demand with electricity from the CHP unit. Backup generators will only be brought on-line if cumulative demand exceeds available generation capacity from the CHP unit and solar array. To conserve the limited supply of diesel fuel and reduce GHG emissions, the MCS will bring natural gas backup generators on-line before diesel backup generators.

2.2.3 Local Power in both Grid-Connected and Islanded Mode

The microgrid will provide on-site power in both grid-connected and island mode. In island mode, the MCS will optimize on-site generation to maintain stable and reliable power flow. The control system is capable of automatic load shedding, but the microgrid does not include the necessary switches to do so.[3] The peak cumulative microgrid load was 6.745 MW in 2014, and proposed generation assets are sized so load shedding in island mode will typically not be necessary. In grid-connected mode, the microgrid will optimize the use of available assets to reduce energy costs when possible and export to the larger NYSEG grid when economic and technical conditions align.

The CHP unit will operate continuously in grid-connected mode, exporting energy to the larger NYSEG grid. The solar PV array will stay on-line throughout the year, but its output will depend on weather conditions and insolation. Provided Elmira College and the Hilliard Corporation do not simultaneously reach their 2014 peak demand, the CHP unit and backup generators have sufficient capacity to provide all of the microgrid's electricity in island mode, guaranteeing facilities will have a reliable source of power regardless of weather or time of day.

2.2.4 Intentional Islanding

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

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

When the Elmira microgrid switches to island mode, it will disconnect all downstream non-microgrid loads that normally receive power from the Madison Avenue 090 feeder. This means the microgrid will not switch to islanded mode to participate in DR programs or to beat high electricity prices during peak demand events. Intentional island mode will only be utilized in forecasted grid outage scenarios.

2.2.5 Resynchronization to NYSEG Power

When operating in island mode, the microgrid will constantly monitor the status of the larger grid and will re-connect when conditions have stabilized. Signals from the MCS will prompt re-connection when monitored operational variables on the larger grid satisfy predetermined

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

conditions. The MCS will be capable of both automatic and manual re-connection using synchronization and protection equipment.

The microgrid design requires a new automated switch along West 5th Street to serve as the point of common coupling (PCC) between the microgrid and NYSEG's system. The control system will trigger the opening or closing of this breaker, as appropriate, during system transitions. See Section 2.7.7 for more information.

2.2.6 Standardized Interconnection

The microgrid design complies with New York State Public Service Commission (NYPSC) interconnection standards. Table 3 outlines the most significant state interconnection standards that apply to this microgrid project. Customers that wish to connect distributed energy resource projects to NYSEG's system must follow the same New York State Standard Interconnection Requirements (SIR) identified in Table 3. The NYPSC Standardized Interconnection Requirements apply to distributed generators with less than 2 MW capacity. Although the proposed CHP unit is larger than 2 MW, generators that are close to 2 MW (approximately 2-4 MW) still usually follow NYPSC SIR. A recent proposal to modify the New York SIR to include generators up to 5 MW has not yet been approved. The proposed CHP unit will likely need to follow the normal New York State SIR, but there is a possibility that interconnection will need to follow the Federal Energy Regulatory Commission (FERC) guidelines for small generators (2-20 MW).[4]

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

Table 3. New York State Interconnection Standards

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

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

Source: NYS Standardized Interconnection Requirements and Application Process, NYPSC

2.2.7 24/7 Operation Capability

The project concept envisions a natural gas-fired generator as the microgrid's main generation source (the solar array will also contribute significantly throughout the year). The City's existing natural gas supply line can support continuous operation of the CHP unit at Elmira College.

The microgrid's continuous operation capability should not be limited by diesel storage tanks. Backup diesel generators will only come on-line as necessary, when cumulative demand exceeds available capacity from the CHP unit, solar array, and natural gas backup generators. Although the peak cumulative load was approximately 6.7 MW in 2014, the average was closer to 2.1 MW. The CHP unit, solar array, and natural gas backup generators should therefore normally have sufficient capacity to provide reliable electricity, assuring at least seven days of continuous operation in island mode.

2.2.8 Two Way Communication with Local Utility

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

2.2.9 Voltage and Frequency Synchronism When Connected to the Grid

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

2.2.10 Load Following and Frequency and Voltage Stability When Islanded

The microgrid's control scheme in island mode operates similarly to the larger transmission system. The system maintains frequency by controlling real power generation and regulates voltage by controlling reactive power availability. To the degree that flexible loads are available, the MCS can curtail facility load—however, the Elmira microgrid is not currently equipped with load shedding capability.

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

2.2.11 Diverse Customer Mix

Connected facilities have different effects on power quality and stability based on load size and economic sector. A microgrid with too many industrial or digital electronics-based loads may be less reliable because these loads can negatively affect power quality and stability. The Elmira microgrid will connect a college, an industrial facility, and a group of residential units. No individual facility will have a significant negative impact on local power quality. The approximate load breakdown by sector for the Elmira microgrid is as follows:[5]

- Elmira College – 51% of load
- Hilliard Corporation – 48% of load
- Load Cluster – 1% of load

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

Together Elmira College and the Hilliard Corporation account for almost all of the microgrid's electricity demand. Targeted energy efficiency upgrades at these facilities could significantly reduce each facility's (and therefore the microgrid's) average electricity demand (see Section 2.2.14 for more details).

2.2.12 Resiliency to Weather Conditions

The City of Elmira is exposed to the normal range of weather conditions that affects the Northeastern United States. Extreme weather events include, but are not limited to, torrential rain, snow, and wind that could cause falling objects and debris to disrupt electric service and damage equipment and lives. By implementing line fault notifications and deploying other sensors, microgrid owners can ensure the network is as resilient as possible to storms and other unforeseen forces of nature. The new CHP unit (the microgrid's main generation asset) will be constructed inside the Waldorf Power Plant or Campus Center Power Plant on Elmira College's campus and will therefore be protected from extreme weather. The solar array will not produce energy during extreme weather events, but the CHP unit and backup spinning generators will be capable of maintaining power to the microgrid without supplemental power from renewable sources.

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

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

2.2.13 Black-Start Capability

The proposed CHP unit will be equipped with black-start capabilities. If the Elmira grid unexpectedly loses power, the MCS will initiate island mode by orchestrating the predefined black-start sequence. The CHP unit will require an auxiliary source of direct current (DC) power to start multiple times in case of failure. The generator will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. After the CHP unit has established a stable power supply, the MCS will synchronize output from the 50 kW solar PV array and bring it on-line.

The included backup generators can also be outfitted with the necessary equipment for black start, if required.

2.2.14 Energy Efficiency Upgrades

Energy efficiency is critical to the overall microgrid concept. Several facilities in Elmira have invested in significant EE upgrades. For example, the Hilliard Corporation recently upgraded lighting and variable frequency drives, and the college has upgraded 25% of its light fixtures to light-emitting diodes (LEDs).

Although these facilities have already begun reducing energy use, there is still significant potential for EE upgrades in Elmira. The college and the Hilliard Corporation currently use almost all of the microgrid's electricity, so targeted EE upgrades will have a major impact on energy security and reliability. The Project Team was unable to obtain information on the specific EE upgrades that could be implemented at these facilities, but they will likely qualify for some of the incentive programs around lighting, HVAC, and building envelope improvements.

The Project Team estimates the reduction potential for the included facilities and load group to be approximately 250 kW or more. The project will leverage existing NYSEG EE programs to reduce load at existing facilities and will seek to qualify for NYSERDA funded EE programs.

2.2.15 Cyber Security

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

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

2.2.16 Use of Microgrid Logic Controllers

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

2.2.17 Smart Grid Technologies

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

2.2.18 Smart Meters

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

2.2.19 Distribution Automation

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

2.2.20 Energy Storage

The Project Team's analysis of battery storage technologies found their cost to be prohibitively high. In a recent study, Lazard estimated the levelized cost of batteries in microgrids to be between $319/megawatt-hour (MWh) to $1,000/MWh, depending on the application.[6] A natural gas generator that runs throughout the year can produce power at well under $100/MWh, and even diesel generators have operating costs of less than $250/MWh. Other technologies provide necessary resiliency in the Elmira microgrid, and battery storage units do not provide sufficient cash flows to recover capital costs even at the lowest prices at this time.

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

2.2.21 Active Network Control System

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

2.2.22 Demand Response

The Elmira microgrid will not intentionally switch to island mode to participate in DR programs because doing so will disconnect all downstream loads on the Madison Avenue 090 feeder. The microgrid's participation in DR programs will therefore be limited to curtailing flexible loads

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

and ramping up generation from the CHP unit or the existing backup generators. The generation assets in the proposed microgrid are sized to approximately match the City's peak demand, so the microgrid cannot guarantee that capacity from these spinning generators will always be available. Participation in DR programs will likely be limited to voluntary participation when capacity is available—specifically, the microgrid may participate in the NYSEG Emergency Demand Response Program (EDRP).

2.2.23 Clean Power Sources Integration

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

2.2.24 Optimal Power Flow

The proposed community microgrid has an average load of approximately 2,101 kW and a peak load of 6,745 kW. The Project Team expects microgrid owners will negotiate a long-term power purchase agreement (PPA) with NYSEG in which proposed DERs are compensated for exporting energy to the larger grid in grid-connected mode. The structure of this power purchase agreement will influence each generator's level of operation throughout the year. The MCS will optimize the output of generation sources at the lowest cost in a unique approach that includes fuel cost, maintenance, and energy cost as part of security constrained optimal power flow (SCOPF).

2.2.25 Storage Optimization

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

2.2.26 PV Monitoring, Control, and Forecasting

The microgrid's PV inverters will usually operate at their maximum power point (MPP) because there is no associated O&M cost. In some rare situations, the 50 kW solar PV array might have to reduce its output to help regulate frequency of local power flow or follow facility electricity demand in island mode. In such situations, the control is almost exclusively local with the output set point communicated by the central controller. As with other renewable energy sources, power output depends on weather and time of day.

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

2.2.27 Protection Coordination

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

2.2.28 Selling Energy and Ancillary Services

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

Most lucrative NYISO ancillary service markets, such as the frequency regulation market, require participants to bid at least 1 MW of capacity. The microgrid's generation assets have an aggregate capacity of 6.73 MW, so participation in these ancillary service markets would represent around 15% of overall generator capacity. Additionally, available generator capacity will likely be minimal because the CHP will be configured to operate continuously and sell energy to NYSEG. Other ancillary service markets, such as spinning and non-spinning reserves, do not provide competitive payments to relatively small scale generators such as the microgrid's 4.4 MW CHP unit. The Project Team has concluded that the microgrid most likely will not participate in NYISO ancillary service markets unless project owners overbuild generation assets.

2.2.29 Data Logging Features

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

2.2.30 Leverage Private Capital

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

2.2.31 Accounting for Needs and Constraints of Stakeholders

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

2.2.32 Demonstrate Tangible Community Benefit

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

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As described above, the Elmira microgrid design includes a new 4.4 MW CHP unit, a new 50 kW solar PV array, and interconnection of seven existing backup generators at the Hilliard Corporation and Elmira College. This section will discuss the benefits of the proposed resources and how they will meet the microgrid's objectives in greater details.

2.3.1 Existing Generation Assets

The Elmira microgrid will incorporate the existing backup generators at Elmira College and the Hilliard Corporation (see Table 4 for details). These assets will only come on-line in island mode when the proposed CHP unit and solar PV array cannot meet aggregate facility demand. The CHP unit and solar PV array are sized to meet aggregate microgrid demand at most times, but if the college and Hilliard Corporation simultaneously approach their peak load, the MCS will need to bring some of the backup generators on-line. Each generator will require grid paralleling switchgear and controllers to regulate and synchronize the generator's output.

In order to reduce GHG emissions and conserve the limited supply of diesel fuel, the MCS will bring the natural gas generators at Elmira College on-line first, followed by the diesel generators at the college and Hilliard Corporation if necessary. Sizes of supply tanks for the existing diesel generators can be found in Table 4. The different tanks can support continuous operation anywhere from four to twenty-two hours.

Table 4. Existing Distributed Energy Resources

Table describes the existing DERs to be incorporated into the microgrid, including their description, fuel source, capacity, and address. Table also provides labels for reference to Figure ES-1.

Name	Description	Fuel Source	Generation Capacity (kW)	Tank Capacity (gallons)	Address
DER1	Backup generator (Hilliard)	Diesel	125	366	100 W Fourth St.
DER2	Backup generator (Hilliard)	Diesel	600	1347	100 W Fourth St.
DER3	Backup generator (Hilliard)	Diesel	900	1600	100 W Fourth St.
DER4	Backup generator (Elmira College)	Natural Gas	150	N/A	1 Park Place
DER5	Backup generator (Elmira College)	Natural Gas	150	N/A	1 Park Place
DER6	Backup generator (Elmira College)	Natural Gas	55	N/A	1 Park Place
DER7	Backup generator (Elmira College)	Diesel	300	500	1 Park Place

2.3.2 Proposed Generation Assets

The microgrid design includes two new generation assets: a 4.4 MW natural gas-fired continuous duty reciprocating generator with CHP capability and a 50 kW PV array system, shown in Table 5. Both new DERs will be located at Elmira College. The CHP system will supply 100% of the college's annual hot water demand, and may provide chilled water for cooling in the summer months. Existing natural gas infrastructure in Elmira will support continuous operation of the CHP unit.

The CHP unit will likely be constructed in the college's Waldorf Power Plant or Campus Center Power Plant and will require approximately 1,500 square feet of space (56 feet by 26 feet). The solar array will likely be ground-mounted on the college's campus and will likely require around 0.1 acres of space.

Table 5. Proposed Generation Assets

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

Name	Technology	Rating (kW)	Fuel	Address
DER8	New Solar PV Array	50	Sun Light	1 Park Place
DER9	New CHP System	4400	Natural Gas	1 Park Place

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides Elmira with two new energy resources. In grid-connected mode, the solar PV array and CHP unit will operate in parallel with the main grid, exporting electricity to the larger NYSEG grid and providing hot water to Elmira College in the winter months. The CHP unit will be outfitted with an absorption chiller, and in the summer months may provide chilled water to the college, Hilliard Corporation, or some combination of the numerous residential or commercial loads surrounding the unit. In islanded mode, the MCS will first deploy energy from the solar array and then regulate output from the CHP unit to meet remaining electricity demand. It will bring backup generators on-line only when cumulative microgrid demand exceeds available capacity from the CHP unit and solar array. The Elmira microgrid's load factor is quite low—the peak cumulative demand is around three times higher than average demand. The CHP unit can easily meet average demand, and because backup generators will only come on-line when the college and Hilliard Corporation simultaneously approach their peak demands, the Project Team expects fairly limited use of the included backup generators.

The CHP unit will be constructed inside the college's Waldorf Power Plant or Campus Center Power Plant, where it will be protected from severe weather events. The natural gas pipeline is already buried to protect it from severe weather. The distribution lines in Elmira will not be buried to provide extra resiliency to storms, wind, and falling trees. The Project Team evaluated the possibility of trenching and burying distribution lines and found the cost to be prohibitively high.

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

The proposed CHP unit will provide:

- Automatic load following capability – the generator will be able to respond to frequency fluctuations within cycles, allowing the microgrid to balance demand and supply in island mode.
- Black-start capability – the generator will have auxiliary power (batteries) for black starts and can establish island mode grid frequency. After the CHP unit has established stable power flow, the main microgrid controller will synchronize the solar array and, if necessary, backup generators to match the CHP unit's frequency and phase.
- Conformance with New York State Interconnection Standards,[7] described in Table 3.

