34 - Town of Cortlandt

Notice

Town of Cortlandt Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

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Abstract

Together with the Town of Cortlandt (Cortlandt), Booz Allen Hamilton has completed the feasibility study for a proposed microgrid. This study summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is technically feasible. The commercial and financial viability of the project have been analyzed and detailed in this document. The Cortlandt microgrid project faces the challenge of high capital costs relative to the loads served, but it benefits from the high local electricity prices. The proposed 100 kilowatt (kW) natural gas engine and 350 kW and 60 kW solar generation will provide a steady source of clean generation in Cortlandt while lessening dependence on existing diesel backup generation. In addition, the Cortlandt microgrid provides an ideal opportunity to explore the viability and interoperability of a community microgrid in a suburban, investor-owned utility (IOU) footprint. Many of the takeaways of the feasibility study may be generalized across the spectrum of the NY Prize and community microgrids.

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

Contents

Notice i
Abstract ii
Figures vi
Tables vi
Acronyms and Abbreviations viii
Executive Summary x
1. Introduction 1
2. Microgrid Capabilities and Technical Design and Configuration 1
2.1 Project Purpose and Need 1
2.2 Microgrid Required and Preferred Capabilities (Sub Tasks 1.1 and 1.2) 3
2.2.1 Serving Multiple, Physically Separated Critical Facilities 3
2.2.2 Limited Use of Diesel Fueled Generators 3
2.2.3 Local Power in both Grid-Connected and Islanded Mode 4
2.2.4 Intentional Islanding 4
2.2.5 Resynchronization to Con Ed Power 4
2.2.6 Standardized Interconnection 5
2.2.7 24/7 Operation Capability 5
2.2.8 Two Way Communication with Local Utility 6
2.2.9 Voltage and Frequency Synchronism When Connected to the Grid 6
2.2.10 Load Following and Frequency and Voltage Stability When Islanded 6
2.2.11 Diverse Customer Mix 6
2.2.12 Resiliency to Weather Conditions 7
2.2.13 Black-Start Capability 7
2.2.14 Energy Efficiency Upgrades 7
2.2.15 Cyber Security 8
2.2.16 Use of Microgrid Logic Controllers 9
2.2.17 Smart Grid Technologies 9
2.2.18 Smart Meters 9
2.2.19 Distribution Automation 9
2.2.20 Energy Storage 9
2.2.21 Active Network Control System 10
2.2.22 Demand Response 10
2.2.23 Clean Power Sources Integration 10
2.2.24 Optimal Power Flow 10
2.2.25 Storage Optimization 11
2.2.26 PV Monitoring, Control, and Forecasting 11

2.2.27 Protection Coordination 11
2.2.28 Selling Energy and Ancillary Services 11
2.2.29 Data Logging Features 12
2.2.30 Leverage Private Capital 12
2.2.31 Accounting for Needs and Constraints of Stakeholders 12
2.2.32 Demonstrate Tangible Community Benefit 12
2.3 Distributed Energy Resources Characterization (Sub Task 2.3) 12
2.3.1 Existing Generation Assets 13
2.3.2 Proposed Generation Assets 13
2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics 13
2.4 Load Characterization (Sub Task 2.2) 14
2.4.1 Electrical Load 14
2.4.2 Thermal Consumption 18
2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1) 18
2.5.1 Grid Parallel Mode 19
2.5.2 Intentional Islanded Mode 19
2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4) 20
2.6.1 Electrical Infrastructure 20
2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure 22
2.6.3 Basic Protection Mechanism within the Microgrid Boundary 23
2.6.4 Thermal Infrastructure 23
2.7 Microgrid and Building Control Characterization (Sub Task 2.5) 23
2.7.1 Microgrid Supporting Computer Hardware, Software and Control Components 25
2.7.2 Grid Parallel Mode Control 26
2.7.3 Energy Management in Grid Parallel Mode 26
2.7.4 Islanded Mode Control 27
2.7.5 Energy Management in Islanded Mode 27
2.7.6 Black Start 29
2.7.7 Resynchronization to Con Ed Power 29
2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6) 30
2.8.1 Existing IT & Telecommunications Infrastructure 30
2.8.2 IT Infrastructure and Microgrid Integration 30
2.8.3 Network Resiliency 31
2.9 Microgrid Capability and Technical Design and Characterization Conclusions 31
3. Assessment of Microgrid's Commercial and Financial Feasibility (Task 3) 32
3.1 Commercial Viability – Customers (Sub Task 3.1) 33
3.1.1 Microgrid Customers and Investors 33
3.1.2 Benefits and Costs to Other Stakeholders 34

3.1.3 Purchasing Relationship 35
3.1.4 Solicitation and Registration 36
3.1.5 Energy Commodities 37
3.2 Commercial Viability – Value Proposition (Sub Task 3.2) 37
3.2.1 Business Model 37
3.2.2 Replicability and Scalability 39
3.2.3 Benefits, Costs, and Value 40
3.2.4 Demonstration of State Policy 43
3.3 Commercial Viability – Project Team (Sub Task 3.3) 44
3.3.1 Stakeholder Engagement 44
3.3.2 Project Team 44
3.3.3 Financial Strength 48
3.4 Commercial Viability – Creating and Delivering Value (Sub Task 3.4) 48
3.4.1 Microgrid Technologies 48
3.4.2 Operation 49
3.4.3 Barriers to Completion 49
3.4.4 Permitting 50
3.5 Financial Viability (Sub Task 3.5) 50
3.5.1 Revenue, Cost, and Profitability 50
3.5.2 Financing Structure 52
3.6 Legal Viability (Sub Task 3.6) 53
3.6.1 Ownership and Access 53
3.6.2 Regulatory Considerations 53
3.7 Project Commercial and Financial Viability Conclusions 55
4. Cost Benefit Analysis 56
4.1 Facility and Customer Description (Sub Task 4.1) 57
4.2 Characterization of Distributed Energy Resource (Sub Task 4.2) 59
4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3) 62
4.3.1 Peak Load Support 62
4.3.2 Deferral of Transmission/Distribution Requirements 62
4.3.3 Ancillary Service 63
4.3.4 Development of a Combined Heat and Power System 63
4.3.5 Environmental Regulation for Emission 63
4.4 Project Costs (Sub Task 4.4) 65
4.4.1 Project Capital Cost 65
4.4.2 Initial Planning and Design Cost 68
4.4.3 Operations and Maintenance Cost 69
4.4.4 Distributed Energy Resource Replenishing Fuel Time 70

4.5 Costs to Maintain Service during a Power Outage (Sub Task 4.5) 71
4.5.1 Backup Generation Cost during a Power Outage 71
4.5.2 Cost to Maintain Service during a Power Outage 74
4.6 Services Supported by the Microgrid (Sub Task 4.6) 74
4.7 Industrial Economics Benefit-Cost Analysis Report 75
4.7.1 Project Overview 75
4.7.2 Methodology and Assumptions 76
4.7.3 Results 77
5. Summary and Conclusions 86
5.1 Lessons Learned and Areas for Improvement 86
5.1.1 Cortlandt Lessons Learned 86
5.1.2 Statewide Lessons Learned 87
5.1.3 Stakeholder Lessons Learned 90
5.2 Benefits Analysis 92
5.2.1 Environmental Benefits 92
5.2.2 Benefits to Local Government 92
5.2.3 Benefits to Residents of Cortlandt 92
5.2.4 Benefits to New York State 92
5.3 Conclusion and Recommendations 93
Appendix 95