The New York State Public Service Commission publishes Standardized Interconnection Requirements for distributed generators that are smaller than 2 MW. Although the proposed CHP unit is larger than 2 MW, generators that are close to 2 MW (2-4 MW) still usually follow normal Standardized Interconnection Requirements (SIR). The proposed CHP unit will most likely follow the normal New York State SIR, but there is a possibility that interconnection will instead follow the Federal Energy Regulatory Commission (FERC) guidelines for small generators (2-20 MW).[8] However, the NYPSC recently proposed modifications to the SIR that would allow generators up to 5 MW to follow the standards listed in Table 3 above. The Project Team expects that, by the time of construction, the proposed CHP unit will need to follow the normal New York State SIR.

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[7] 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*.

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

2.4 Load Characterization (Sub Task 2.2)

The Project Team sized proposed DERs according to electricity and thermal energy demand data from Elmira's load points. The load characterizations below describe the electrical and thermal loads served by the microgrid.[9] Descriptions of the load sizes to be served by the microgrid along with redundancy opportunities to account for downtime are included.

2.4.1 Electrical Load

The Project Team evaluated two primary electrical loads and a load cluster for the Elmira microgrid. For aggregate weekly, monthly, and yearly energy consumption as well as average and peak power demand, see Table 7. For a cumulative 24 hour load profile, see Figure 2. Typical 24 hour load profiles for each facility can be found in the Appendix.

Elmira's proposed community microgrid will cover Elmira College, the Hilliard Corporation, and a group of residential units between the two primary loads. All included facilities are connected to the same NYSEG feeder in Elmira (Madison Avenue 090).

Table 6. City of Elmira List of Prospective Microgrid Facilities

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

	Property	Address	Classification
1	**Elmira College**	1 Park Place	School
2	**Hilliard Corporation**	100 W Fourth St.	Industrial
3	**Load Cluster**	307 W 5th St. – 653 N Main St.	Residential

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

[9] Estimated loads are based on metering data from the facility's account numbers via NYSEG's on-line metering portal wherever possible. The Project Team simulated load data for the Load Cluster.

Figure 1. Elmira Equipment Layout

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

NYSEG provided the Project Team with twelve months of metering data for Elmira College and the Hilliard Corporation (January through December 2014), summarized in Table 7. The Project Team estimated the intervening residential cluster's load based on facility type, size, and approximate number of customers served. In 2014 the aggregate peak load was 6.745 MW, and the average was 2.101 MW.

Table 7. Elmira's 2014 Microgrid Load Points

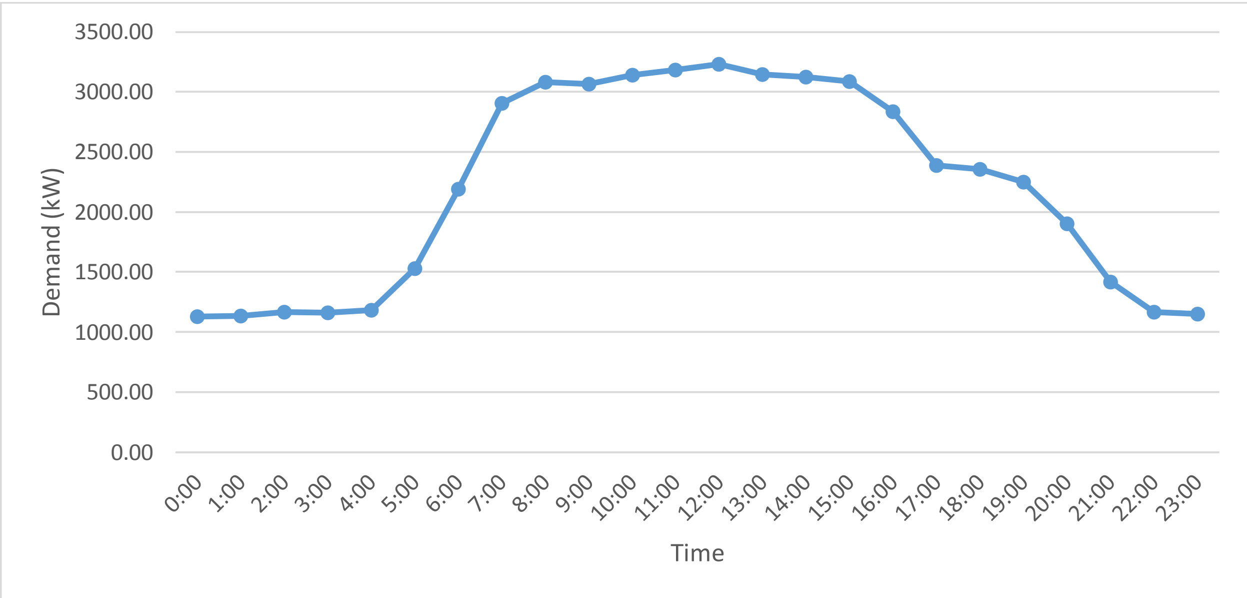
Table shows the microgrid electric demand in kW, electric consumption in kWh, and thermal consumption in MMBTU.

	Electric Demand (kW)		Electric Consumption (kWh)			Thermal Consumption, Heated Water (MMBTU)[10]		
	2014 Peak	2014 Average	2014 Annual	2014 Monthly Average	2014 Weekly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average
Microgrid Loads	6,745	2,101	18,413,999	1,534,500	356,860	49,504	6,188	1,428

Figure 2 provides a typical aggregate hourly load profile for Elmira. Aggregate demand rises sharply around dawn, plateaus at about three times the night-time baseline, then returns to the night-time baseline from 18:00 to 22:00.

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

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



[10] Thermal consumption data estimated for Elmira College. Because the college has negligible thermal energy demand in the summer months, "Monthly Average" and "Weekly Average" represent approximate normal values during the school year. "Yearly annual consumption" value accounts for the summer months. Estimates only include heated water production—they do not include estimates of steam usage for the college or Hilliard Corporation.

The proposed 4.4 MW CHP unit will operate continuously in both grid-connected and islanded mode. The 50 kW solar PV array will also stay on-line throughout the year. Although the output of the solar array will be variable due to weather conditions and insolation, it will typically be most productive when facility demand is highest.

When the solar array is operating close to its name plate capacity, the microgrid's generation capacity will approach 6.73 MW, with a guaranteed 6.68 MW from the CHP unit and spinning backup generators. Aggregate demand from microgrid facilities averaged 2.101 MW and never exceeded 6.745 MW in 2014.[11] Provided all microgrid facilities do not simultaneously reach their peak 2014 loads, the proposed DERs should have adequate capacity to supply the microgrid with continuous, stable power flow.

The Project Team expects some degree of natural load growth after construction of the microgrid. Because generators are sized to approximately match current facility demand, significant load growth could threaten the reliability of the microgrid's electricity supply in island mode. Microgrid facilities can mitigate the threat of natural load growth by investing in energy efficiency upgrades or intelligent building energy management systems (BEMS) that respond to commands from the main microgrid controller. Microgrid owners may also invest in additional supply-side resources such as additional solar PV arrays, small dual fuel generators, or battery storage systems.

The proposed solar array will have downtime available at various points throughout the year when the CHP covers aggregate demand. The CHP unit will also be available for maintenance because the design includes seven standby backup generators that can briefly power the microgrid if the larger grid unexpectedly loses power. The backup generators will only operate in island mode, and therefore should have considerable downtime throughout the year.

2.4.2 Thermal Consumption

The CHP unit will provide hot water for Elmira College. The college currently uses a 10 MMBTU/hour hot water boiler during the winter months. The CHP unit will produce up to 12 MMBTU/hour of hot water at 190-195° F, offsetting 100% of the college's hot water demand in the winter. The Project Team evaluated the thermal energy consumption of the Hilliard Corporation and found that the facility's steam demand did not merit an additional CHP unit.

The CHP unit will also be packaged with a 500 ton absorption chiller that will operate continuously during the summer months. The absorption chiller will ensure thermal energy produced by the CHP during the summer months has an economic value, and could replace chillers at the college or Hilliard Corporation.

11 This number sums the individual yearly peak demands from connected facilities. It therefore assumes that all facilities reached their peak demands at the same time, which is unlikely. The true peak demand was almost certainly less than 6.745 MW, but the Project Team was unable to obtain synchronized real-time load data for all included facilities.

2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1)

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

2.5.1 Grid Parallel Mode

The microgrid will most often operate in grid-connected mode. In this mode, the proposed 4.4 MW CHP unit will operate continuously, exporting electricity to the larger NYSEG grid and providing hot water to Elmira College. The solar PV array will stay on-line throughout the year, although its output will be dependent on weather conditions and time of day. The microgrid design also includes seven existing backup generators, but these DERs will not come on-line in grid-connected mode.

If the larger grid experiences an emergency while the microgrid is connected, the parallel mode control scheme allows for the export of a predetermined amount of active and reactive power from microgrid DERs. By injecting power into the larger grid, the microgrid may be able to balance frequency and voltage to avert an outage.[12]

2.5.2 Intentional Islanded Mode

The proposed energy management and control scheme will balance generation with microgrid demand and maintain adequate frequency, voltage, and power flow across the microgrid network in islanded mode. Islanded mode can be intentionally used during forecasted NYSEG grid outages or disturbances to maintain electricity supply for microgrid facilities—the system will manage the CHP unit, solar array, and backup generators to match aggregate demand in real time. The CHP unit and backup generators can provide real-time response to fluctuations in system frequency and voltage. Refer to the simplified one-line diagram in Figure 3 for a detailed device representation showing both existing and proposed generation assets and their utility interconnection points.

2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)

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

2.6.1 Electrical Infrastructure

The local utility, NYSEG, owns the existing electrical infrastructure in the City of Elmira. The Madison Avenue 090 line is the primary feeder in the microgrid coverage area.

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

The PCC with the NYSEG system will be located along the Madison Avenue 090 feeder (SW1 in Figure 3). One new automated switch will disconnect the microgrid from this feeder at the PCC. Another automated switch will disconnect downstream loads on this feeder (SW2 in Figure 3). Additionally, automated switch SW12 on West Washington Avenue will disconnect the microgrid from the redundant distribution line (Hillcrest Road 316) at Elmira College, which is not necessary for the proposed microgrid design. The team's understanding of this secondary feeder is that it was originally designed to be utilized when the primary Madison Avenue 090 feeder went down. To avoid unnecessary power flows conflicts, SW12 will remain open, thereby, disconnecting the Hillcrest Road 316 distribution line as a secondary feeder.

All of the microgrid's generation assets (including existing generators) will require switchgear and controllers to communicate with the microgrid control system. To ensure compatibility with the MCS, microgrid owners will need to upgrade the existing switches that connect the backup generators to the power supply (SW3-9 in Figure 3). See Figure 1 for a map of proposed equipment and infrastructure. For a detailed outline of microgrid equipment, see the one-line diagram in Figure 3.

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

Table 8. Elmira Distributed Switches Description

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

Name	Description	New/Upgrade
SW1	Automated switch for feeder isolation	New
SW2	Automated switch for feeder isolation	New
SW3	OEM Diesel Generator Switch	Upgrade
SW4	OEM Diesel Generator Switch	Upgrade
SW5	OEM Diesel Generator Switch	Upgrade
SW6	OEM Diesel Generator Switch	Upgrade
SW7	OEM Diesel Generator Switch	Upgrade
SW8	OEM Diesel Generator Switch	Upgrade
SW9	OEM Diesel Generator Switch	Upgrade
SW10	OEM PV Inverter Switch	New
SW11	OEM Generator Switch	New
SW12	Automated switch for feeder isolation	New

Table 9. Elmira's Network Switch Description

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

Name	Description	Status	Address
NS1	Near Switch 1 for communication	Proposed	Refer to Eqp. Layout
NS2	Near Switch 2 for communication	Proposed	Refer to Eqp. Layout
NS3	Near DER 1-3 for communication	Proposed	Refer to Eqp. Layout
NS4	Near DER 4-7 for communication	Proposed	Refer to Eqp. Layout
NS5	Near DER 8-9 for communication	Proposed	Refer to Eqp. Layout
NS6	Near Supervisory Control and Data Acquisition (SCADA)/Energy Management Systems (EMS) servers and workstations for communication	Proposed	1 Park Place
NS7	Near Switch 12 for communication	Proposed	Refer to Eqp. Layout

Table 10. Elmira's Server Description

Table describes the workstation and servers, their status as proposed, and their addresses. The Project Team has assumed that the servers will be placed inside the college.

Name	Description	Status	Address
Workstation	Operator/Engineer workstation	Proposed	1 Park Place
Server1	Primary EMS and SCADA	Proposed	1 Park Place
Server2	Secondary EMS and SCADA	Proposed	1 Park Place

The NYSEG distribution system in Elmira consists of medium voltage lines (4.8 kilovolt (kV)). All branches off these medium voltage lines have their own transformers that step incoming power down to low voltage.

Figure 3. Elmira One-Line Diagram

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

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2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The proposed components and interconnection points for the Elmira community microgrid are listed in Table 11. The design does not include the necessary switches for load shedding capability. The proposed generation assets and existing backup generators will reliably meet peak aggregate demand, so load shedding will not be strictly necessary for the Elmira microgrid. Further, the design only includes three loads. Shedding any one load would drastically reduce the microgrid's value in an emergency situation by disconnecting a large percentage of its customers.

The MCS will also have precise control over generator output and can disconnect any of the generators from the microgrid in real time. The fast ramp rates of natural gas and diesel generators will allow the MCS to provide voltage and frequency control within the millisecond response intervals required for maintaining a stable microgrid.

Table 11. List of Components

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

Device	Quantity	Purpose/Functionality
Microgrid Control System Protocol Converter (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	Protocol Converter responsible for operating the microgrid's field devices via protocol IEC-61850.
Automated, Pole-mount Circuit Breaker/Switches (Siemens 7SC80 relay or equivalent)	3	New relays/controllers at pole mounted distribution switches/breakers. These components will isolate the microgrid from the local feeder and downstream loads. They include synchro-check capability.
Generation Controls (OEM CAT, Cummins, etc.) **Load Sharing Controls (Basler or equivalent)**	8	OEM Generation controllers serve as the primary resource for coordinating generator ramp up/ramp down based on external commands and reaction to Microgrid load changes Basler distributed network controllers allow primary generator to establish Microgrid frequency and supply initial load, while also managing load sharing between other spinning generators. Also manages paralleling sequence.
PV Inverter Controller (OEM Fronius or equivalent)	1	Controls PV output and sends live solar/power output data to SCADA and EMS for forecasting.
Network Switch (RuggedCom or equivalent)	7	Located at IEDs and controllers for network connection, allowing remote monitoring and control.

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

2.6.3 Basic Protection Mechanism within the Microgrid Boundary

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

The current design includes controls that can prevent back-feeding of power to the larger NYSEG grid. However, the business model is structured such that it is assumed power will flow onto the NYSEG grid and be purchased by the utility.

2.6.4 Thermal Infrastructure

The proposed CHP unit requires a steady supply of natural gas to operate. An existing medium pressure natural gas line in Elmira brings a reliable supply of natural gas to the college's steam and hot water boilers. This line will support continuous operation of the CHP unit.

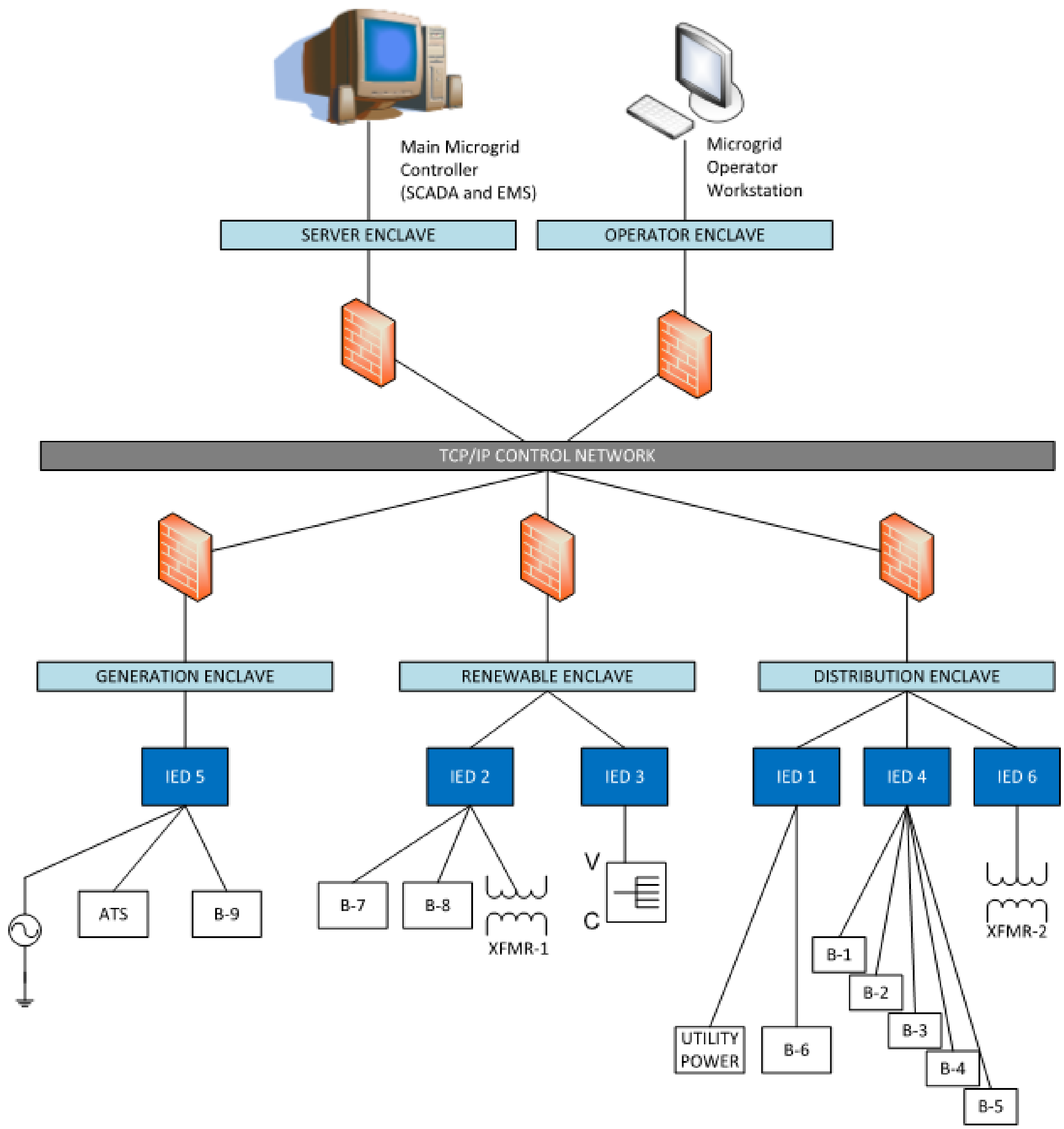
The design uses existing thermal infrastructure to carry hot water from the CHP unit to college facilities. Depending on the final thermal off-taker in the summer months, the design may require new infrastructure to transport chilled water.

2.7 Microgrid and Building Control Characterization (Sub Task 2.5)

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

Figure 4. Diagram of Representative Microgrid Control System Hierarchy

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



2.7.1 Microgrid Supporting Computer Hardware, Software and Control Components

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

- Energy sources – The microgrid requires DERs in order to supply electricity to connected facilities. To some degree, flexible loads that can be reduced during peak demand events may also be considered energy resources.
- Microgrid control system – The MCS is composed of an Energy Management System and SCADA based control center. The MCS is responsible for logging relevant data, regulating generator output, curtailing flexible loads (where possible), and managing transitions between modes of operation.
- Distribution system – The microgrid requires automated switches and breakers to isolate the microgrid from the local feeder and disconnect downstream loads. Other control elements at or near individual loads will allow the MCS to maintain adequate power stability in islanded mode.
- Utility breakers and controls – These automatic controls will interface between the microgrid and the main NYSEG feeder (Madison Ave 090).
- Generator controls/relays – These components will be installed at each generating unit/inverter. They will control generator output based on signals from the MCS.

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

- SOA software platform – The SOA platform facilitates the monitoring and control of included power devices and control systems.
- Redundant Array of Independent Disks (RAID) 5 servers (including 1 primary, 1 backup) for the MCS – The MCS will include an EMS and a SCADA based control center, and will optimize the operation of the microgrid. This includes determining which critical loads will be supplied, integrating PV output into the energy portfolio (including high resolution solar forecasting), and controlling the charge/discharge of energy storage wherever applicable. The system combines information on power quality, utilization, and capacity in real time, which allows the community and control algorithms to balance electricity supply with microgrid demand.
- Historian database server – Historian database collects and logs data from various devices on the network.
- Application servers (one or more) – Depending on the software and hardware vendors' preference, application servers may be used for numerous purposes. Common uses for an application server include (but are not limited to) backup and recovery, antivirus, security

updates, databases, a web server, or use as some other software (depending on how the SCADA and EMS vendors configure their platform).

- Operator workstations for SCADA and EMS – Workstation computers, sometimes called thin-clients, allow operators to view real-time data and control the microgrid from the SCADA control room or a remote location. Users must have proper access rights and permissions to operate workstation computers.
- Intelligent Electronic Device Distribution Switches: Automated pole mount circuit breaker/switch (Siemens 7SC80 relay) – The microprocessor based logic controllers, also referred to as IEDs, are located at or near loads and are programmed to act on predetermined set points. They can also be manually overridden by the MCS or a human operator. The control system host servers continuously poll these logic controllers for data using discrete or analog signals. Resulting data is processed by the IEDs connected to control elements.
- PV Inverter Controller (OEM Fronius or equivalent) – This component will control output from the 50 kW solar PV array and send data to the MCS for forecasting.

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

2.7.2 Grid Parallel Mode Control

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

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

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

2.7.3 Energy Management in Grid Parallel Mode

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

Data logging features will allow the main microgrid controller to measure historical performance and track significant trends. Human operators can use this data to prioritize loads, manage generator output, and schedule maintenance for generators and microgrid components. The microgrid executive dashboard will collect and filter information on the current operating strategy as well as performance metrics for SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), and CAIDI (Customer Average Interruption Duration Index), all adjusted to reflect the high sampling frequency of the system. Other performance metrics include power interruptions (defined as 50% variance of predicted voltage to measured voltage for 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 Hz for more than 10 minutes). The executive dashboard will calculate daily, weekly, and monthly rolling totals for all of these metrics.

After analyzing historical trends and monitoring real-time data, the main microgrid controller will optimize operation of the microgrid by managing generator output and flexible loads.[13] In grid-connected mode the MCS will prioritize the deployment of renewable generation and will aim to offset electrical demand charges whenever possible.

2.7.4 Islanded Mode Control

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

[13] The Elmira microgrid will not have load shedding capability, but by installing intelligent building energy management systems, microgrid customers may be able to reduce load on a signal from the MCS.

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

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

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

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

2.7.5 Energy Management in Islanded Mode

After completing the transition to island mode, the main microgrid controller will perform a series of operational tests to ensure the microgrid is operating as expected and that power flow is stable and reliable. The MCS will gather data on power flow, short circuit, voltage stability, and power system optimization using an N+1 (N components plus at least one independent backup component) contingency strategy to determine whether additional load can be added.[14] The N+1 strategy ensures that extra generation is always online to handle the loss of the largest spinning generator and assumes the running generator with the highest capacity could go off line unexpectedly at any time.

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

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

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

[14] The microgrid control system will not truly have control over load resources unless additional isolation switches or BEMS are installed. The Project Team recommends installing some form of BEMS that will allow the MCS to manage demand side resources.

renewable generation assets and adjust the CHP unit's output to match remaining electricity demand. If necessary, the MCS will bring backup generators on-line. The microgrid design relies on the CHP unit's fast ramp rate to compensate for changing output from the solar array. However, other designs may incorporate battery storage to smooth these rapid fluctuations and ensure a reliable supply of energy when sunlight is not available.

The Booz Allen team found the cost of battery storage to be prohibitively high for the Elmira microgrid. The analysis considered the potential of using storage for three purposes:

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

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

2.7.6 Black Start

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

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

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

The MCS will manage any contingencies that arise during the black-start operation (e.g., breakers do not respond to trip commands and the microgrid does not properly disconnect from the larger grid). If the CHP unit does not start as expected during a utility outage, the MCS is equipped with contingency algorithms to appropriately manage the situation. If possible, the main microgrid controller will still isolate the microgrid, using backup generators to initiate and maintain power flow.

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

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

2.7.7 Resynchronization to NYSEG Power

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

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

Please refer to the Elmira 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 at Elmira is best suited for a wireless microgrid communication system. The communication system and network switches (which have local backup batteries) will communicate wirelessly with the base station located at Elmira College. During the intermittent stage, or black start sequence mode, the headend IT network equipment and base station for the IT network communications system will be powered by their backup batteries. The microgrid design will require minimal additional hardware (i.e., the network switches, WiMax Base Station, WiMax subscriber units, servers, and computers required to manage a microgrid) to seamlessly integrate with the IT system.

2.8.1 Existing IT & Telecommunications Infrastructure

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

2.8.2 IT Infrastructure and Microgrid Integration

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

2.8.3 Network Resiliency

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

For the planning stage, design considerations address cyber security by assigning roles to network-attached components on NYSEG's WAN thereby controlling data flow and access permissions over the integrated MCS and overarching IT architecture.[15] For example, the design utilizes a network segmentation scheme by function (separate segments/enclaves for servers, operators, generation, and distribution), in addition to network firewalls, for clean and continuous monitoring and control of data flow. The firewall routes noncritical traffic such as utility's unrelated corporate printers and other drivers, email, and all other non-essential internet services (which could be backdoors for hackers into the MCS) to a dedicated "demilitarized zone" usually consisting of a single security hardened server.

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

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

disconnects, the program disables the port and thus prevents an unauthorized device that may have malicious code from entering the IT system.[16]

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

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

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

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

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

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

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

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

2.9 Microgrid Capability and Technical Design and Characterization Conclusions

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

In conclusion, the project is technically feasible. However, two significant items remain in order for Elmira's microgrid to become a reality. First, microgrid owners must establish clear business rules of use for the existing backup generators that will be connected. The proposed generation assets were sized assuming that the backup generators could come on-line in island mode, so it is crucial the college and Hilliard Corporation allow their generators to be interconnected. Second, microgrid owners must obtain access to the proposed generators for maintenance and service. The Project Team is currently working with Elmira College and the Hilliard Corporation to ensure access. Because these two facilities are major stakeholders in the microgrid project and have significant incentive to support project completion, the Project Team expects these challenges to be resolved by the time of construction.

The microgrid design proposes three new automated isolation switches and upgrades to existing generator switchgear. Existing natural gas infrastructure in the City will support continuous operation of the CHP unit, and investments in thermal infrastructure to carry hot water from the CHP unit to Elmira College facilities should be minimal.

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:

- Private investors will own the DERs, and NYSEG or a third party operator will own the control and distribution infrastructure. Although NYSEG has neither confirmed nor denied interest in owning and operating microgrid infrastructure, the Project Team views hybrid ownership as a simple, effective model that provides benefits to both NYSEG and the SPV.
- The CHP unit and solar array will sell electricity to NYSEG at the average local supply charge (the price NYSEG currently pays to purchase electricity, excluding transmission,

distribution, and capacity charges). Elmira College will purchase thermal energy produced by the CHP unit.

- NYSEG, as the local expert in energy distribution and the current owner and operator of the City's distribution infrastructure, will operate the microgrid via a long-term operations and maintenance contract. NYSEG's existing infrastructure is used extensively in the preliminary microgrid design, so operational participation from the utility is vital to the project's success.
- The current regulatory, legal, and policy environment will stay consistent. The proposal outlined in this report falls within the existing frameworks.

The microgrid design relies on the SPV to finance the construction of the CHP unit and the solar array, while NYSEG will construct the required microgrid infrastructure and control components. Elmira College and the Hilliard Corporation will retain ownership of existing standby generators, and will be compensated for the operation of those systems during island mode. As the Elmira microgrid proposal may not qualify for ancillary services or demand response given the small system size and placement on the feeder with downstream loads. The project's cash flows will likely be limited to sale of electricity and thermal energy. Although the project will consistently generate positive operating profits, cash flows will not recover initial investment costs without additional subsidies.

3.1 Commercial Viability – Customers (Sub Task 3.1)

Elmira College and the Hilliard Corporation provide critical services (as defined by NYSERDA) to the City during emergency situations. The project will affect several groups of stakeholders in the Elmira community not physically connected to the microgrid—the benefits and challenges to these stakeholders are discussed further in this section.

3.1.1 Microgrid Customers

The Elmira microgrid includes two critical facilities and a residential load cluster (see Table 12 for a list of direct microgrid customers). These customers will continue to purchase electricity from NYSEG throughout the vast majority of the year. However, when there is an outage on the larger NYSEG system, the microgrid will switch to island mode and customers will purchase electricity directly from the microgrid SPV via NYSEG infrastructure. The transition to islanded operation may be intentional or unintentional.

Table 12 (below) identifies each of the direct microgrid customers. The full group of stakeholders that will benefit from the microgrid is discussed in Section 3.2.3.

Table 12. Microgrid Customers

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

Property	Address	Classification	Critical Service	Back-up Generation
Elmira College	1 Park Place	School	Yes	Yes
Hilliard Corporation	100 W Fourth St.	Industrial	Yes	Yes
Load Cluster	307 W 5th St. – 653 N Main St.	Residential	No	No

3.1.2 Benefits and Costs to Other Stakeholders

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

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

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

Details of each will be discussed in turn below.

Supply of power during emergency outages: The microgrid will supply power to two critical facilities as well as a small residential load cluster. The critical facilities can provide shelter to residents of the City in the event of a long-term grid outage.

Electricity generation in grid-connected mode: The new 4.4 MW CHP and 50 kW solar array will operate throughout the year in grid-connected mode, selling electricity to NYSEG under a long-term PPA. Continuous energy generation will reduce load for the larger NYSEG system during both peak demand events and normal periods of operation, stabilizing electricity prices in the area and possibly deferring the utility's future capacity investments. Although Elmira is not considered a congestion point on the larger NYSEG and NYISO systems, peak load support from proposed generation assets will reduce congestion costs to NYISO, NYSEG, and their electricity customers.

Thermal energy generation in grid-connected mode: The CHP unit will be outfitted with a water heater and absorption chiller to provide thermal energy to Elmira College throughout the year. In the winter months the college will purchase hot water from the SPV. In the summer months the college will purchase chilled water from the SPV. Cogenerated thermal energy will provide nearly all of the college's hot water demand, replacing an existing high pressure hot water boiler in the Campus Center Power Plant. The college will benefit from reduced operation and maintenance costs associated with this boiler.

Cash flows to DER owners: Cash flows will be limited to electricity sales to NYSEG and thermal energy sales to Elmira College. The microgrid project will produce consistently positive operating cash flows, but they will not be high enough to cover financing costs or recover initial capital costs. The project's commercial viability therefore depends on NYSERDA NY Prize Phase III funding.