Figures

Figure ES- 1. Map of Cortlandt Microgrid Coverage Area xi
Figure 1. Cortlandt Equipment Layout 16
Figure 2. Typical 24-Hour Cumulative Load Profile 17
Figure 3. Cortlandt One-Line Diagram 22
Figure 4. Diagram of a Typical Microgrid Control System Hierarchy 24
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Figure 5. Normal Operation Purchasing Relationship 36
Figure 6. Island Operation Purchasing Relationship 36
Figure 7. Present Value Results (No Major Power Outages; 7 Percent Discount Rate) 78
Figure 8. Present Value Results, Scenario 2 (Major Power Outages Averaging 7.3 Days/Year; 7 Percent Discount Rate) 84

Tables

Table ES- 1. Prospective Microgrid Facilities x
Table ES- 2. Microgrid Generation Assets xi
Table 1. Outage Summary by Category 3

Table 2. New York State Interconnection Standards 5
Table 3. Existing Distributed Energy Resources 13
Table 4. Proposed Generation Assets 13
Table 5. Cortlandt's 2014 Microgrid Load Points 17
Table 6. Cortlandt's Distributed Switches (SW) Description 20
Table 7. Cortlandt's Network Switch Description 21
Table 8. Cortlandt's Server Description 21
Table 9. List of Additional Components 22
Table 10. Microgrid Customers 34
Table 11. Cortlandt Microgrid SWOT 38
Table 12. Benefits, Costs, and Value Proposition to SPV Owners 40
Table 13. Benefits, Costs, and Value Proposition to Consolidated Edison, Inc. 41
Table 14. Benefits, Costs, and Value Proposition to the Town of Cortlandt 41
Table 15. Benefits, Costs, and Value Proposition to Connected Facilities 42
Table 16. Benefits, Costs, and Value Proposition to the Larger Community 42
Table 17. Benefits, Costs, and Value Proposition to New York State 43
Table 18. Project Team 45
Table 19. Project Team Roles and Responsibilities 46
Table 20. Savings and Revenues 50
Table 21. Capital and Operating Costs 51
Table 22. Available Incentive Programs 52
Table 23. Facility and Customer Detail Benefit 58
Table 24. Distributed Energy Resources 61
Table 25. Distributed Energy Resource Peak Load Support 62
Table 26. Emission Rates 64
Table 27. Distributed Equipment Capital Cost 66
Table 28. Capital Cost of Proposed Generation Units 67
Table 29. Initial Planning and Design Cost 68
Table 30. Fixed Operating and Maintenance Cost 70
Table 31. Maximum Fuel Operating Time for Distributed Energy Resource 70
Table 32. Cost of Generation during a Power Outage 73
Table 33. Critical Services Supported 75
Table 34. BCA Results (Assuming 7 Percent Discount Rate) 77
Table 35. Detailed BCA Results (No Major Power Outages; 7 Percent Discount Rate) 79
Table 36. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 7.3 Days/Year; 7 Percent Discount Rate) 85

Acronyms and Abbreviations

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

NYISO	New York Independent System Operator
NYMPA	New York Municipal Power Agency
NYPA	New York Power Authority
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
QF	Qualifying Facility
RAID	Redundant Array of Independent Disks
REV	Reforming the Energy Vision
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCOPF	Security Constrained Optimal Power Flow
SOA	Service Oriented Architecture
SOW	Statement of Work
SPV	Special Purpose Vehicle
TCP/IP	Transmission Control Protocol/Internet Protocol
VAC	Volt Alternating Current

Executive Summary

Booz Allen Hamilton was awarded a contract by the New York State Energy Research and Development Authority (NYSERDA) through its New York Prize initiative to conduct a Feasibility Study of a community microgrid concept in the Town of Cortlandt. This report presents the findings and recommendations from the previous four tasks, discusses the results and lessons learned from the project, and lays out the environmental and economic benefits for the project. Our design demonstrates the Town can improve energy resiliency with intentional and emergency island mode capabilities, stabilize energy prices with distributed energy resource (DER) assets, and comply with the greater New York Reforming the Energy Vision (REV) by constructing 510 kW of clean energy generation capability. The study concludes the technical design is feasible, however it is financially infeasible as a standalone project.

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

Table ES- 1. Prospective Microgrid Facilities

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

Name	Description	Address
F1	Cortlandt Healthcare	110 Oregon Rd
F2	St. Columbanus School	122 Oregon Rd
F3	Town Hall/Police Department complex	1-2 Heady St

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

- An existing 120 kW diesel backup generator at Cortlandt Healthcare
- An existing 100 kW natural gas backup generator at the Town Hall / Police Department
- A proposed 350 kW solar photovoltaic (PV) system at Cortlandt Healthcare
- A proposed 60 kW solar PV system at the Town Hall / Police Department
- A proposed 100 kW natural gas generator at the Town Hall / Police Department

The existing and proposed generation assets will supply 100% of the electricity requirements of the facilities in Table ES-1 during emergency outage conditions, providing relief to residents in and around the Town of Cortlandt. The backup power provided by the microgrid will ensure shelter, municipal services, and medical care all remain accessible in the event of a long-term grid outage. Both the natural gas generators and the photovoltaic (PV) arrays will operate in islanded and grid-connected mode, pushing electricity to the Consolidated Edison (Con Ed) grid via a long-term power purchase agreement (PPA). Generation assets will be located at Cortlandt Healthcare and the Town Hall / Police Department Complex, as described above.

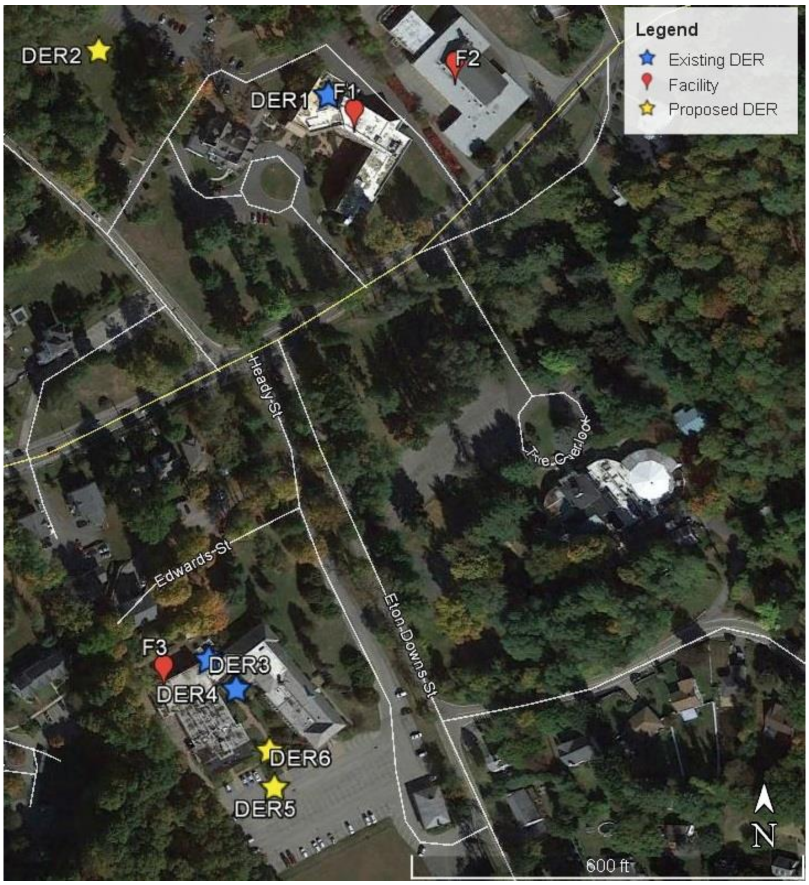
Table ES- 2. Microgrid Generation Assets

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

Name (on map)	Location	Description	Fuel Source	Capacity (kW)	Address
DER1	Cortlandt Healthcare	Existing diesel generator	Diesel	120	110 Oregon Rd
DER2	Cortlandt Healthcare	New PV system	Sunlight	350	110 Oregon Rd
DER3	Town Hall/Police Department complex	Existing natural gas generator	Natural Gas	100	1-2 Heady St
DER4	Town Hall/Police Department complex	New PV system	Sunlight	60	1-2 Heady St
DER5	Town Hall/Police Department complex	New natural gas reciprocating generator	Natural Gas	100	1-2 Heady St

Figure ES- 1. Map of Cortlandt Microgrid Coverage Area

Figure displays a detailed map of the coverage area illustrating where all three facilities are located relative to each other and the main streets within Cortlandt.