Upfront capital investment and land requirements: The primary costs will be purchasing and installing necessary microgrid equipment and proposed generation assets. Elmira College has moderate land available for the proposed 50 kW solar PV array on campus, but this array will prevent any alternative future use of the land. The college owns several natural gas-fired boilers housed in two primary boiler rooms: the Waldorf Power Plant and the Campus Center Power Plant. Either of these rooms would be an ideal location for the CHP.

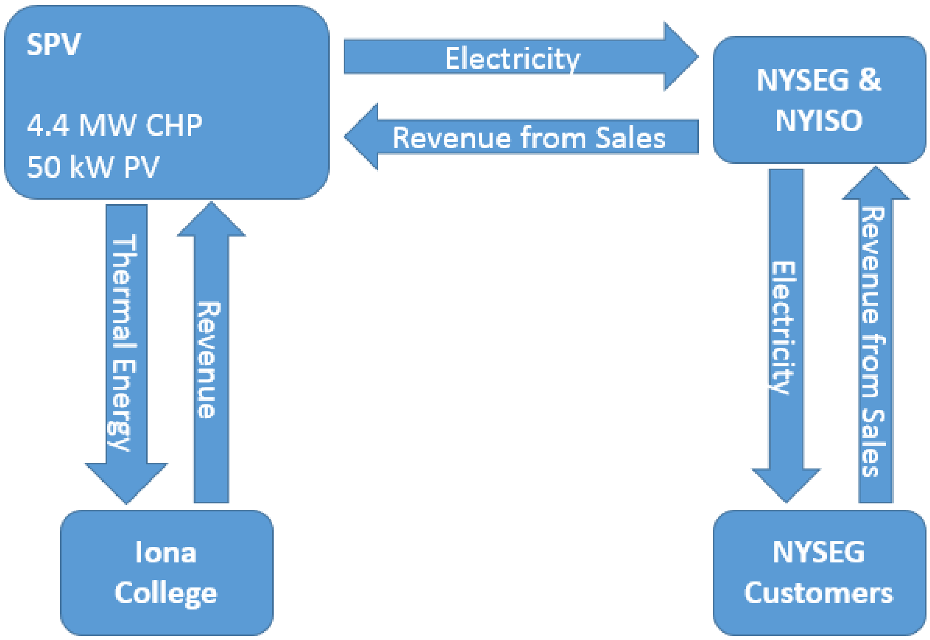
3.1.3 Purchasing Relationship

In grid-connected mode, the SPV will sell electricity from the proposed CHP unit and 50 kW solar array to NYSEG under a long-term PPA.[17] Microgrid connected facilities will maintain their current electricity-purchaser relationship with NYSEG during grid-connected mode. In island mode, however, the facilities will be physically disconnected from the larger grid and directly supplied by the proposed generation assets. NYSEG will continue to bill microgrid facilities as normal, and proposed DERs will continue to sell electricity to NYSEG under a long-term PPA. However, the CHP unit will be configured to follow the microgrid's electrical load in island mode rather than operating at full capacity. Islanded operation contracts will be established during development and construction, and will address both the order in which islanded facilities are brought back on-line following an island event and the associated cost for participating in the microgrid. See Figure 5 below for the purchasing relationships.

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

Figure 5. Normal Operation Purchasing Relationship

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



3.1.4 Solicitation and Registration

The microgrid design team will work with the City and utility to formalize agreements with the critical facilities identified. This outreach will include informal discussions and, ultimately, signed agreements of participation in the microgrid and any fee structure determined by the 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 agreements with the utility. The Project Team views registration as an operational feature and not a legal requirement.

3.1.5 Energy Commodities

Proposed generation assets include a 4.4 MW CHP unit and a 50 kW solar PV array. During normal operation, electricity from these assets will be sold to NYSEG and distributed on the NYSEG system as dictated by system needs. Conversely, if NYSEG wishes to prevent energy from flowing to the grid, the generation assets will be equipped with controls that have the necessary hardware and protection scheme to prevent back-feeding power into the system. The SPV will sell co-generated hot water to Elmira College in the winter months and will switch to chilled water in the summer months.

The volume of electricity purchased from the CHP will depend on the generator's output as dictated by the microgrid controllers, system demand, and agreements between the SPV and NYSEG. It will likely operate at nearly full load throughout the year in order to maintain a steady supply of thermal energy to Elmira College. The CHP will not participate in NYISO ancillary service markets because most lucrative markets require at least 1 MW of available capacity, which represents around 23% of the CHP unit's nameplate capacity. The requisite fast changes in output would also make the CHP unit's thermal output unpredictable, which would discourage the college from purchasing co-generated thermal energy. Ancillary service markets that do not have minimum capacity requirements (such as spinning and non-spinning reserves) rarely offer competitive payments. As such, ancillary services sales are unlikely.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to Elmira, private investors, NYSEG, direct participants, and the larger State of New York. The new 50 kW solar array and 4.4 MW CHP unit will produce reliable, relatively low-emission electricity in both normal and islanded operation. SPV members will receive stable cash flows from operation of the proposed energy generation resources for the life of the project. The benefits, costs, and total value of the microgrid project are discussed in detail below.

3.2.1 Business Model

An SPV will own the proposed DERs, while NYSEG will own microgrid infrastructure and operate the system. In grid-connected mode, the SPV will sell electricity to NYSEG and thermal energy to Elmira College. In islanded mode, electricity will flow directly to microgrid facilities, but NYSEG will continue to bill facilities for electricity usage and pay the SPV for electricity from the DERs. The SPV will continue to sell thermal energy directly to Iona College in island mode. SPV members will receive shares of operating cash flow that correspond to their initial investments. Investors will determine the most appropriate financing mix to achieve their financial goals. As NYSEG will be responsible for the installation, ownership, and operation of the non-revenue generating controls infrastructure, as well as the operation of the DERs, the SPV will remit payment to NYSEG to offset these costs. Elmira College and the Hilliard Corporation will retain ownership of existing backup diesel generators, and will be compensated appropriately for their operation in island mode.

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

Table 13. Elmira Microgrid SWOT Analysis

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

Strengths	Weaknesses
• Full NYSEG participation in operation and ownership may demonstrate to other IOUs the value of community microgrids in their service territories and prove out a win-win for the utility and ratepayers • Allows for the use of existing transmission and distribution infrastructure, thereby reducing the potential cost burden of constructing new lines and feeders (microgrid project will only require isolation switches to disconnect the microgrid from the feeder and downstream loads) • Co-generated thermal energy will provide an additional revenue stream to the SPV and replace an existing high pressure hot water boiler at Elmira College • Draws on NYSEG's expertise to facilitate daily operation of the microgrid (load aggregation, load following, voltage regulation, and other requirements) • Engages key critical facilities as well as local residents and businesses	• Selling electricity at NYSEG's supply price and thermal energy at a competitive local rate will not recover all initial investment costs. The commercial feasibility of the project therefore depends on NYSERDA NY Prize Phase III funding • Separating significant capital costs from the revenues necessitates further agreement between revenue drivers (DERs) and control infrastructure owners (NYSEG). DER owners may balk at paying revenue into non-revenue generating components
Opportunities	**Threats**
• Encourages teamwork between local government, private investors, and local investor-owned utilit. Because most communities are served by IOUs, this model could serve as a template for future projects • Demonstrates the feasibility of reducing load on the larger grid with distributed energy resources • Provides a proof point for utility operated microgrids in partnership with silent DERs investor group	• Changes in regulatory requirements could impact the proposed business model and stakeholder goals. • If natural gas prices increase, it will significantly raise the microgrid's marginal cost of producing electricity, which may prompt a re-negotiation of NYSEG's purchasing price

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

- **Financial** – SPV members will seek a long-term PPA, or some other form of long-term purchase agreement, with NYSEG to guarantee steady future revenue streams. As long as the agreement reliably guarantees fair compensation for generator output over the project lifespan, SPV members must be content with flexible compensation rates and a low amount of risk. NYSEG's average supply price of electricity is too low to ensure full recovery of initial investment costs without subsidies. This weakness is partially offset by NY Prize Phase III funding, which is a requirement for project viability.
- **Organizational Competition** – This business model requires collaboration among groups of stakeholders that may have different motivations for participation in the

microgrid project. NYSEG will construct and own non-revenue generating control infrastructure and switchgear with an expectation of financial support from DER revenues. DER owners will see significant revenues from their assets and may be disinclined to support the non-revenue assets. Further, though NYSEG will have no ownership interest in the generation assets, they could exercise day-to-day operational responsibility for them according to an agreement with the SPV if the SPV was not interested in operations and maintenance. This arrangement may misalign incentives if NYSEG can source electricity from other suppliers at a lower rate than the price paid to the SPV. Open communication and early agreement between NYSEG and private DER investors regarding operational parameters, volumes of electricity to be purchased, and the price per unit of electricity will be paramount for the smooth operation of the microgrid.

- **Regulatory** – Utilities in New York State cannot own generation assets unless they demonstrate why full vertical integration provides value to their customers. The State of New York wishes to avoid situations in which a single entity monopolizes energy generation and distribution resources. Utilities may not purchase DERs, and microgrid investors that purchase distribution infrastructure may be considered utilities. To avoid this regulatory threat, the SPV will purchase only new generation assets, while NYSEG will retain ownership of existing power lines and new distribution infrastructure. The proposed business model will therefore function within the existing regulatory landscape and may provide evidence that privately owned generation assets can successfully sell electricity over a utility-owned power distribution platform.

3.2.2 Replicability and Scalability

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

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

Organizational Replicability. Because most municipalities in NYS follow a similar electricity model in which the local IOU distributes power purchased from third-party owned generation assets, the project’s power distribution structure is easily replicable, if novel. Private DER ownership coupled with utility infrastructure ownership is both replicable and desirable as it brings private capital into the energy arena and provides a platform for utilities to realize revenue from the projects. A model in which an IOU has full operational control over the generation assets without any financial stake in them is not one that has been widely implemented. It is the opinion of the Project Team, however, that the proposed model provides a path ahead for grid-integrated microgrids in a fashion that engages utilities, which may otherwise be skeptical of their value proposition. The model may also promote innovations in rate calculations and help change the services that IOUs are expected to provide. Its replicability expands the potential market for resulting innovations to include a larger part of New York State. As such, this project presents a valuable opportunity for NYSERDA to examine the changing role of the investor-owned utility in energy generation and distribution.

The proposed generation assets qualify for significant incentive payments—the NY Sun program will offset around 30% of the solar array's capital cost, the Federal investment tax credit (ITC) will offset an additional 30% of the solar array's capital cost, and the NYSERDA CHP Performance Program will recover around $2 million of the CHP's capital cost in the project's first three years. However, after these incentives, the project's commercial viability still depends on NYSERDA NY Prize Phase III funding, which will not be available to most community microgrid projects. This hinders the project's replicability.

Scalability. The Elmira microgrid is scalable on the Madison Avenue 090 feeder, but expansion would require the addition of new isolation switches as well as additional generation. Expanding the microgrid to adjacent feeders would require new lines, new switches and breakers, and additional power flow studies to ensure safe operation of the microgrid. Incongruent line voltages could further increase the electrical complexity of linking two different feeders.

3.2.3 Benefits, Costs, and Value

The microgrid will provide widely distributed benefits, both direct and indirect, to a multitude of stakeholders. The SPV will receive stable cash flows for the lifetime of the project, the City and citizens will benefit from a more resilient electricity system, and the community will reap the positive effects of living in and around the microgrid during times of emergency. These costs and benefits are described in Tables 14 through 19. Moreover, the local community will not bear any of the project's costs. However, without funding from NY Prize Phase III, the cash flows generated by proposed DERs will not fully recover initial investments at NYSEG's average supply rates. This proposal involves a wide group of stakeholders—from local, non-customer residents to the State of New York—and provides value to all involved parties.

Tables 14 through 19 below provide an overview of the benefits and costs to members of the SPV, direct microgrid customers, citizens of Elmira and surrounding municipalities, and the State of New York.

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
SPV	- Investors will receive annual cash flows from electricity sales, thermal energy sales, and microgrid connection or participation fees - Federal ITC and NY Sun incentive together recover around 60% of solar array's cost in the project's first year - CHP Performance Program pays around $2 MM in the project's first three years - NY Prize Phase III funding would recover 50% of capital costs	- Initial capital outlay will be moderate because the SPV must purchase and install generation assets - Forecasted installed capital costs for the solar array and CHP unit are $120,000 and $8.8 MM, respectively - Ongoing maintenance of DERs - Financing costs associated with initial capital outlay will persist for many years	- Low risk returns assured through long-term purchase contracts make the proposed DERs an attractive investment

Table 15. Benefits, Costs, and Value Proposition to NYSEG

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

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

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

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

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

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Connected Facilities	- Resilient and redundant energy supply to operations - Access to a local market for distributed energy resources makes investments in small DERs more attractive to connected facilities - Thermal energy from the CHP unit will reduce the need for existing high pressure heat boilers at Elmira College	- Slightly higher electricity prices during island mode	- Maintain operations during emergency outages and provide valuable critical services to the Elmira 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 - Elmira College will reduce operation and maintenance costs associated with generating thermal energy

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

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

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

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

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

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

3.2.4 Demonstration of State Policy

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

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

3.3 Commercial Viability – Project Team (Sub Task 3.3)

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

3.3.1 Stakeholder Engagement

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

3.3.2 Project Team

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

Table 20. Project Team

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

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

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

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

3.3.3 Financial Strength

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

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

Given the relatively reliable return on investment for solar PV arrays and efficient CHP units, the microgrid project should attract attention from outside investors. However, the project will require subsidies to reach a competitive IRR.

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.

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

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

The Elmira microgrid includes numerous components that have been previously used and validated. Solar PV and natural gas CHP units are both widely used technologies, with more than 6 gigawatts of solar PV installed in 2015 in the United States. In NY State alone, there are more than 400 installed reciprocating CHP units with aggregate nameplate generating capacity that exceeds 295 MW.[18] The switch components are all industry standard and are widely used in utilities worldwide, and the intelligent electronic devices, which are robust and safe via embedded electrical protections, are similarly standard across the industry. Siemens microgrid technologies are recognized worldwide for their flexibility, reliability, and expandability—successful examples of Siemens microgrid technology at work include the Parker Ranch and Savona University microgrids.[19] Team partner Power Analytics has similarly successful implementations of its Paladin software in microgrid environments, including the 42 MW, 45,000 person UC San Diego microgrid project.[20]

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

3.4.2 Operation

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

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

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

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

3.4.3 Barriers to Completion

The barriers to constructing and operating the microgrid are primarily financial. The high capital costs and relatively long payback make the investment a difficult one. Assuming the SPV will sell electricity to NYSEG at their current supply charge through a long-term purchase agreement, the microgrid will produce positive operating cash flows from year to year. 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. The Elmira microgrid qualifies for several state and federal incentives for DER assets—the NY Sun program, Federal ITC, and NYSERDA CHP Performance Program will together offset around 22% of total project cost—but requires additional subsidies to become financially feasible. As such, it must rely on NY Prize Phase III funding or other subsidies for its commercial viability.

3.4.4 Permitting

The Elmira microgrid may require certain permits and permissions depending on the ultimate design choices. Proposed DERs will likely need to be permitted under local code 116-17 (Non-residential Structures), but will be located on the Elmira College campus. Elmira College deploys several natural gas-fired boilers for steam and hot water throughout the year, and the CHP unit will be placed in one of the existing boiler rooms. It will therefore require the same or similar permits as the existing boilers. Elmira is not in any EPA Criteria Pollutant Non-Attainment zones. The CHP unit will require air quality permits pursuant to the Clean Air Act.

3.5 Financial Viability (Sub Task 3.5)

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

3.5.1 Revenue, Cost, and Profitability

The microgrid has a number of savings and revenue streams, as outlined in Table 22. The revenues will sum to approximately $2.17 million per year, while fuel, operation, and maintenance will cost around $1.99 million per year. Although yearly cash flows will consistently be positive, they do not recover initial investment costs after discounting. The commercial viability of the Elmira microgrid project is therefore dependent on Phase III NY Prize funding.

Table 22. Savings and Revenues

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

Description of Savings and Revenues	Savings or Revenue	Relative Magnitude	Fixed or variable
Electricity sales from CHP unit[21]	Revenue	$1.98 MM/yr	Variable
Thermal energy sales from CHP unit	Revenue	$185,000/yr	Variable
Electricity sales from solar PV array	Revenue	$4,000/yr	Variable
Total Yearly Revenue and Savings		**$2.17 MM/yr**	Variable

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

Table 23. Capital and Operating Costs

Expected costs from construction and operation of the microgrid.

Description of Costs	CapEx or Ops	Relative Magnitude	Fixed or Variable
4.4 MW CHP unit	Capital	$8.8 MM	Fixed
50 kW solar PV array	Capital	$120,000	Fixed
Distributed Equipment	Capital	$160,000	Fixed
Microgrid Control System	Capital	$450,000	Fixed
IT costs (wireless and cables)	Capital	$60,000	Fixed
Total CapEx		**$9.59 MM**	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 MM**	Fixed
CHP Fuel	Operating	$1.46 MM/yr	Variable
CHP Maintenance	Operating	$460,000/yr	Variable
Solar PV Maintenance	Operating	$1,000/yr	Variable
Microgrid Control O&M	Operating	$70,000/yr	Fixed
Total OpEx		**$1.99 MM/yr**	Variable

The proposed microgrid will qualify for three existing incentive programs: the NY Sun program, the Federal solar ITC, and the NYSERDA CHP Performance Program. Together these incentive programs provide around $2.1 million over the first three years of the project, or approximately 22% of total project capital expenditures. Other possible sources of incentive payments include NYSERDA Phase III NY Prize funding (up to $5 million but will not exceed total capital costs). See Table 24 for details on the available incentive programs.

Table 24. Available Incentive Programs

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

Incentive Program	Value	Required or Preferred
NYSERDA NY Prize Phase III	$4,800,000	Required
NY Sun	~$36,000	Required
Federal Solar ITC	~$36,000	Required
NYSERDA CHP Performance Program	~$2,000,000	Required

3.5.2 Financing Structure

The development phase is characterized by the negotiation and execution of the construction financing and debt structure and agreements with any equity partners. Awards from Phase II of the NY Prize Community Microgrid Competition will supply most of the funding for project design and development, with the SPV providing capital for any costs that exceed available NYSERDA funding. The Project Team anticipates NYSERDA to supply 75% of the required funds for Phase II with the balance coming from a cost-share. This is based on the Phase II cost structure as described in NYSERDA RFP-3044. Elmira and their Project Team will provide cash support or needed in-kind services consisting primarily of system expertise and support. Development will conclude with formal contract relationships between the utility and the customers of the microgrid, available and relevant rate and tariff information from the NYPSC, and firm financing for the construction of the project (described below).

The SPV and NYSEG will leverage Phase III funding from NYSERDA to complete the construction phase. Phase III NY Prize funding, which will provide up to $5 million to the SPV for microgrid and DER equipment and installation, will cover half of the capital cost of the project (estimated to be approximately $4.8 million in total), and private and utility funding will represent the balance of the financing.

The Project Team assumes that Elmira College will grant the physical space to site the DERs at no cost because they will be the primary beneficiary of the proposed microgrid. The SPV will maintain ownership over all generation assets and NYSEG over the control infrastructure.

3.6 Legal Viability (Sub Task 3.6)

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

3.6.1 Regulatory Considerations

State and Utility Regulation

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

Local Regulation

All entities that require the use of public ways (i.e., for transmission or distribution facilities) must be granted permission by the presiding municipal authority in the form of a franchise or some lesser consent, depending on the scope of the usage. Cities in New York have specific statutory authority to grant franchises. As the distribution infrastructure already exists in Elmira, new permissions for the running of lines should not be a concern. As outlined in City zoning documents, a zoning permit is required for the modification in use of any property and this may apply to the accessory addition of distributed energy resources. Given the relatively small scale of the proposed generating assets and the municipal support for the project, the Project Team does not foresee this condition as prohibitive.

Air Quality

Natural gas generators may be subject to a variety of federal permits and emission standards depending on the type of engine, the heat or electrical output of the system, how much electricity is delivered to the grid versus used onsite, and the date of construction. The specific details associated with the proposed reciprocating generator in Elmira 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 (diesel generators)
- NSPS for Stationary Spark Ignition (SI) ICE: 40 CFR part 60 subpart JJJJ (natural gas generators)

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

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

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

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

3.7 Project Commercial and Financial Viability Conclusions

The Elmira microgrid project will include two critical facilities from the City of Elmira (Elmira College and the Hilliard Corporation) and a residential cluster. Private investors will finance an SPV for the purchase of the proposed DERs, and NYSEG will finance the capital expense of microgrid control infrastructure. NYSEG, or a third party operator, will operate the control infrastructure as well as the DERs, under an agreement with the SPV, and will be responsible for the safe operation and maintenance of all components.

The proposed microgrid's commercial feasibility depends on NY Prize Phase III funding or other subsidies. Its design includes two new DERs to be located at Elmira College: a 4.4 MW natural gas fired CHP unit and a 50 kW solar photovoltaic array. The SPV will provide the capital required to purchase and install these generators and will receive revenues from electricity and thermal energy sales throughout the generators' lifespan. Investors in the SPV will contribute funds to the daily operation and maintenance of the DERs, and NYSEG will leverage its local expertise to keep the microgrid components and control infrastructure running smoothly. The Project Team forecasts yearly revenues of approximately $2.17 million and yearly operation and maintenance costs of approximately $1.99 million. The project will produce positive annual operating cash flows, but these cash flows will not recover investment costs without additional subsidies.

These estimates and value propositions are predicated on several assumptions.

- Private investors will own the DERs, and NYSEG will own the control and distribution infrastructure. Although NYSEG has neither confirmed nor denied interest in owning and operating microgrid infrastructure, the Project Team views hybrid ownership as a simple, effective model that provides benefits to both NYSEG and the SPV.
- The CHP unit and solar array will sell electricity to NYSEG at the average local supply charge (the price NYSEG currently pays to purchase electricity, excluding transmission, distribution, and capacity charges). Elmira College will purchase thermal energy produced by the CHP unit.
- NYSEG, as the local expert in energy distribution and the current owner and operator of the City's distribution infrastructure, will operate the microgrid. NYSEG's existing infrastructure is used extensively in the preliminary microgrid design, so operational participation from the utility is vital to the project's success.
- The current regulatory, legal, and policy environment will stay consistent. The proposal outlined in this report falls within the existing frameworks.

The microgrid will not enter island mode to participate in DR programs, as doing so would disconnect downstream customers on the Madison Avenue 090 feeder.

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

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

4. Cost Benefit Analysis

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

- ***Section 4.1*** analyzes the *facilities connected to the microgrid* and their energy needs.
- ***Section 4.2*** discusses the *attributes of existing and proposed DERs*, including factors such as nameplate capacity and expected annual energy production.
- ***Section 4.3*** analyzes *potential ancillary services sales and the value of deferring transmission capacity investments*.
- ***Section 4.4*** reviews the *overall costs* associated with construction and installation of the microgrid as well as the fuel, operation, and maintenance costs required over the lifetime of the microgrid.
- ***Sections 4.5 and 4.6*** discuss the *community benefits* of maintaining power during a grid-wide outage and outline the costs associated with operating the microgrid in island mode.
- ***Section 4.7*** presents the Industrial Economics (IEc) *benefit-cost analysis report and associated Project Team commentary*.

4.1 Facility and Customer Description (Sub Task 4.1)

The Elmira microgrid will include three facilities from various rate classes and economic sectors. NYSERDA designates three primary rate classes based on type of facility and annual electricity consumption: residential, small commercial (less than 50 MWh per year), and large commercial (greater than 50 MWh per year). See Table25 for basic statistics on each facility's energy usage. Two of the proposed microgrid facilities belong to the large commercial rate class requiring approximately 18,164 MWh of electricity per year. One of the proposed microgrid facilities belongs to the residential rate class requiring approximately 250 MWh of electricity per year. Additionally the average aggregate demand in 2014 was 2.10 MW and rose as high as 6.74 MW.

There are three kinds of facilities in the microgrid including educational, commercial, and residential in the proposed Elmira microgrid footprint. The education facility, Elmira College, represents the largest electricity load, comprising more than 51% of the microgrid's total annual electricity usage. The commercial facility, the Hilliard Corporation, makes up 48% of electricity usage while the residential facility, the Load Cluster, makes up the remaining 1% of the electricity usage.

The combination of existing and proposed generation assets included in the microgrid design will be capable of meeting 100% of average aggregate facility energy usage during a major power outage, but may approach their generation limits if several large facilities simultaneously reach peak energy use. In these situations, the backup generators will need to come online to supply additional electricity. For information on each facility's average daily operation during a major power outage, see Table 25.

Table 25. Facility and Customer Detail Benefit[22]

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

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[22] Load data was provided to Booz Allen by NYSEG.

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates new and existing DERs, including seven existing diesel generators, a proposed CHP system, and one proposed solar PV array. The proposed CHP unit and solar PV arrays will produce an average of 3.474 MW of electricity throughout the year[23] (including projected capacity factors), and the existing backup generators at Elmira College and the Hilliard Corporation will provide up to 2.28 MW of backup generation capacity during emergencies.

The CHP has a nameplate capacity of 4.4 MW and will operate nearly continuously. Assuming a capacity factor of 85%, the CHP will produce approximately 32,762 MWh of electricity over the course of the year. If a major power outage occurs, the CHP will produce an average of 89.76 MWh of electricity per day, which would provide over 100% of the microgrid's average daily demand. The CHP system will use around 9.5 Mcf (1000 ft^3) of natural gas per MWh generated, which amounts to a fuel cost of around $45/MWh to operate.[24]

Limited by weather conditions and natural day-night cycles, the 0.05 MW solar PV array is expected to produce a combined 61 MWh per year. Because many outages are caused by severe weather events, solar panels cannot be relied upon to provide energy during emergency outages without supplementary battery storage. However, on average the solar array will produce 0.168 MWh of electricity per day, which represents 0.3% of average daily electricity demand from microgrid-connected facilities. Maintenance costs for the solar array will be around $1,000 per year,[25] which means the marginal cost of producing solar electricity will be about $34/MWh.[26]

The existing backup generators at Elmira College and the Hilliard Corporation will be used only in emergency situations when the microgrid requires a black start or when the proposed CHP and solar array are not producing sufficient electricity to meet aggregate demand. The diesel generators at the Hilliard Corporation have a combined nameplate capacity of 1.625 MW, while the diesel and natural gas generators at Elmira College have a combined nameplate capacity of 0.655 MW. This total of 2.28 MW of backup generation capacity could be vital in emergency situations, or when the solar array or CHP go offline for maintenance. The Booz Allen team forecasts around 1.153 hours of larger grid outage based on NYSEG's Customer Average Interruption Duration Index from 2013,[27] and therefore predicts annual output from the backup generators will be insignificant. The backup diesel generators require around 159 gallons of fuel

[23] NG generator capacity factor: 85% (EPA estimate for 10 MW generator, http://www3.epa.gov/chp/documents/faq.pdf), Solar array capacity factor: 14% (NREL PV Watts Calculator).
[24] Price of natural gas: $5.74 per Mcf (average CHG&E supply price from 2013-2015).
[25] Annual fixed O&M cost: $20/kW per year (NREL, http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html).
[26] Capital cost: $717,500 (pro-rated from Siemens estimate for 2 MW solar array), Variable cost: 30 years of production at a cost of $20/kW per year (Siemens lifecycle estimate, NREL), Discount rate: 7% (industry standard discount rate; NREL http://www.nrel.gov/docs/fy13osti/58315.pdf).
[27] Grid outage data from DPS 2013 Electric Reliability Performance Report (NYSEG average CAIDI).

per hour of operation[28], while the backup natural gas generator requires 25.26 Mcf per hour. [29] In the event of a major power outage, the generators could produce up to 54.7 MWh/day.[30] See Table 26 for a detailed list of all proposed and existing distributed energy resources in Elmira.

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

[29] NG fired internal combustion engine heat rate: 9.573 MMBTU/MWh (2013 EIA average, http://www.eia.gov/electricity/annual/html/epa_08_02.html).

[30] The Booz Allen team forecasts a 60% level of operation from the backup generator based on historical loads and expected generator output. In 2014, the average load in Elmira was 2.10 MW. The natural gas generator and solar array can provide an average of 3.747 MW of generation. Load is expected to exceed the proposed generation's maximum output for approximately 60% of time spent in island mode. Solar output is unreliable, but it should provide significant support on the most irradiated days of the year when peak demand is highest.

Table 26. Distributed Energy Resources

Table lists DERs incorporated in the microgrid, including their energy/fuel source, nameplate capacity, estimated average annual production under normal operating conditions, average daily production in the event of a major power outage, and fuel consumption per MWh generated (for fuel-based DERs). "Normal operating conditions" assumes approximately 1.158 effective hours of operation per year for the diesel backup generator.

Distributed Energy Resource Name	Location	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Expected Daily Production During Major Power Outage (MWh)	Potential Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
							System fuel	Units of MMBTUs
DER1 - Existing backup generator (Hilliard)	Hilliard Corporation	Diesel	0.125	0.145	0.00040	3.0	71.17 Gallons[31]	9.88 MMBTUs
DER2 - Existing backup generator (Hilliard)	Hilliard Corporation	Diesel	0.6	0.695	0.00190	14.4	71.17 Gallons	9.88 MMBTUs
DER3 - Existing backup generator (Hilliard)	Hilliard Corporation	Diesel	0.9	1.042	0.00286	21.6	71.17 Gallons	9.88 MMBTUs
DER4 - Existing backup generator (College)	Elmira College	Natural Gas	0.15	0.290	0.00079	3.6	9.26 Mcf	9.5 MMBTUs
DER5 - Existing backup generator (College)	Elmira College	Natural Gas	0.15	0.290	0.00079	3.6	9.26 Mcf	9.5 MMBTUs
DER6 - Existing backup generator (College)	Elmira College	Natural Gas	0.055	0.106	0.00029	1.32	9.26 Mcf	9.5 MMBTUs

31 Diesel fuel consumption was averaged over all the diesel generators for simplicity.

Distributed Energy Resource Name	Location	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Expected Daily Production During Major Power Outage (MWh)	Potential Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
							System fuel	Units of MMBTUs
DER7 - Existing backup generator (College)	Elmira College	Diesel	0.3	0.347	0.00095	7.2	71.17 Gallons	9.88 MMBTUs
DER8 - Solar PV Array (College)	Elmira College	Sun Light	0.05	61.32	0.168	0.4[32]	N/A	N/A
DER9 - CHP System (College)	Elmira College	Natural Gas	4.4	32,762.4	89.76	105.6	9.26 Mcf	9.5 MMBTUs

32 Assumes 10 hours of production (daylight) at 80% of capacity.

4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3)

4.3.1 Peak Load Support

The microgrid's proposed generation assets will operate nearly continuously throughout the year, providing a constant level of load support. Although continuous operation will limit the CHP's ramp-up capability during peak demand events, it will also maximize revenue for owner of the microgrid. The existing backup generators will also be available to reduce peak load in cases of extreme demand. See Table 27 for the maximum generation capacities of the proposed and existing DERs.