The Town of Cortlandt and private investors will own the microgrid through a special purpose vehicle (SPV). The single SPV ownership model also affords Cortlandt a seamless integration of generation, microgrid controllers, and distribution infrastructure and allows the SPV owners to capture the full suite of revenue streams, estimated at $120,000 per year. The model will maintain the existing Con Ed billing and rate capture mechanisms, and revenues cover variable costs and required payments on capital expenditures before being proportionally distributed to SPV ownership.

The microgrid will incur initial capital costs of $1.8 million as well as operation, maintenance, and fuel costs totaling approximately $125,000 per year. The Town may be willing to support a portion of the project costs and private partners are expected to contribute the balance of the capital required. NY Prize Phase III funding is critical to this proposal's viability because the revenues generated by electric sales will not cover operational expenditures nor the $1.8 million in capital expenditures.

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

In order to successfully establish a microgrid in the proposed Cortlandt footprint, a new line between the Town Hall/Police Department, St. Columbanus, and Cortlandt Healthcare must be constructed. The line is necessary to connect two separate feeders while leaving intermediate and downstream loads undisturbed when the microgrid islands. While the new line is an added cost, it allows for islanding on a blue-sky day for economic or operational reasons and supports an eventual business model shift to a load-following, fully behind-the-meter entity.

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

1. Introduction

The Town of Cortlandt (Cortlandt) is seeking to develop a community microgrid to improve energy service resiliency, accommodate distributed energy resources, stabilize energy prices, and reduce greenhouse gas (GHG) emissions. Working with Cortlandt and Con Ed, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary microgrid concept that will connect three critical and important facilities to three new generation assets, a 100 kW natural gas generator, a 350 kW solar photovoltaic (PV) array, and a 60 kW solar PV array. In addition, the microgrid will intertie the existing 120 kW diesel generator at Cortlandt Healthcare and the existing 100 kW natural gas generator at the Town Hall/Police Department complex. The microgrid will serve physically disparate facilities, providing shelter and municipal services to the residents of Cortlandt and surrounding areas. 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.

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

2. Microgrid Capabilities and Technical Design and Configuration

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

2.1 Project Purpose and Need

Cortlandt faces several challenges that could be resolved with a community microgrid.

- The St. Columbanus School (a NYSERDA-defined critical facility) does not own backup generators and is therefore vulnerable to prolonged interruptions or outages in grid-supplied power. By connecting the facility to the microgrid, the Town will ensure that the school always has a reliable power supply. Cortlandt faces the normal range of weather that affects the northeastern United States. The electricity supply is occasionally disrupted by rain, snow, wind (that can cause trees to fall on distribution lines), and heat waves. The microgrid will maintain power to connected facilities throughout the year and may expand in the future to include more businesses, residences, and government buildings in Cortlandt.

- 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.
- Cortlandt has nearly 15 miles of shoreline, which makes the town particularly vulnerable to storms and subsequent flooding. For example, Hurricane Sandy caused over two-thirds of Con Ed customers in the area to lose power for almost two weeks. The proposed microgrid will maintain power to facilities that will provide critical services to the Town of Cortlandt and surrounding communities during emergencies. The generation assets will sit onsite limiting exposure to downed overhead distribution lines elsewhere in the system. See Table 1 for a summary of historical power outages in Westchester County.

The Cortlandt microgrid will improve the resilience of the local electricity grid in emergency outage situations, accommodate distributed energy generation, stabilize energy prices during peak events, and reduce the town's GHG emissions. The Town of Cortlandt experiences the usual range of extreme weather that faces the Downstate area, including torrential rain, snow, wind, and flooding, all of which may impact the larger grid's ability to safely, reliably, and efficiently deliver electricity to customers.

Avoiding outages has monetary value to the connected facilities, and while it is difficult to specify exact amounts for a given facility and the level of granularity in the data the Project Team possesses, estimates of outage costs for small and medium businesses are between $5,000 and $10,000 for a four to eight hour outage. Conservatively estimated, this suggests at least $15,000 a year in lost productivity and costs, and likely more given the criticality of the infrastructure. Interruptions to the power supply can derail operations, cause damage to machinery, and render direct health/safety equipment ineffective. When the larger grid loses power or experiences large fluctuations in voltage or frequency, the Cortlandt microgrid will disconnect from the larger grid to supply power to connected facilities. Cortlandt, like many cities and towns in New York, has experienced several extreme weather events in recent years that affected power quality (Tropical Storm Lee, Hurricane Irene, and Hurricane Sandy). Flooding and falling branches destroyed power lines and interrupted the delivery of electricity to the city's critical facilities. Prolonged grid outages can create potentially hazardous situations for all of the city's residents—the microgrid will alleviate some of this danger by maintaining power to healthcare providers, law enforcement, and shelters.

Table 1. Outage Summary by Category

Table provides an overview of major historical outages in Westchester County. Con Ed did not provide outages by feeder, which would allow the Project Team to estimate how many citizens were affected.

Cause	Westchester County Outages
Hurricane Sandy	206,000
2011 Blizzard	71,000
Hurricane Irene	203,821
2010 Northeaster	173,000
Tropical Storm Ernesto	80,000
July 2006 Heatwave and Storms	35,000

Implementing a community microgrid will improve energy resiliency, reduce the greater need for high-emission peaking assets (by expanding distributed energy resources), and reduce the strain on the local electricity transmission and distribution network.

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

The following section demonstrates how the design concept meets the required and select preferred capabilities provided by NYSERDA in the Statement of Work (SOW) 66650.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

At this stage of the study, the Town of Cortlandt and the Booz Allen team, in cooperation with Con Ed, have identified three facilities that will be connected to the microgrid, all of which will provide critical services (as defined by NYSERDA) to the community in the case of an outage. See Table ES-1 for a full list of prospective facilities to be tied into the microgrid.

The proposed microgrid footprint occupies approximately 20 acres in Cortlandt. Loads will be interconnected via one new medium-voltage power line that will run along Heady Street. Facilities will communicate over Con Ed's WAN (utilizing the existing IT fiber optic backbone). Utilizing industry standard protocols, such as Distributed Network Protocol (DNP3), Open Platform Communication (OPC), Modbus, 61850, and Inter-Control Center Communications Protocol (ICCP) (IEC 60870-6) will allow remote monitoring and control of distributed devices, regardless of manufacturer. The microgrid design is flexible and scalable to accommodate future expansion and technologies.

2.2.2 Limited Use of Diesel Fueled Generators

Cortlandt has established a preference for solar arrays to serve as the primary energy source. However, unless they are integrated with battery storage systems or some other form of backup generation, solar arrays do not provide sufficiently reliable electricity. The Project Team determined that installing a new natural gas reciprocating generator would be 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 arrays whenever it is available, and it will meet remaining facility demand with electricity from the reciprocating generator. Backup diesel generators will only come on-line in island mode when other assets cannot meet aggregate facility demand.

2.2.3 Local Power in both Grid-Connected and Islanded Mode

The microgrid will provide on-site power in both grid-connected and islanded mode. In island mode, the MCS will optimize on-site generation and automatically shed loads as needed to maintain stable and reliable power flow. In grid-connected mode, the microgrid will optimize the use of available assets to reduce energy costs when possible and export to the Con Ed grid when economic and technical conditions align.

The proposed generation assets will operate continuously in grid-connected mode, reducing local dependence on grid-supplied power. In island mode, the backup spinning generators will come on-line as necessary to meet cumulative demand. The spinning generators have sufficient capacity to provide all of the microgrid's electricity in island mode, guaranteeing that facilities will have a reliable source of power regardless of weather or time of day.

2.2.4 Intentional Islanding

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

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

2.2.5 Resynchronization to Con Ed Power

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

The existing ATS at the PCC must be upgraded to function within the microgrid design. The PCC may also require an additional breaker to accommodate new microgrid generation. The control system will trigger the opening or closing of this breaker during system transitions.

2.2.6 Standardized Interconnection

The microgrid design complies with NYPSC interconnection standards. Table 3 outlines the most significant state interconnection standards that apply to this microgrid project. Con Ed customers connecting to the grid via distributed energy resource projects must follow the same New York State Standard Interconnection Requirements detailed in Table 2.

Table 2. New York State Interconnection Standards

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

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

2.2.7 24/7 Operation Capability

The project concept envisions a reciprocating natural gas-fired generator as the microgrid's main generation source (the solar arrays will also contribute significantly throughout the year). The Town's existing natural gas supply line can support continuous operation of the reciprocating generator and the existing natural gas generator at the Town Hall. The Project Team was unable to acquire sizes for the diesel fuel tanks at Cortlandt Healthcare and the Town Hall, but these tanks will limit the microgrid's 24/7 operation capability during long-term outages.

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 Cortlandt. The new automation solution proposed in this deliverable will serve as a protocol converter to send and receive all data available to the operator over Con Ed's WAN using industry standard protocols such as DNP3, OPC, Modbus, 61850, and ICCP (IEC 60870-6).

2.2.9 Voltage and Frequency Synchronism When Connected to the Grid

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

2.2.10 Load Following and Frequency and Voltage Stability When Islanded

The microgrid's control scheme in islanded mode is quite similar to that of the larger transmission system. The system maintains frequency by controlling real power generation and regulates voltage by controlling reactive power availability. To the extent that flexible loads are available, the MCS can curtail a facility's load or disconnect entire facilities. One of the proposed PMEs will be able to simultaneously disconnect Cortlandt Healthcare and the school based on a command from the MCS, and the other can remove the Town Hall/Police Department complex. However, disconnecting these loads from the microgrid also entails removing any on-site generation.

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

2.2.11 Diverse Customer Mix

Connected facilities will have varying effects on power quality and stability based on their load size and economic sector. The Cortlandt microgrid will connect three small commercial-sized facilities, none of which will have a significant negative impact on local power quality. The approximate load breakdown for the Cortlandt microgrid is as follows:[1]

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

- Cortlandt Healthcare – 51% of load
- St. Columbanus School – 8% of load
- Town Hall/Police Department complex – 41% of load

Cortlandt Healthcare and the Town Hall/Police Department complex together account for approximately 90% of the microgrid's electricity demand. Targeted energy efficiency (EE) upgrades at Cortlandt Healthcare could significantly reduce the facility's (and therefore the microgrid's) average electricity demand.

2.2.12 Resiliency to Weather Conditions

The Town of Cortlandt is exposed to the normal range of weather conditions that affects the Northeastern United States. Extreme weather events include (but are not limited to) torrential rain, snow, and wind that could cause falling objects and debris to disrupt electric service and damage equipment and lives. The Town of Cortlandt experienced several significant disruptions to power service during hurricanes Irene and Lee and Superstorm Sandy.

By implementing line fault notifications and deploying other sensors, microgrid owners can ensure the network is as resilient as possible to storms and other unforeseen forces of nature. The new natural gas reciprocating generator (the microgrid's main generation asset) will be constructed with a container and will therefore be protected from extreme weather. The existing backup generators are similarly enclosed. The solar arrays will not produce energy during extreme weather events, but the microgrid's spinning generators should be capable of maintaining power to the microgrid alone. Generators will be placed in elevated locations to avoid disruptions from flooding.

If constructed overhead, the new medium-voltage distribution line may be exposed to severe weather; however, burying the line underground may represent a crippling capital cost. The Project Team will weigh the benefits and costs of overhead versus underground line placement during the next phase of the NY Prize competition.

2.2.13 Black-Start Capability

The proposed natural gas reciprocating generator will be equipped with black-start capabilities. If the Cortlandt grid unexpectedly loses power, the MCS will initiate island mode by orchestrating the predefined black-start sequence. The reciprocating generator will require an auxiliary source of DC power to start multiple times in case of failure. It will ramp up to 60 hertz (Hz) and prepare to supply each of the microgrid loads in sequence. The MCS will bring backup generators on-line and synchronize their output as necessary. After the spinning generators have established a stable power supply, the MCS will synchronize output from the solar arrays and bring them on-line.

2.2.14 Energy Efficiency Upgrades

Energy efficiency (EE) is critical to the overall microgrid concept. As a certified Climate Smart Community, the Town of Cortlandt has demonstrated its commitment to reducing energy use. The Town's Master Plan for future development includes an extensive section on sustainability.

The Town implemented a Green Team executive board in 2009, and several facilities in Cortlandt have invested in significant EE upgrades. For example, the Town Hall/Police Department complex recently installed upgraded motion sensors and light-emitting diode (LED) lights based on the results of several energy audits.

The Town of Cortlandt has formed a Green Team executive board to guide future EE upgrades in the Town. As a Climate Smart Community, Cortlandt has adopted a green procurement policy and a green building code for residential or commercial construction. Although the community has had success in reducing local energy use, there is still significant potential for EE upgrades in Cortlandt. Cortlandt Healthcare, a microgrid facility, currently owns a 40-year-old chiller that is a prime target for an efficiency upgrade. The healthcare facility plans to target EE as a principal component of its upcoming remodeling effort.

The Project Team estimates the reduction potential for the four facilities to be approximately 30 kW. The project will leverage existing Con Ed EE programs to reduce load at existing facilities and will seek to qualify facilities for NYSERDA funded EE programs.

Potential EE programs include:

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

2.2.15 Cyber Security

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

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), used to monitor the unique address of the device and its designated network port, and if the device is ever disconnected, the program will disable that port and prevent an unauthorized device from entering the IT system.

2.2.16 Use of Microgrid Logic Controllers

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

2.2.17 Smart Grid Technologies

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

2.2.18 Smart Meters

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

2.2.19 Distribution Automation

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

2.2.20 Energy Storage

The Project Team's analysis of battery storage technologies found their cost to be prohibitively high. In a recent study, Lazard estimated the levelized cost of batteries in microgrids to be between $319/MWh to $1,000/MWh, depending on the application.[2] 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 Cortlandt microgrid, and battery storage units do not provide sufficient cash flows to recover capital costs.

Despite this, the microgrid MCS will have the capability to fully utilize and optimize the storage resources—including charging and discharging cycles for peak demand shaving, should the Town reevaluate its options in the future. The price of battery storage technology is constantly decreasing, and by "stacking" different uses of energy storage (i.e., microgrid resiliency,

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

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 microgrid will be under continuous and close monitoring and control when it operates in either grid-connected or islanded mode. Both monitoring and control will be decomposed 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 on the microgrid will communicate bi-directionally with the MCS via MODBUS, OPC, DNP3 TCP/IP, or other protocols as required. The communication infrastructure will be based on the fiber optics backbone partitioned using gigabit Ethernet switches. The Project Team believes this is a required capability.

2.2.22 Demand Response

The microgrid MCS has the capability to participate in demand response (DR) programs by increasing generator output or curtailing flexible load on a signal from Con Ed. Given sufficient generator capacity or load flexibility, the Cortlandt microgrid can participate in Con Ed's Commercial System Relief Program (CSRP) and/or Distribution Load Relief Program (DLRP), which would provide the utility load relief on the hottest days. Con Ed provides comparatively lucrative capacity payments to participants that can guarantee load reduction, paying $10/kW-month and $6/kW-month in the CSRP and DLRP respectively. Moreover, by enrolling in three consecutive years upfront, the project would qualify for an additional Three Year Incentive Payment.