The proposed solar array will be at its most productive on days with peak solar irradiance when peak demand events are common, thus providing peak load support when it is most needed. The solar array will provide around 0.007 MW of load support on average over the course of a year. However, their generation depends on weather conditions and time of day, therefore solar array is not a reliable source of peak load support.

Table 27. Distributed Energy Resource Peak Load Support

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

Distributed Energy Resource Name	Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER8 - Solar PV Array (College)	Elmira College	Maximum of 0.05	No
DER9 - CHP System (College)	Elmira College	Maximum of 4.4	No

4.3.2 Demand Response

Demand response programs require facilities to curtail load or expand generation using generators or battery storage in response to forecasted or real-time peak demand events on the larger grid. For more information on DR programs see Section 2.2.22.

4.3.3 Deferral of Transmission/Distribution Requirements

The 3.747 MW of average local generation produced by the DERs will slightly reduce the amount of electricity imported from the larger NYISO and NYSEG power lines, which may defer the need to invest in new or upgraded power lines. Although these power lines will last up to one hundred years if well maintained,[33] they can only transmit a limited amount of power. As demand for electricity in Elmira increases, the lines might need to be supplemented to handle additional load.

The same is true for distribution capacity investments on a local, feeder-by-feeder basis. However, in many cases constructing DERs could actually increase the distribution capacity

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

investment cost in certain cases (e.g., if the assets are placed in remote locations and thus expensive to connect to the local grid). This is not the case in Elmira, as the community has ample capacity within the town, construction of DERs will not require a significant distribution capacity investment.

4.3.4 Ancillary Services

None of the existing and proposed generation resources in Elmira will participate in ancillary services markets. Although the CHP 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 26.7% of the CHP system's maximum output. If the CHP runs at projected levels, it will never have the minimum regulation capacity available.

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

Elmira College will be a steady and reliable customer for the thermal energy produced by the CHP facility. At normal levels of operation, the CHP unit will produce approximately 12 MMBTU per hour of hot water, providing 100% of the Colleges average demand of 10 MMBTU per hour. An absorption chiller will provide cooling to Elmira College in the summer months, but the Project Team is currently unable to identify the value of this resource.

4.3.6 Environmental Regulation for Emission

The microgrid's generation assets will drive a net 3,607 $MTCO_2e$ (metric tons CO_2 equivalent) increase in GHG emissions in Elmira as compared to the New York State energy asset mix. The proposed generation assets will produce around 32,846 MWh of electricity per year. The proposed CHP unit and backup generators will emit approximately 17,995 $MTCO_2e$ per year, [34] while the solar array will emit none. The current New York State energy asset mix would emit approximately 11,922 $MTCO_2e$ to produce the same amount of electricity[35] and natural gas-fired boilers would emit around 2,466 $MTCO_2e$ to produce the same amount of thermal energy.[36]. The

[34] CHP 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).

[35] 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).

[36] Average emissions rate for natural gas boilers: 0.053 MTCO2e/MMBTU. Info from EIA (117 lb CO2 per MMBTU; http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).

microgrid's generation assets will therefore result in a net increase in emissions by 3,607 $MTCO_2e$.

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

The CHP 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 generators are already permitted and therefore will not incur any significant emissions costs.

Table 28 catalogs the CO_2, SO_2, NO_x, and Particulate Matter (PM) for the CHP, natural gas and diesel generators.

Table 28. Emission Rates

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

Distributed Energy Resource Name	Location	Emissions Type	Emissions Per MWh (Metric Tons/MWh)
DER1 - DER3 & DER4 – Backup Diesel Generator	Hilliard Corporation & Elmira College	CO_2	0.7196[37]
		SO_2	0.1911[38]
		NO_x	2.9074
		PM	0.2046
DER4 - DER6 – Backup Natural Gas Generator	Elmira College	CO_2	0.508
		SO_2	9.09358E-07[39]
		NO_x	0.006309834
		PM	1.19237E-07[25]
DER9 – CHP System	Elmira College	CO_2	0.553
		SO_2	0.0000067[40]
		NO_x	0.00055[41]

4.4 Project Costs (Sub Task 4.4)

4.4.1 Project Capital Cost

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

- A control system to provide one point of control for operating the microgrid and synthesizing real-time electricity data from the connected facilities.
- Intelligent electronic devices to interface with the 4.8 kV distribution feeder.
- Automated breakers installed throughout Elmira to allow the microgrid to isolate and maintain power to the microgrid connected facilities.
- Grid-paralleling switchgear to synchronize each generator's output to the system's frequency.

The total installed capital cost of the distributed equipment and IT gear is estimated to be $565,500. The Project Team estimates the 0.05 MW solar PV array and 4.4 MW CHP system carry an installed costs of $120,000 and $8.8 million, respectively.[42] This brings the total installed capital cost to approximately $9.49 million. Additionally the estimated capital cost does not account for any financial incentives or tax credits that may lower the overall cost of the

[37] 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).
[38] Michigan Department of Environmental Quality; Environmental Science and Services Division. "Potential to Emit, Diesel Fired Generator Calculation Worksheet."
[39] "Natural Gas-fired Reciprocating Engines" – EPA, http://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s02.pdf.
[40] CHP calculator, EPA.
[41] EPA, http://www3.epa.gov/chp/documents/faq.pdf.
[42] CHP Capital Cost: $2,000/kW (Siemens CHP estimate), Solar PV Capital Cost: $2,400/kw (Siemens Solar PV estimate).

microgrid. See Tables 29 and 30 below for estimated installed costs for each microgrid component. Table 29 details capital cost of the microgrid components; it includes equipment such as the microgrid control system and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid.

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

Table 29. Distributed Equipment Capital Cost

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

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Microgrid Control System	1 Primary	$50,000	7 - 8 years	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
(Siemens SICAM PAS or equivalent)	1 Back-up			
Microgrid Control Center (Siemens MGMS or equivalent)	1	$300,000	20	Provides data trending, forecasting, and advanced control of generation, loads and AMI/SCADA interface, interface to NYISO for potential economic dispatch.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay)	3	$90,000	20	New breaker/switch at distribution load feeders to enable IED interface with and control by the microgrid
Generation Controls (OEM CAT, Cummins, etc.) (Load Sharing via Basler, etc.)	8	$32,000	20	OEM generation controllers serve as the primary resource for coordinating generator ramp up/ramp down based on external commands. Basler distributed network controllers allow primary generator to establish Microgrid frequency and supply initial load, while also managing load sharing between all spinning generators and paralleling sequence.
PV Inverter Controller (OEM Fronius or equivalent)	1	$4,000	20	Controls PV output and sends data to SCADA and EMS for forecasting.
Network Switches	6	$4,500	20	Located at IEDs and controllers for network connection, allowing remote monitoring and control.

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
WiMax Base Station	1	$8,000	20	Located near microgrid control cabinet. Communicates wirelessly with WiMax subscriber units for remote control and monitoring of breakers and switches. Should be installed at high location.
WiMax Subscriber Units	7	$14,000	20	Each subscriber unit can communicate back to the WiMax base station for SCADA monitoring and control or remote relay to relay GOOSE messaging.
WiMax configuration and testing	1	$23,000	-	The configuration and testing of the WiMax hardware
Installation Costs	-	$40,000	-	Installation of capital components in the microgrid

Table 30. Capital Cost of Proposed Generation Units

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

Proposed Generation Units				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
0.05 MW PV System	1	$120,000	30	Generation of electricity
4.4 MW CHP System	1	$8,800,000	20	Generation of electricity

The microgrid IT infrastructure will also require Cat-5e Ethernet cables for communication between distribution switches, generation switchgear, PV inverters, and network switches. The design uses Cat-5e cabling, including RJ-45 connectors at $0.61 per cable.[43] The total installation cost of cabling is approximately $5.65 per foot for Cat-5e cables.[44] 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 $15,000.[45]

[43] Commercially available RJ-45 connectors, $0.30 per connector.
[44] Installation costs for Cat5e: $5.45/ft Component cost for Cat5e: $0.14/ft (commercially available).
[45] The Project Team estimated ~2,500 feet of Cat5e.

4.4.2 Initial Planning and Design Cost

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

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

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

Table 31. Initial Planning and Design Cost

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

Initial Planning and Design Costs ($)[46]	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 proposed CHP will cost approximately $460,000.[47] The microgrid owner will also incur $13,300/year in total costs for annual fixed system service agreements for the solar PV array and backup generators. [48]

The DER assets will also incur variable O&M costs that fluctuate based on output. These include fuel and maintenance costs outside of scheduled annual servicing. First, the CHP will require capital for fuel, consumable chemicals, and other operating expenses. The average price of

[46] Estimates developed by Booz Allen Project Team and independent consultant.
[47] CHP O&M Estimate: $0.014/kw (Siemens estimate).
[48] $1,000 for solar PV array ($20/kW per year), $4.60/kW-year for backup diesel generators (Electric Power Research Institute, "Costs of Utility Distributed Generators, 1-10 MW") and $1,500 for natural gas generator (Pete Torres, Prime Power; yearly service for small scale natural gas generator).

natural gas for the microgrid will be $5.74/Mcf, which translates to an average fuel cost of $53/MWh for the CHP system.

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

The solar PV array will not require fuel to operate, and it should not require service outside of the normally scheduled downtime. Normally scheduled downtime should cost approximately $20/kW per year.[49]

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[50]

Table32 outlines all fixed operations and maintenance (O&M) costs associated with normal operation of the DERs.

Table 32. Fixed Operating and Maintenance Cost

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

Fixed O&M Costs ($/year)	Cost Components
~ $1,000	Solar PV System Service Agreements – Annual costs of maintenance and servicing of unit
~ $460,000	CHP System Service Agreement – Annual costs of maintenance and servicing of unit
~ $8,800	Backup Diesel Generator Service Agreement – Annual costs of maintenance and servicing of unit
~ $4,500	Backup Natural Gas Generator Service Agreement – Annual costs of maintenance and servicing of unit
$70,000	Non-DER Microgrid Components Service Agreement - Annual costs of maintenance and servicing of components

4.4.4 Distributed Energy Resource Replenishing Fuel Time

The both the CHP and natural gas units will have a continuous supply of fuel unless the pipeline is damaged or destroyed, therefore the CHP and natural gas units will be able to operate continuously. There is effectively no maximum operating duration for the CHP and natural gas

[49] NREL (projects $0/kWh variable maintenance costs): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
[50] O&M for non-DER microgrid components: $70,000/year (Siemens).

units in island mode. DERs such as diesel generators have limited tank sizes and have clear maximum operating times in island mode.

At full operation, all of the diesel generators will require 137 gallons of diesel fuel per hour at full load. The Hilliard Corporation's generators have variably sized storage tanks and can operate for as little as 5.15 hours for the 0.125 MW generator and as long as 22.48 hours for the 0.9 MW generator. Elmira College's sole diesel generator can operate for up to 7 hours at full load, given the size of its storage tank.

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

Table 33 shows the fuel consumption and operating times for all of the microgrid DERs.

Table 33. Maximum Fuel Operating Time for Distributed Energy Resource

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

Distributed Energy Resource	Location	Energy Source	Maximum Operating Time in Islanded Mode without Replenishing Fuel (hours)	Fuel Consumption During this Period	
				Quantity	Unit
DER1 - Existing backup generator (Hilliard)	Hilliard Corporation	Diesel	5.15	366	Gallon
DER2 - Existing backup generator (Hilliard)	Hilliard Corporation	Diesel	18.92	1,347	Gallon
DER3 - Existing backup generator (Hilliard)	Hilliard Corporation	Diesel	22.48	1,600	Gallon
DER4 - Existing backup generator (College)	Elmira College	Natural Gas	N/A	N/A	N/A
DER5 - Existing backup generator (College)	Elmira College	Natural Gas	N/A	N/A	N/A
DER6 - Existing backup generator (College)	Elmira College	Natural Gas	N/A	N/A	N/A
DER7 - Existing backup generator (College)	Elmira College	Diesel	7.02	500	Gallon
DER8 - Solar PV Array (College)	Elmira College	Sun Light	N/A	N/A	N/A
DER9 - CHP System (College)	Elmira College	Natural Gas	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

All microgrid generation assets will serve as backup generation in the event of an extended power outage. The CHP will be the most reliable and productive of the DERs, providing a maximum of 4.4 MW to the microgrid at any given time. Because the CHP will use natural gas via pipeline as fuel, disruptions to its fuel source are unlikely. The CHP can generate a maximum of 105.6 MWh per day, using approximately 977.7 Mcf (1,003 MMBTU) of natural gas. The CHP will not require startup or connection costs in order to run during island mode and should not incur any daily variable costs other than fuel.

The solar array will be available for backup generation during a power outage, but its production is too inconsistent for it to qualify as a true backup generator. Extreme weather is responsible for many emergency outages in New York State, and such weather will greatly reduce the output of the solar panels. However, when high state-wide electricity demand on the most irradiated days of summer causes outages, the solar panels will be at their most productive and could provide up to 0.05 MW of load support to the Elmira microgrid. Table 34 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

The backup generators will only come online when the natural gas unit and solar array do not provide sufficient power to the islanded microgrid. Because the CHP can produce 4.4 MW of power at full capacity and the microgrid's loads had an average power demand of 2.10 MW during 2014, the CHP and solar array should be capable of satisfying the microgrid's power demand in all situations with the assistance of the backup generators. The backup generators will be necessary for about 60% of total outage time to cover peak demand beyond the CHP unit's capacity. At 60% of expected outage operation the combine 2.28 MW of generation would produce an average of 2.1 MWh per day. At full capacity, the backup generators can produce up to 54.72 MWh. The backup generators will require around 3,288 gallons of diesel and 78.9 Mcfs per day at full capacity. One-time startup costs or daily non-fuel maintenance costs for either of the diesel generators are not anticipated.

Table 34. Cost of Generation during a Power Outage

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

Location	Distributed Energy Resource	Energy Source	Nameplate Capacity (MW)	Expected Operating Capacity (%)	Avg. Daily Production During Power Outage (MWh/ Day)	Fuel Consumption per Day		One-Time Operating Costs ($)	Ongoing Operating Costs per day – Fuel and variable O&M
						Quantity	Unit		
Hilliard Corporation	DER1 - Existing backup generator (Hilliard)	Diesel	0.125	100%	3.0	213.51	Gallons	N/A	$751
Hilliard Corporation	DER2 - Existing backup generator (Hilliard)	Diesel	0.6	100%	14.4	1,024.85	Gallons	N/A	$3,600
Hilliard Corporation	DER3 - Existing backup generator (Hilliard)	Diesel	0.9	100%	21.6	1,537.27	Gallons	N/A	$5,400
Elmira College	DER4 - Existing backup generator (College)	Natural Gas	0.15	100%	3.6	33.3	Mcf	N/A	$195
Elmira College	DER5 - Existing backup generator (College)	Natural Gas	0.15	100%	3.6	33.3	Mcf	N/A	$195

Location	Distributed Energy Resource	Energy Source	Nameplate Capacity (MW)	Expected Operating Capacity (%)	Avg. Daily Production During Power Outage (MWh/ Day)	Fuel Consumption per Day		One-Time Operating Costs ($)	Ongoing Operating Costs per day – Fuel and variable O&M
						Quantity	Unit		
Elmira College	DER6 - Existing backup generator (College)	Natural Gas	0.055	100%	1.32	12.2	Mcf	N/A	$74
Elmira College	DER7 - Existing backup generator (College)	Diesel	0.3	100%	7.2	512.42	Gallons	N/A	$1,800
Elmira College	DER8 - Solar PV Array (College)	Sun Light	0.05	14%[51]	0.4[52]	N/A	N/A	N/A	$2.75
Elmira College	DER9 - CHP System (College)	Natural Gas	4.4	100%	105.6	977.78	Mcf	N/A	$6,900

[51] NREL PV Watts Calculator.