However, the current design does not include energy storage systems or sufficient excess generator capacity to *reliably* participate in DR programs. The microgrid will be capable of *voluntary* participation in Con Ed DR programs, but the payments from these programs will not represent significant sources of revenue (compared to payments from the reservation program).

It is unclear whether disconnecting from the larger grid (entering island mode) will qualify the microgrid for participation in Con Ed DR programs. Because entering island mode would take both generation and load off the larger grid, the Project Team has assumed Con Ed will not accept island mode as acceptable load reduction for participation in DR programs.

2.2.23 Clean Power Sources Integration

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

2.2.24 Optimal Power Flow

As recommended by Con Ed, the proposed community microgrid is fairly small, with only three facilities and six small generation resources. If the microgrid owners negotiate a long-term power purchase agreement (PPA) with Con Ed, the Project Team expects the generators to run continuously throughout the year. The MCS will fully utilize the optimum output of generation sources at the lowest cost in a unique approach that includes fuel cost, maintenance and energy cost as part of the security constrained optimal power flow (SCOPF).

2.2.25 Storage Optimization

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

2.2.26 PV Monitoring, Control, and Forecasting

The microgrid's PV inverters will usually operate at their maximum power point (MPP) because there is no associated O&M cost. In some rare situations, the PV arrays might have to reduce their output to help regulate the frequency of local power flow or to follow facility electricity demand in island mode. In such situations, the control is almost exclusively local with the output set point communicated by the central controller. As with other renewable energy sources, power output depends on weather and time of day. The MCS will fully integrate and optimize output from the proposed solar arrays at Cortlandt Healthcare and the Town Hall/Police Department complex.

The microgrid power management system includes high resolution solar forecasting, which will 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 Cortlandt microgrid design does not include battery storage.

2.2.27 Protection Coordination

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

2.2.28 Selling Energy and Ancillary Services

It is unclear whether the microgrid will be permitted to back-feed power through Cortlandt's main substation into the broader Con Ed transmission system. If allowed, the microgrid will sell excess energy from the solar arrays and reciprocating generator to Con Ed.

Most lucrative NYISO ancillary service markets (such as the frequency regulation market) require participants to bid at least 1 MW of capacity. The microgrid's generation assets have an aggregate capacity of 810 kW, under the required minimum, so the microgrid will not qualify for participation in these ancillary service markets. Other ancillary service markets, such as spinning and non-spinning reserves, do not provide competitive payments to small-scale generators, such as the microgrid's 100 kW reciprocating generator. The Project Team has concluded that the microgrid most likely will not participate in NYISO ancillary service markets unless project owners overbuild generation assets.

Overbuilding the reciprocating generator could provide microgrid owners with interesting options—microgrid owners could sell extra electricity capacity into NYISO frequency regulation or ICAP (installed capacity) energy markets. With one extra MW of generation capacity, the microgrid could also participate in the novel NYISO Behind the Meter: Net Generation program.[3] Expansive discussion of these programs is outside the scope of this feasibility study, but the Project Team will consider these options in future phases of the competition.

2.2.29 Data Logging Features

The microgrid control center includes a Historian Database to maintain real-time data logs. The Historian Database can also display historical trends in system conditions and process variables.

2.2.30 Leverage Private Capital

The microgrid project will seek to leverage private capital where possible in order to develop components of the microgrid. The Project Team is actively developing relationships with investors and project developers that have expressed interest in NY Prize. As the project concept matures, the Project Team will continue to engage these groups to better understand how private capital can be leveraged for this specific project. The Project Team currently envisions continuous operation of the proposed reciprocating generator and solar arrays and sale of energy under a custom long-term PPA with Con Ed. Investors will receive revenue from electricity sales. More detail is provided in Section 3.5.2.

2.2.31 Accounting for Needs and Constraints of Stakeholders

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

2.2.32 Demonstrate Tangible Community Benefit

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

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As described above, the Cortlandt microgrid design includes 400 kW of spinning generation and 410 kW of solar energy capacity. This section will discuss the benefits of the proposed resources and how they will meet the microgrid's objectives in greater detail.

[3] This program has not yet been implemented in New York State. However, the Project Team expects that the program will have been enacted by the time of construction (2018-2020).

2.3.1 Existing Generation Assets

The Cortlandt microgrid will incorporate the existing backup generators at Cortlandt Healthcare and the Town Hall/Police Department complex (see Table 3 for details on existing generation assets). These assets will come on-line to provide supplemental power as necessary in island mode. Every existing generator connected to the microgrid will require grid paralleling switchgear and controllers to regulate and synchronize the generator's output.

Table 3. 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 each asset's label for Figure ES-1.

Name	Description	Fuel Source	Capacity (kW)	Address
DER1	Diesel Generator	Diesel	120	110 Oregon Rd
DER3	Diesel Generator	Diesel	80	1-2 Heady St
DER4	Natural Gas Generator	Natural Gas	100	1-2 Heady St

2.3.2 Proposed Generation Assets

The microgrid design includes three new generation assets: a 100 kW natural gas-fired continuous duty reciprocating generator, a 350 kW solar PV array, and a 60 kW solar PV array, shown in Table 4. The 350 kW solar array will be located at Cortlandt Healthcare, while the reciprocating generator and 60 kW solar array will be located at the Town Hall/Police Department complex. Existing natural gas infrastructure in Cortlandt will provide an adequate supply of fuel for the reciprocating generator.

Table 4. Proposed Generation Assets

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

Name	Technology	Rating (kW)	Fuel	Address
DER2	Solar PV array	350	Sun Light	110 Oregon Rd
DER5	Natural Gas Generator	100	Natural Gas	1-2 Heady St
DER6	Solar PV array	60	Sun Light	1-2 Heady St

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides Cortlandt with several additional energy resources. In grid-connected mode, the new DERs listed in Table 4 will operate in parallel with the main grid, exporting excess power when generation exceeds demand and importing power from the larger grid to meet peak demand when necessary. In islanded mode, the MCS will first deploy the proposed reciprocating generator and solar arrays and then bring backup generators on-line as necessary. The new reciprocating generator is sized so spinning generators can meet the entire microgrid load (so long as the microgrid's load does not exceed the 2014 peak). In general, peak demand is coincident with the peak output of solar units. Therefore, the combination of spinning generators and solar arrays should be sufficient to meet peak demand (absent significant load growth).

At minimum, the new natural gas reciprocating generator will be protected by a container, and thus will be safe from severe weather events. The natural gas pipeline is buried to protect it from severe weather.

The proposed natural gas reciprocating generator will be capable of supplying reliable electricity by providing:

- Automatic load following capability – generation units and controls will be able to respond to frequency fluctuations within cycles, allowing the microgrid to balance demand and supply in island mode.
- Black start capability – the reciprocating generator will have auxiliary power (batteries) for black starts and can establish island mode grid frequency. After the reciprocating generator has established stable power flow, the main microgrid controller will synchronize the solar array inverters to match the generator's frequency and phase.
- Conformance with New York State Interconnection Standards.[4]

The existing backup generators to be incorporated into the microgrid can also provide these services.

2.4 Load Characterization (Sub Task 2.2)

The Project Team sized proposed DERs according to electricity demand data from Cortlandt's load points. The load characterizations below describe the electrical loads served by the microgrid.[5] Descriptions of the loads to be served by the microgrid along with redundancy opportunities to account for downtime are included below and also in the Appendix. None of the connected facilities have sufficient thermal energy demand to merit the addition of combined heat and power (CHP) capability to the proposed reciprocating generator.

2.4.1 Electrical Load

The Project Team evaluated three primary electrical loads for the Cortlandt microgrid: the St. Columbanus School, Cortlandt Healthcare, and Cortlandt Police Department/Town Hall complex. Typical 24-hour load profiles for each facility can be found in the Appendix. Cortlandt's proposed community microgrid will incorporate a healthcare facility, a law enforcement office, and a school that can be used as a shelter, all within close proximity to the primary Con Ed feeders on Heady Street and Oregon Road.

After extensive consultation with Con Ed representatives, the Project Team has determined a new distribution line will be necessary to connect microgrid facilities. The design also utilizes an existing automatic transfer switch (ATS) at the point of common coupling with the larger grid (on Heady Street). Two new pad mounted equipment (PME) systems will be able to shed loads and isolate generators as necessary to maintain power in islanded mode. One switch can

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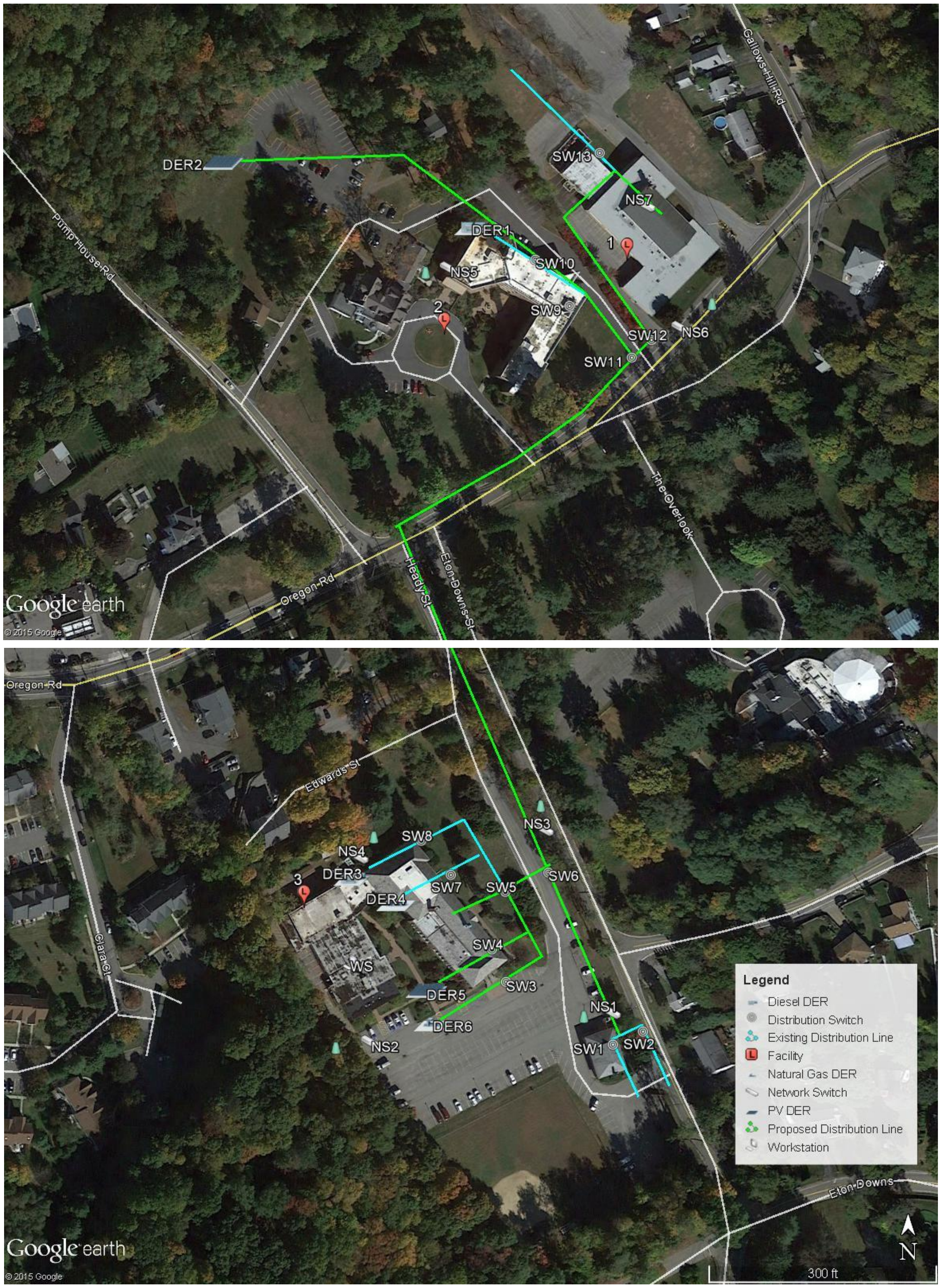
[4] New York State Public Service Commission. *Standardized Interconnection Requirements and Application Process for New Distributed Generators 2 MW or Less Connected in Parallel with Utility Distribution Systems* (2014). Available from *www.dps.ny.gov*.

[5] Estimated loads are based on metering data from the facility's account numbers via Con Ed's on-line metering portal.

simultaneously disconnect the school and healthcare center, but doing so will also remove associated generation assets. The other switch can disconnect the Town Hall/Police Department complex. Figure 1 provides an illustration of the proposed microgrid design and layout, including loads, switches, existing electrical infrastructure, and proposed electrical infrastructure.

Figure 1. Cortlandt Equipment Layout

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



Con Ed provided the Project Team with twelve months of metering data for connected facilities (January through December 2014), summarized in Table 5. The aggregate peak load in 2014 was 413 kW, and the monthly average was 153 kW.

Table 5. Cortlandt's 2014 Microgrid Load Points

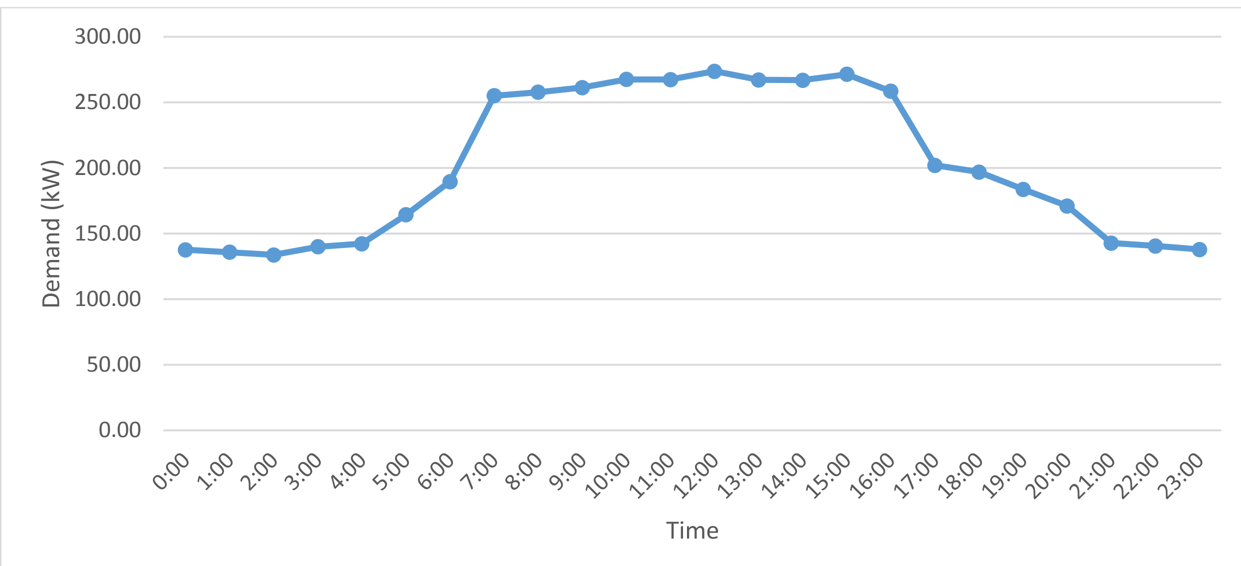
Table shows the microgrid electric demand in kW, electric consumption in kilowatt hours (kWh), and thermal consumption in MMBTU.