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

4.5.2 Cost to Maintain Service during a Power Outage

There are no costs associated with switching the microgrid to island mode during a power outage other than the operational costs already accounted for Table 34. Please refer to Table 34 for one-time and ongoing costs of microgrid generation per day. The proposed microgrid has the capacity to support all the connected facilities, which means even those facilities with backup generators will not have to rely on or pay for on-site backup power. Facilities not connected to the microgrid will experience power outages and may need emergency services depending on the severity of the emergency event. Any other cost incurred during a wide spread power outage will be related to the emergency power (i.e. portable generators) rather than electricity generation costs.

4.6 Services Supported by the Microgrid (Sub Task 4.6)

All of the facilities to be connected to the microgrid are privately owned buildings that serve smaller populations for most of the year, but provide critical services to the entire population during emergency situations such as Elmira College. For estimates of the population served by each critical facility, see Table 35.

Backup power supplied by the microgrid should provide 100% of each facility's electricity demand during outage situations. However, if backup power from the microgrid is not available, the critical services provided by these facilities will be severely hampered. Some critical services do not require electricity (e.g. driving a police car to the scene of a crime), while others are completely dependent on a stable power supply (e.g. some municipal buildings or local water sanitizing operations). Based on the portfolio of services that each facility provides and the electricity dependency of each service, Table 35 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 35. Critical Services Supported

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

Facility Name	Population Served by This Facility	Percentage Loss in Service During a Power Outage[53]	
		When Backup Power is Available	When Backup Power is Not Available
Elmira College	~ 1,400[54]	0%	> 90%
Hilliard Corporation	~ 300 [55]	0%	> 90%
Load Cluster	~ 110	0%	> 50 %

4.7 Industrial Economics Benefit-Cost Analysis Report

As follows is a direct cost-benefit analysis deliverable from Industrial Economics. IEc was hired by NYSERDA to conduct a benefit-cost analysis of each feasibility study. The benefit-cost analysis of the Elmira microgrid was delivered to the Project Team on March 8, 2016.

4.7.1 Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the City of Elmira has proposed development of a microgrid that would serve 28 facilities within the City, including:

- Elmira College
- Hilliard Corporation
- Twenty-six residences

The microgrid would be powered by two new distributed energy resources: a 4.4 MW natural gas-fired CHP unit and a 0.05 MW photovoltaic array; both would be installed at Elmira College. In addition, the microgrid would incorporate four currently installed backup diesel generators, and three currently installed backup natural gas generators. Three of the diesel generators support Hilliard Corporation; the total capacity of these three units is 1.625 MW. The four remaining backup generators (one diesel, the others natural gas) are located at Elmira College; the diesel generator has a capacity of 0.3 MW, two of the natural gas generators have capacities of 0.15 MW, and the capacity for the remaining natural gas generator is 0.055 MW. The City anticipates that the new CHP unit and the photovoltaic system would produce electricity for the grid during periods of normal operation. In contrast, the existing backup generators would produce power only during an outage, when the microgrid would operate in islanded mode. The system as designed would have sufficient generating capacity to meet

[53] 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).
[54] Relevant statistics for Elmira College (http://colleges.usnews.rankingsandreviews.com/best-colleges/elmira-2718).
[55] Relevant statistics for Hilliard Corporation (https://www.linkedin.com/company/hilliard-corporation).

average demand for electricity from the 28 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 Ide 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 benfits* 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.[56] 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

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

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.[57]

4.7.3 Results

Table 36 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 5.5 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

Table 36. BCA Results (Assuming 7 Percent Discount Rate)

Economic Measure	Expected Duration of Major Power Outages	
	Scenario 1: 0 Days/Year	Scenario 2: 5.5 Days/Year
Net Benefits - Present Value	-$8,390,000	$74,300
Benefit-Cost Ratio	0.9	1.0
Internal Rate of Return	-3.1%	6.8%

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

Scenario 1

Figure 6 and Table 37 present the detailed results of the Scenario 1 analysis.

Figure 6. Present Value Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

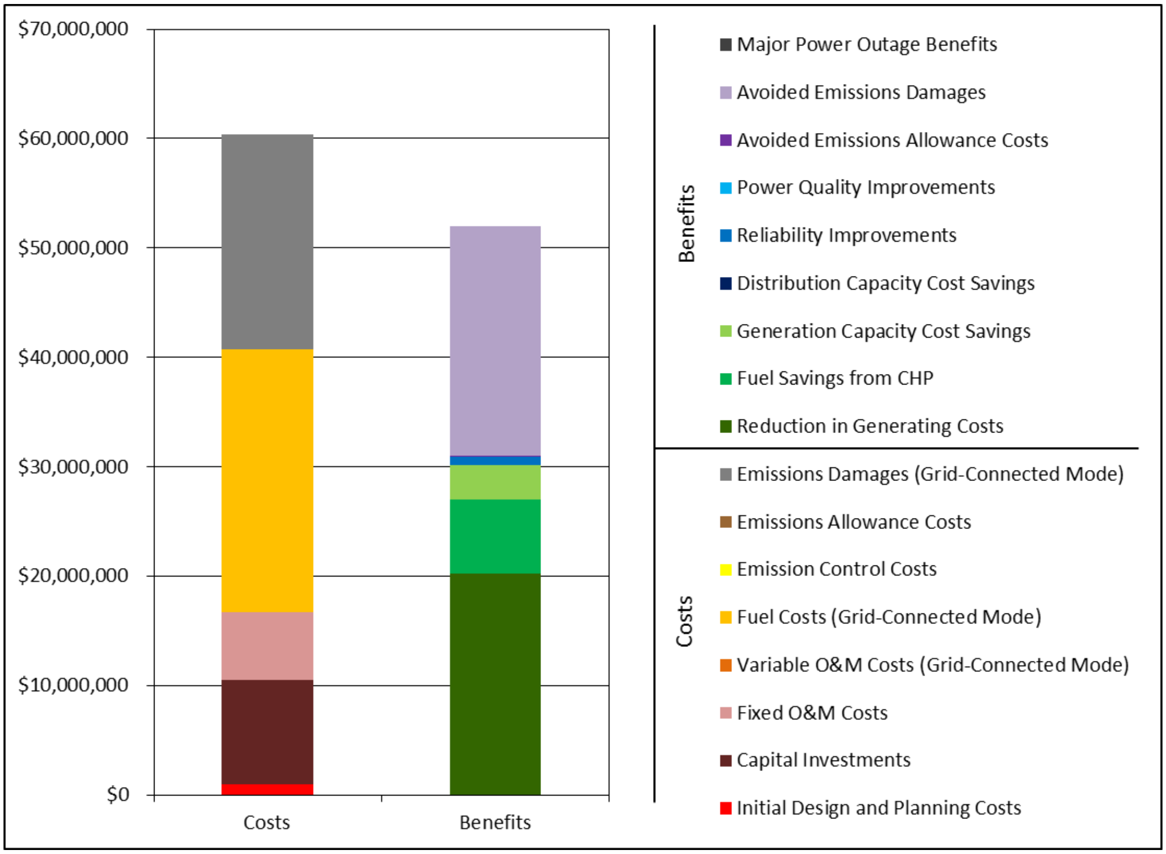

Table 37. Detailed BCA Results, Scenario 1

(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	$9,520,000	$839,000
Fixed O&M	$6,160,000	$543,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$24,100,000	$2,130,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$19,600,000	$1,280,000
Total Costs	**$60,400,000**	
Benefits		
Reduction in Generating Costs	$20,300,000	$1,790,000
Fuel Savings from CHP	$6,720,000	$593,000
Generation Capacity Cost Savings	$3,190,000	$281,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$772,000	$68,200
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$11,100	$982
Avoided Emissions Damages	$21,000,000	$1,370,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$52,000,000**	
Net Benefits	**-$8,390,000**	
Benefit/Cost Ratio	**0.9**	
Internal Rate of Return	**-3.1%**	

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 $9.5 million, including costs associated with installing a microgrid control system; equipment for the substation that would be used to manage the microgrid; the IT infrastructure (communication cabling) for the microgrid; and the new 4.4 MW natural gas unit and 0.05 MW photovoltaic array. Operation and maintenance of the entire system would be provided under fixed price service agreements, at an estimated annual cost of $543,000. The present value of these O&M costs over a 20-year operating period is approximately $6.2 million.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the new gas-fired combined heat and power unit. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the Project Team and projections of fuel costs from New York's State Energy Plan (SEP), adjusted to reflect recent market prices.[58] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $24.1 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 $1.3 million 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 $19.6 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 Elmira's proposed microgrid, one significant 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 $20.3 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. The reduction in demand for electricity from bulk energy suppliers, coupled with a reduction in demand for heating fuel, would also avoid emissions of CO_2, SO_2, NO_x, and particulate matter, yielding emissions allowance cost savings with a present value of approximately $11,000 and avoided emissions damages with a present value of approximately $21 million.[59]

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.[60] 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 3.7 MW per year (the team estimates no impact on distribution capacity). Based on this figure, the BCA estimates the present value of the project's generating capacity benefits to be approximately $3.2 million over a 20-year operating period.

[58] 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.

[59] 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.

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

The Project Team has indicated that the proposed microgrid would be designed to provide black start support to the NYISO. Whether NYISO would select the project to provide these services depends on NYISO's requirements and the ability of the project to provide support at a cost lower than that of alternative sources. Based on discussions with NYISO, it is our understanding that the market for black start support is highly competitive, and that projects of this type would have a relatively small chance of being selected to provide support to the grid. In light of this consideration, the analysis does not attempt to quantify the potential benefits of providing this service.

Reliability Benefits

An additional benefit of the proposed microgrid would be to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $68,000 per year, with a present value of approximately $772,000 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:[61]

- System Average Interruption Frequency Index – 1.03 events per year
- Customer Average Interruption Duration Index – 118.2 minutes[62]

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.[63] 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 0.9; i.e., the estimate of project benefits is approximately 90 percent of project costs. Accordingly, the analysis moves to Scenario 2,

[61] www.icecalculator.com.
[62] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for New York State Electric & Gas.
[63] 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.[64,65]

As noted above, the City of Elmira's microgrid project would serve Elmira College, Hilliard Corporation, and 26 residences. The project's consultants indicate that at present, Elmira College and Hilliard Corporation are both equipped with backup generators; these units can support 75 percent and 50 percent of service at the two facilities, respectively. In order to provide complete power during an outage, both facilities would rent and operate portable diesel generators. Operation of the existing backup generators and portable generators would cost approximately $34,500 per day at Elmira College, and approximately $17,200 per day at Hilliard Corporation. In the absence of backup power – i.e., if the backup generators failed and no replacement was available – Elmira College and Hilliard Corporation would both experience a 90 percent loss in service capabilities. Similarly, the Project Team indicates that backup power could be provided to the 26 residences by renting and operating portable generators; the cumulative cost would be approximately $1,100 per day.

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:

- Elmira College and Hilliard Corporation would rely on their existing backup generators in combination with rented portable generators to maintain 100 percent of service

[64] 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.

[65] 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.

capabilities while the generators operate. If the backup generators fail, the facilities would experience a 90 percent loss of service.

- The 26 residences would rely on portable generators to maintain electric service, at a cumulative cost of approximately $1,100 per day. If the portable generators fail, the residences would experience a total loss of power.
- In all cases, the supply of fuel necessary to operate backup generators would be maintained indefinitely.
- At each facility, there is a 15 percent chance that the backup generator would fail.

The economic consequences of a major power outage also depend on the services the facilities of interest provide. The analysis calculates the impact of a power outage on the project's 26 residential customers using a standard FEMA methodology. The impact of an outage on the other facilities is based on the following approaches to estimating the value of the services they provide:

- For Elmira College, the value of a day of operations is estimated by dividing the college's operating budget for the fiscal year ending June 30, 2014 by the number of days in a year. This yields a value of approximately $197,000 per day, assuming 24 hours of microgrid demand per day during an outage.[66]
- For Hilliard Corporation, the value of service is estimated at approximately $561,000 per day. This figure is based on the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, assuming 24 hours of microgrid demand per day during an outage.[67]

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for all facilities is approximately $137,000 per day.

Summary

Figure 7 and Table 38 present the results of the BCA for Scenario 2. The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 5.5 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

[66] President's Report, Operating Budget of FY ending June 30, 2014 (pg. 5 of https://issuu.com/elmiracollege/docs/pres_report_1314_final_s).
[67] http://icecalculator.com/.

Figure 7. Present Value Results, Scenario 2

(Major Power Outages Averaging 5.5 Days/Year; 7 Percent Discount Rate)

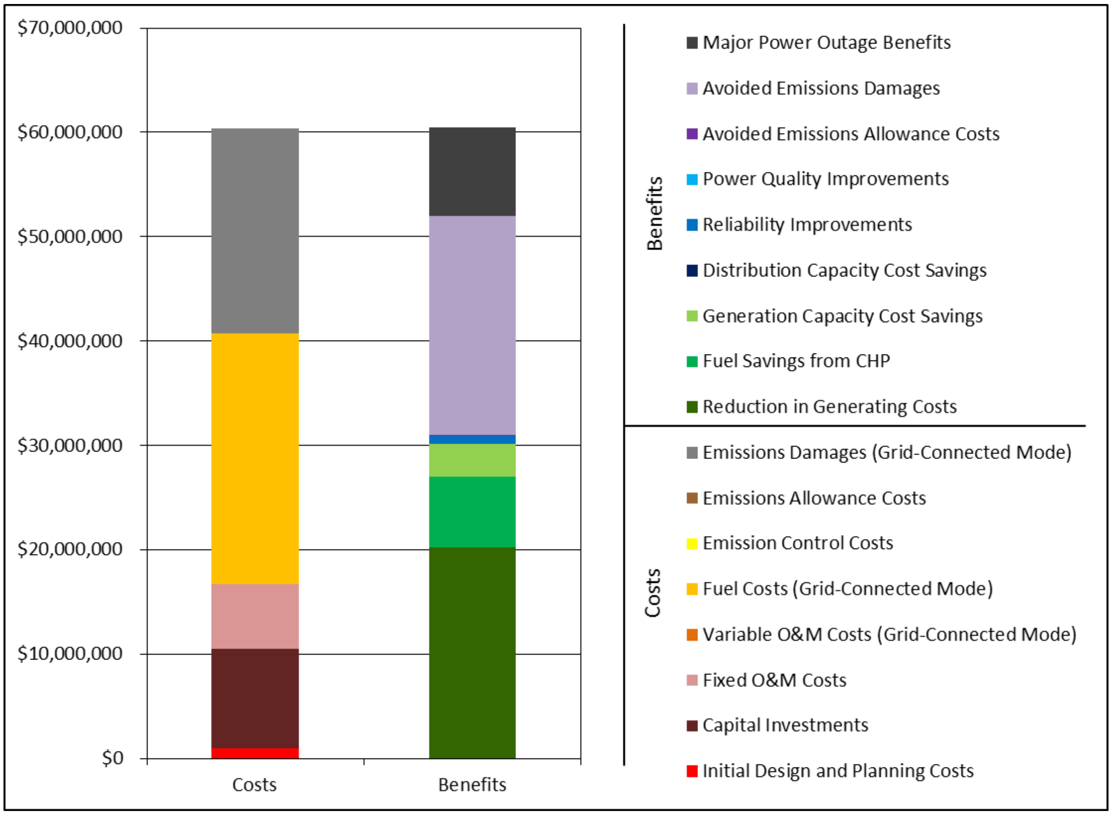

Table 38. Detailed BCA Results, Scenario 2

(Major Power Outages Averaging 5.5 Days/Year; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$1,000,000	$88,200
Capital Investments	$9,520,000	$839,000
Fixed O&M	$6,160,000	$543,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$24,100,000	$2,130,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$19,600,000	$1,280,000
Total Costs	**$60,400,000**	
Benefits		
Reduction in Generating Costs	$20,300,000	$1,790,000
Fuel Savings from CHP	$6,720,000	$593,000
Generation Capacity Cost Savings	$3,190,000	$281,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$772,000	$68,200
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$11,100	$982
Avoided Emissions Damages	$21,000,000	$1,370,000
Major Power Outage Benefits	$8,460,000	$754,000
Total Benefits	**$60,400,000**	
Net Benefits	**$74,300**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.8%**	

The Project Team assumed an electricity sales price of $0.061 per kWh in Elmira. This is the supply cost for NYSEG, the average amount spent by NYSEG to import electricity into their distribution system. On a long term, fixed volume PPA, the Project Team believes this to be the most accurate pricing model. Industrial Economics modeled the location-based marginal price (LBMP) for the local NYISO zone to price electricity sales. The LBMP is effectively the average spot market price, peaking on summer afternoons and dropping to nearly zero in low demand hours. While the LBMP would be an appropriate price for intermittent and unreliable grid sales, the proposal herein supports reliable, continuous electricity injections into the NYSEG grid. In Elmira, the Central LBMP is $32.76 per MWh[68], or $0.033 per kWh, a more than 45% reduction in price from the supply cost. The benefits allowed for capacity cost reductions do not bring the electricity prices to parity. This has a predictable influence on the economics of the projects and is the driving force behind the divergent cost benefit analyses developed by the Project Team and by IEc. The Project Team is unaware of any community microgrid business model or generation set that is financially self-sufficient at the LBMP.