	Electric Demand (kW)		Electric Consumption (kWh)			Thermal Consumption (MMBTU)		
	2014 Peak	2014 Monthly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average
Microgrid Loads	413	153	1,338,802	111,567	298,678	2,779	232	54

Figure 2 provides a typical aggregate hourly load profile for the Cortlandt microgrid facilities. Aggregate demand sharply increases around dawn and remains at nearly twice the night-time baseline throughout the day.

Figure 2. Typical 24-Hour Cumulative Load Profile

Figure 2 illustrates the typical 24-hour cumulative load profile for connected facilities (St. Columbanus School, Town Hall/Police Department complex, and Cortlandt Healthcare). The figure represents the sum of individual typical 24-hour load profiles from 2014.



The proposed 100 kW reciprocating generator and solar arrays will operate continuously in both parallel and islanded mode. Although the solar arrays will not operate at full capacity throughout the year, they will typically be most productive when facility demand is highest.

When the solar arrays are operating close to their maximum production points, the microgrid's generation capacity will approach 810 kW, with a guaranteed 400 kW from spinning generators. Aggregate demand from microgrid facilities averaged 153 kW and never exceeded 413 kW in 2014.[6] The proposed DERs should therefore have adequate capacity to supply the microgrid facilities with electricity in island mode.

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

Because the microgrid design relies on six (rather than one) primary generation assets, each asset should have downtime available at various points throughout the year. This redundancy will be valuable when generation assets need to be taken offline for maintenance.

2.4.2 Thermal Consumption

The Project Team conducted an extensive study on connected facilities to determine whether the design could include a CHP unit. However, none of the connected facilities have sufficient thermal energy demand to merit the addition of CHP capability.

2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1)

The hardware, software, and DER listed in the introduction must be synchronized to achieve the maximum benefits. Optimization challenges generally consist of an objective, constraints, and optimization variables. For the microgrid, the optimization objective is resiliency and cost minimization of the electrical energy supply where the main constraint is the investment cost. The optimization variables associated with this are distributed energy resources and controllable loads.

The optimization is done in two stages, system planning, design stage, and operational stage. During the system planning and design stages, the goal is to identify the largest set of critical loads that can be supplied by an affordable set of generators located strategically throughout the distribution system. To minimize investment cost generators should also have minimal operation and maintenance (O&M) cost. Optimization should be done over time accounting for different technologies, cost escalations, and load increase and distribution using Optimal Power Flow (OPF) to satisfy operational constraints while minimizing the O&M. The operational, or real time, stage optimization involves stochastic optimal control. The problem is stochastic because of randomly changing load and intermittent renewable energy resources. While the planning

[6] This estimate was calculated by summing each facility's peak demand from 2014. The estimate therefore assumes that all facilities reached peak demand at the same time, which is unlikely. The true peak demand was almost certainly less than 413 kW, but the Project Team was unable to obtain synchronized real-time load data for all included facilities.

stage does not need any communication facilities and does not have to be completed in a certain amount of time, it is critical to include real-time control for reliable and secure communications that produce control signals relatively fast.

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 100 kW natural gas-fired reciprocating engine, 350 kW solar PV array, and 60 kW solar PV array will operate continuously, supplying energy to microgrid-connected facilities and possibly exporting excess energy to the larger Con Ed grid. The Cortlandt microgrid will incorporate three existing backup generators: a 120 kW diesel generator, an 80 kW diesel generator, and a 100 kW natural gas generator. These generators will not operate in grid-connected mode, but they will come on-line when the microgrid transitions to islanded mode. Refer to Table ES-2 for a complete list of microgrid DERs.

If the larger grid experiences an emergency while the microgrid is connected, the microgrid control scheme allows for the export of a predetermined amount of active and reactive power from microgrid DERs. By injecting power into the larger grid, the microgrid may be able to balance frequency and voltage to avert an outage.[7] If the 100 kW natural gas-fired unit has sufficient capacity, it will ramp up generation as necessary to fulfill the power requirement. If available capacity from the new 100 kW natural gas generator cannot meet the power requirement, the control system may access up to 300 kW of power from the backup spinning generators.

2.5.2 Intentional Islanded Mode

The proposed energy management and control scheme will balance generation with microgrid demand and maintain adequate frequency, voltage, and power flow across the microgrid network in islanded (autonomous) mode (as described in Section 2.7.4). Islanded mode can be intentionally used during forecasted Con Ed grid outages or disturbances to maintain electricity supply for microgrid facilities—the system will manage the aggregate 400 kW of spinning generation and 410 kW of inverter-based generation (from the solar PV arrays) to match aggregate demand in real time. Because the output of the solar arrays cannot be controlled, the natural gas and diesel-fired generators will provide flexible real-time response. 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.

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

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

2.6.1 Electrical Infrastructure

The local utility, Con Ed, owns the existing electrical infrastructure in Cortlandt. Electricity will enter the microgrid area through the existing ATS on Heady Street. Although the existing ATS is capable of automatic current sensing, it will need to be upgraded to function correctly in the proposed microgrid scheme. New distribution lines will begin near the point of common coupling (PCC) on Heady Street. These lines will carry electricity to the connected microgrid facilities through proposed PMEs outside the Town Hall/Police Department complex and Cortlandt Healthcare. Proposed PMEs will allow the MCS to simultaneously disconnect Cortlandt Healthcare and the St. Columbanus School (or the Town Hall/Police Department complex) if necessary. See Figure 1, Equipment Layout, for a map of proposed equipment and infrastructure.

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

Table 6. Cortlandt's Distributed Switches (SW) Description

Table outlines all thirteen distributed switches with their names (on equipment layout), descriptions, and status as proposed.

Name	Description	New/Upgrade
SW1	Automatic switch for feeder isolation	Upgrade
SW2	Automatic switch for feeder isolation	Upgrade
SW3	Generator breaker	New
SW4	Inverter internal breaker	New
SW5	Automatic switch for load shedding and Microgrid sequence control	New
SW6	Automatic switch for load shedding and Microgrid sequence control	New
SW7	Generator breaker	Upgrade
SW8	Generator breaker	Upgrade
SW9	Inverter internal breaker	New
SW10	Generator breaker	Upgrade
SW11	Automatic switch for load shedding and Microgrid sequence control	New
SW12	Automatic switch for load shedding and Microgrid sequence control	New
SW13	Automatic switch for feeder isolation	New

Table 7. Cortlandt's Network Switch Description

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

Name	Description	Status	Address
NS1	Near Switch 1 and Switch 2 for communication	Proposed	Refer to Eqp. Layout
NS2	Near DER 5 and DER 6 for communication	Proposed	Refer to Eqp. Layout
NS3	Near Switch 5 and Switch 6 for communication	Proposed	Refer to Eqp. Layout
NS4	Near DER 3 and DER 4 for communication	Proposed	Refer to Eqp. Layout
NS5	Near DER 1 and DER 2 for communication	Proposed	Refer to Eqp. Layout
NS6	Near Switch 11 and Switch 12 for communication	Proposed	Refer to Eqp. Layout
NS7	Near Switch 13	Proposed	Refer to Eqp. Layout

Table 8. Cortlandt's Server Description

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

Name	Description	Status	Address
Workstation	Operator/Engineer workstation	Proposed	1-2 Heady St
Server1	Primary EMS and SCADA	Proposed	1-2 Heady St
Server2	Secondary EMS and SCADA	Proposed	1-2 Heady St

Automated switching equipment distributed throughout the microgrid will enable different routings of power flows and the isolation/bypass of certain areas as needed. Cortlandt's one-line diagram is shown below in Figure 3.