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

5. Summary and Conclusions

5.1 Lessons Learned and Areas for Improvement

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

5.1.1 Elmira Lessons Learned

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

The existing electrical distribution system in Elmira is not conducive to a community microgrid that connects multiple critical facilities. Multiple NYSEG feeders cross paths to power the downtown area. NYSEG indicated that they would not support microgrids that connected multiple feeders, as this would increase the electrical complexity of the system and would require additional power flow studies. The Project Team considered several microgrid configurations, but ultimately identified only two critical facilities along the same feeder that could be connected without energizing an unrealistic number of intervening loads. Most critical facilities in Elmira are physically and electrically separated, or are physically proximate but electrically distant from each other.

The Elmira community liaison was highly engaged and helpful throughout the data collection and design process. Through this liaison, the Project Team was able to obtain electrical and thermal load data for multiple facilities, existing generator size and tank capacity, and existing boiler information.

In comparison to working with a municipal utility, working with the investor-owned NYSEG was a more time-intensive process. As a utility with a large footprint, customer base, and transmission and distribution network, NYSEG has many issues to manage that require its attention, among which microgrids and NY Prize were just one. However, NYSEG was generally helpful and engaged. The utility provided high quality data on existing electrical and thermal infrastructure as well as some data on electrical loads. NYSEG neither confirmed nor denied interest in owning and operating microgrid control and distribution infrastructure, but the Project Team believes that such a hybrid ownership model would be most beneficial to the project. A NY Prize Phase II award would require more extensive conversations with NYSEG about their role in a future microgrid on the proposed footprint and how a microgrid might utilize existing infrastructure most efficiently.

Despite the presence of a thermal off-taker, the Elmira microgrid will not produce positive returns for investors. CHP units generally enhance a project's commercial viability, but low electricity prices and relatively high natural gas prices in Elmira make the financial case less appealing.[69] The CHP unit also loses some efficiency by producing hot water and chilled water instead of dry process steam. If project developers find a reliable steam off-taker, the financial case for a microgrid in Elmira may improve.

5.1.2 Statewide Replicability and Lessons Learned

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

Technical. The existing electrical and natural gas infrastructure in a community is the chief determinant of what is possible. In Elmira, existing electrical infrastructure complicated the design process. There are two critical facilities on the same feeder in Elmira, but the microgrid would need to expand to another feeder to connect additional critical facilities.

However, natural gas infrastructure is well developed in Elmira and can support continuous operation of the proposed 4.4 MW CHP unit. The availability of natural gas infrastructure is a major contributor to project feasibility. In communities without natural gas, generation is typically limited to solar PV, battery storage, and the tie in of existing diesel backup generation, given the high costs of biomass and the larger footprints required for wind. Given the intermittency of solar, and the low capacity factor in New York State (approximately 15%), solar installations of a few hundred kW generally do not provide reliable generation for an islanded microgrid without paired storage assets. In contrast, natural gas-fired generation provides a high reliability baseload, is relatively clean and efficient, and allows for cogenerated thermal energy sales if there is a proximate off-taker.

Financial. Across the portfolio of communities managed by the Project Team, natural gas availability, presence of thermal energy off-takers, and overall project size are the main drivers of financially viable projects. Simply, natural gas generation is more cost efficient and provides highly reliable revenue streams through electricity sales, and sometimes offers thermal energy sales as an added revenue stream that is unavailable to a PV driven system. Given the high cost of battery storage, it is difficult to make a compelling case for a small solar PV-battery system as a reliable baseload option.

Project financial structures are also important to consider. Revenue from these projects is driven almost exclusively by the sale of electricity and thermal energy, if available; however, the microgrid control components may require $600,000 or more of capital investment and will not initially produce significant revenue streams. The case for private investors to finance microgrid infrastructure is fairly weak, as most private investors would prefer to selectively invest in revenue-generating DERs. NYSERDA may need to create new policies that compensate utilities for microgrid ownership and operation if NYS wishes to see more microgrids developed across the state.

[69] Electricity and natural gas prices obtained from NYSEG's publically available supply charge information.

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. Demand response is a potentially lucrative revenue stream in New York; however, current policies do not address microgrid DR participation. For instance, interpretations of the existing NYISO DR programs suggest that microgrids could take payments for islanding in times of high demand on the macrogrid. This scenario, while advantageous from a load shedding perspective, would also remove the microgrid connected generation simultaneously, leaving the macrogrid in a net-neutral position. While the nature of DR payments in such situations is not clear, the Project Team suggests explicit guidance from the NYPSC and the various utilities regarding their respective policies. Due to this lack of clarity, DR revenue has generally been excluded from the Project Team's revenue analysis.

Lastly, local community involvement is an important contributor to microgrid design success. Though even the most robust community engagement may not overcome highly unfavorable infrastructure, it is nonetheless imperative for steady forward progress. In Elmira, support from the utility has been robust and the community has been exceptionally engaged. In other communities, as in Elmira, the Project Team has been in close and frequent contact with administrators, elected officials, and non-governmental community representatives; this type of engagement is necessary to not only build support among prospective facilities but also to engage on ownership models, generation options, and other considerations that will directly affect the feasibility of the proposal. The engagement and commitment from the community is instrumental to the Project Team's ability to make recommendations that are acceptable and reasonable to the community. In those communities that are more removed from the process it is difficult to make firm recommendations, and the Project Team runs the risk of suggesting solutions that are, for whatever reason, unpalatable to the community.

Scalability. Scalability is governed by three factors. The structure of the electrical infrastructure, defined in the technical lessons learned section above, is a key factor to expansion of the microgrid. At some point of expansion, it becomes necessary to link multiple feeders, and having proximate feeders of the same voltage and connected to desirable facilities is an important criteria. Second, widespread AMI infrastructure makes expansion far less complicated and allows for the selective disconnect of facilities that are not microgrid participants. Elmira's microgrid is not an AMI remote disconnect based design; however, the utility of AMI is evident in other projects in the Project Team's portfolio. Lastly, as the microgrid grows larger, more switches and controls need to be installed, connected, and maintained for smooth islanding and grid-reconnect processes. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are also likely to push back if the microgrid grows to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the local utilities to find acceptable footprints that meet the goals of NYSERDA and respect the operational concerns of the utilities.

5.1.3 Stakeholder Lessons Learned

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

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

Investor-owned-utilities in the Project Team's portfolio, including NYSEG in Elmira, were uniformly against allowing a third party operational control of utility-owned infrastructure. This view is understandable, however it engenders a particularly difficult situation if the utility does not support the microgrid development. In such situations, the microgrid will generally be forced to construct duplicate infrastructure, with is both prohibitively expensive and against the spirit of the NY Prize. In general, utilities which support the integration of their infrastructure to the extent technically possible allow for more expansive microgrid possibilities.

Academics. Academic considerations in microgrid development may center around three areas. First, research into relatively small grid systems with multiple generators (some spinning, some inverter-based), temporally and spatially variable loads, and multidirectional power flows may inform better designs and more efficient placement of generation and controls relative to loads. Second, financial structures for collection of revenue from distributed energy resources and control infrastructure must be optimized. To-date, most microgrids in the United Stated have been campus-style developments in which the grid serves a single institution and can be easily segregated from the macrogrid. Community microgrids consisting of multi-party owned facilities and generation are a new concept, and literature on how best to own and operate such developments is not yet robust. Lastly, and related to financial structures, research into the management and possible values from a "grid of grids" could reveal new value streams that derive from microgrid control and distribution infrastructure, which would incentivize private investors and utilities to own microgrid infrastructure.

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

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

Second, microgrid control infrastructure is expensive, and distributed energy resources require some scale to become revenue positive enough to subsidize the controls. Therefore, many NY Prize project proposals are not financially feasible without the NY Prize and myriad other rebate and incentive programs. In practical terms, this means that, while the NY Prize will create a body of knowledge around the development of community microgrids that did not previously exist, it is unlikely to spur unbridled growth of community microgrids in the State without policy changes. This is especially true in regions with relatively low electricity costs. Additionally, low income communities, which often have a greater need for improvements to the grid for reliability and resiliency, cannot afford to finance energy reliability projects. This makes the financial case for widespread microgrids across New York State more difficult, as the projects with the least attractive financial returns are often those needed most by the community. This gap is not easily bridged without further subsidization from the State.

5.2 Benefits Analysis

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

5.2.1 Environmental Benefits

New York State's normal energy portfolio is very clean, with primary energy sources being hydropower and nuclear. Therefore, having a microgrid powered by a natural gas-fired CHP will increase the overall emissions per kWh. However, the natural gas CHP is cleaner than many peaking assets, which come online when statewide demand is high, and is significantly cleaner than the existing diesel backup generators at Elmira College and the Hilliard Corporation. In Elmira, cogenerated thermal energy will replace two stand-alone natural gas-fired hot water boilers, increasing the overall efficiency of thermal energy production in the area. The proposed microgrid also offers a platform for expanding renewable generation in the future. The microgrid's generation assets will not exceed current New York State emissions limits for generators of their size and will not need to purchase emissions permits to operate.

5.2.2 Benefits to the City of Elmira

Critical and important facilities in the City of Elmira will receive resilient backup power from the proposed generation assets, ensuring they are available in outage situations and reducing the need for further investments in backup generation. The electricity generated with the solar PV array and the natural gas-fired CHP unit will offset higher-emission peaking assets during peak demand events. The additional electricity supply will also obviate the need for the college and the Hilliard Corporation to run their diesel generators whenever there is a grid interruption, reducing local emissions. The Project Team held a wrap up call with the community and NYSEG on March 9, 216 to summarize the findings and recommended next steps.

5.2.3 Benefits to Residents in and around Elmira

Residents of Elmira and the surrounding community stand to gain from access to a broad range of critical services anytime the microgrid is forced into islanded operation by an outage on the grid. Even if they are not formally connected to the microgrid, all residents of Elmira and nearby surrounding communities will have access to shelter in the event of an outage. The Hilliard Corporation will also continue to bolster the local economy by maintaining productivity. In the future, the microgrid could be expanded to connect more facilities.

5.2.4 Benefits to New York State

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

5.3 Conclusion and Recommendations

The Project Team has concluded the proposed Elmira microgrid is technically feasible. The preliminary design here meets all of the NYSERDA required capabilities and most of its preferred capabilities.

Major challenges include working with NYSEG regarding the proposed interconnections and new distribution infrastructure, and working with the college to site both the CHP and solar PV, as well as secure an off-take agreement for thermal energy. A failure to address any one of these conditions would make it difficult to develop and operate the microgrid as it is currently proposed. If challenges are resolved, the microgrid stands to be a case study in collaborative operation. However, the project will not be financially feasible without significant capital and operating subsidies from NYSERDA or other sources.

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

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

Finally, the project would demonstrate the widely distributed benefits of microgrids paired with distributed energy resource assets. The utility will see improved grid performance, the community will reap the positive benefits of living in and around the microgrid, and industrial customers will benefit from the value of avoided outages.

Path Ahead

Beyond New York Prize, Elmira has several options available to improving energy resilience in the community through energy efficiency, distributed energy resources, and advanced technology such as microgrid controllers. Connected facilities have already begun to invest in energy efficiency, which is always the first line of energy resilience. The Hilliard Corporation recently upgraded lighting and variable frequency drives, and the college has upgraded 25% of its light fixtures to LEDs. However, there is still significant potential for EE upgrades in Elmira. The college and the Hilliard Corporation will likely qualify for some of the NYSEG and NYSERDA funded EE programs listed below:

- NYSEG Commercial and Industrial Rebate Program: NYSEG plans to re-launch this program in January 2016. As of March 1, 2016, the utility had not provided updated information on the program. In its previous iteration, the program offered prescriptive rebates for specific, predetermined EE upgrades such as lighting and controls, natural gas furnaces, HVAC and heat pumps, and HVAC chillers. The program also included a custom rebate option where customers could apply for site-specific rebates for a variety of retrofitting EE opportunities. Finally, the program offered free access to INVEST, a Microsoft Excel-based workbook that helped users calculate cost, savings, and ROI from various EE upgrades. The college and the Hilliard Corporation may be eligible for this program.

- NYSEG Multi-Family Energy Efficiency Program: This program provides incentives for residents and/or property owners in apartments or condominium complexes with 5-50 units. The program offers several incentives for EE upgrades in common areas and individual dwelling units. Select Elmira College buildings may be eligible for this program. Incentives are listed below:
    - Free installation of LED and CFL bulbs in common areas
    - Incentives totaling 70% of the cost of hardwired LED, fluorescent, and exist sign lighting upgrades in common areas
    - Free installation of water heater pipe wrap in buildings with electric water heaters
    - Free installation of CFLs and LEDs in up to six fixtures per dwelling unit
    - Free installation of energy-efficient faucet aerators and showerheads in dwelling units
    - Incentives totaling 30% of the cost of fluorescent fixture upgrades in dwelling units
- NYSEG Refrigerator and Freezer Recycling Program: This program was on hold as of March 1, 2016, but may resume in the future. This program qualifies consumers for six free CFLs and a $50 check for recycling an old refrigerator or freezer. The residential units between the college and the Hilliard Corporation may be eligible for this program.

One of the primary hurdles faced by Elmira in developing a community microgrid is NYSEG's low supply charge for electricity in the area. This condition worsens the financial case for development of large scale DERs in the area, but smaller DERs such as residential solar panels should qualify for net metering and thus generate more competitive revenues and savings. Coupled with battery storage, which is becoming increasingly cost effective, distributed solar panels could become a significant energy resource within the community. This generation solution can be implemented without the expense of full microgrid control and distribution infrastructure.

Appendix

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

REDACTED PER NDA WITH NYSEG