The Con Ed distribution grid in Cortlandt consists of medium-voltage lines (13.2 kilovolts (kV)). All facilities have their own transformers that step incoming power down to low voltage.

Figure 3. Cortlandt One-Line Diagram

Figure displays a one-line diagram for Cortlandt 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 Cortlandt community microgrid are listed in Table 9. The point of common coupling (PCC) between the main grid and the microgrid will be the existing ATS on Heady Street (south of the Town Hall/Police Department complex).

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

Table 9. List of Additional Components

Table lists all the 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/Switch (Siemens 7SC80 relay)	1	New breaker/switch at distribution load feeders to enable IED interface with and control by the microgrid
Automated PME (Siemens 7SJ85 multi breaker control relay)	2	New multi module relays at pad mounted/underground distribution switches. One relay can protect and control multiple switches/breakers at each PME. Isolate the downstream loads, generation, and feeders from the microgrid
Automatic Transfer Switch (Siemens 7SJ85 multi breaker control relay)	2	ATS needs to be upgraded with microgrid controllable relays capable of current sensing and multi-breaker control. Automated logic for switching to available hot feeder with one designated as the preferred. Current sensing on both feeders makes it possible to initiate emergency microgrid mode.
Generation Controls (OEM CAT, Cummins, etc.) (Load Sharing via Basler, etc.)	4	OEM generation controllers serve as the primary resource for coordinating generator ramp up/ramp down based on external commands. Basler distributed network controllers allow the 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)	2	Controls PV output and sends data to main microgrid controller 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 direct current (DC) power. Each device (or cluster of devices) will have a primary and backup power supply source. During normal operation, 120 volt (V) alternating current (AC) power will flow through an 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 available power supply. When normal AC voltage source is unavailable, the battery bank can provide DC power to devices for at least one week.

2.6.3 Basic Protection Mechanism within the Microgrid Boundary

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

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

2.6.4 Thermal Infrastructure

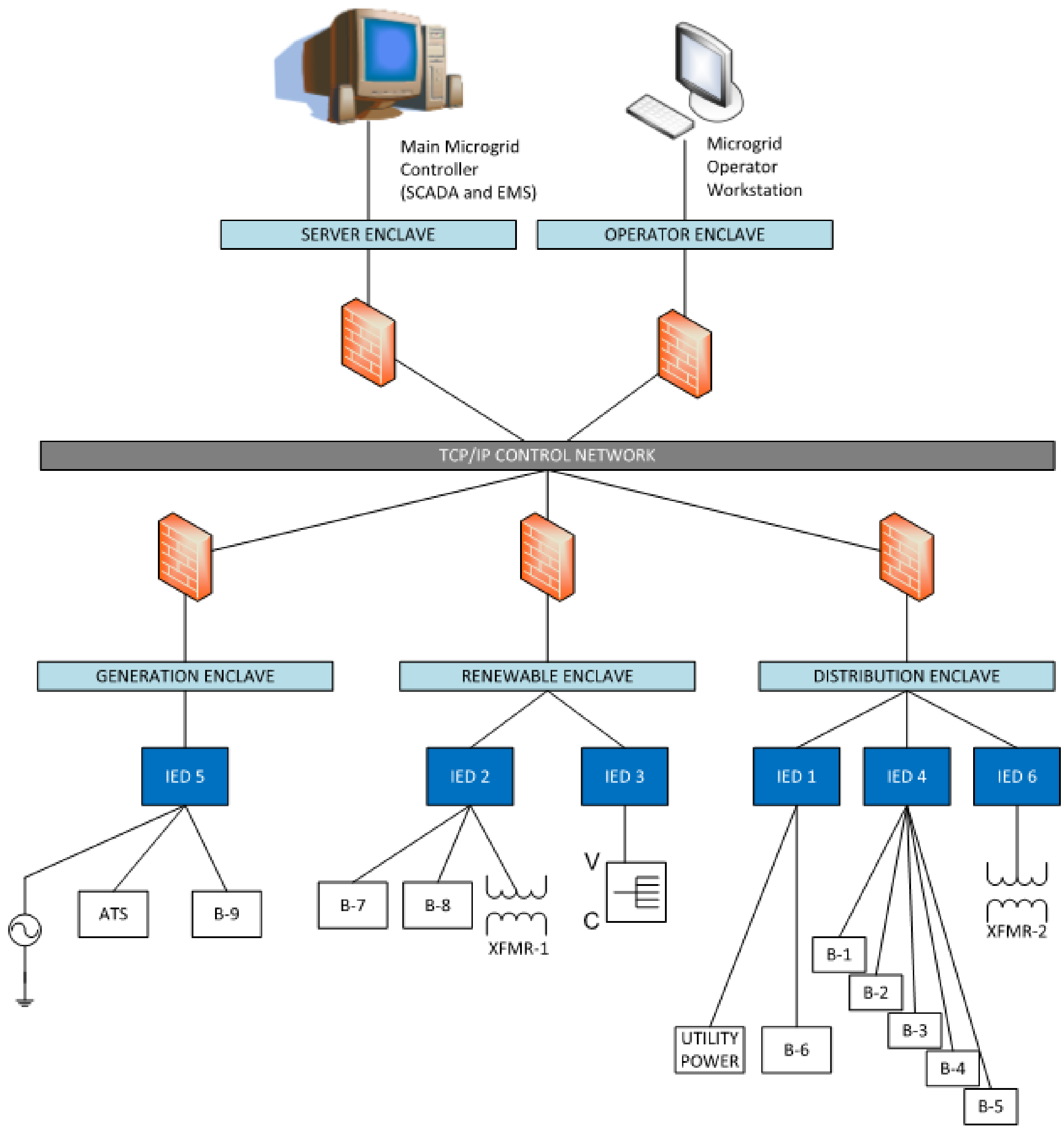
The proposed natural gas reciprocating generator requires a steady supply of natural gas to operate. The proposed reciprocating generator will utilize existing thermal infrastructure in Cortlandt, including a four-inch medium-pressure natural gas pipeline that supplies gas to the existing natural gas generator at the Town Hall/Police Department complex, for its fuel supply. The pipeline will not require significant upgrades or extensions to provide adequate volume and pressure to the proposed reciprocating generator.

2.7 Microgrid and Building Control Characterization (Sub Task 2.5)

This section provides a more detailed description of the microgrid's modes of operation. The microgrid control system will include an EMS and a SCADA-based control center (see Figure 4), hereafter collectively referred to as the main microgrid controller. Distributed intelligent electronic devices (IEDs) 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 the larger Con Ed grid. When controllers detect an outage or emergency disturbance on the larger grid, the microgrid will switch to island mode. In these situations, the microgrid will disconnect from the larger grid and proceed with the programmed black-start sequence (described in Section 2.7.6) to start power flow through included lines and devices. When power returns after an outage, the main microgrid controller will manage re-synchronization to the Con Ed grid (described in Section 2.7.7).

Figure 4. Diagram of a Typical Microgrid Control System Hierarchy

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



2.7.1 Microgrid Supporting Computer Hardware, Software and Control Components

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

- SOA software platform – The SOA platform facilitates the monitoring and control of included power devices and control systems.
- Redundant Array of Independent Disks (RAID) 5 servers (including 1 primary, 1 backup) for the MCS – The MCS will include an EMS and a SCADA based control center, and will optimize the operation of the microgrid. This includes determining which critical loads will be supplied, integrating PV output into the energy portfolio (including high resolution solar forecasting), and controlling the charge/discharge of energy storage wherever applicable. The system combines information on power quality, utilization, and capacity in real time, which allows the community and control algorithms to balance electricity supply with microgrid demand.
- Historian database server – Historian database collects data from various devices on the network and logs information to its database.
- 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 Devices Distribution Switches Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay or equivalent) – The microprocessor-based logic controllers in the field (also referred to as IEDs) are programmed to act on predetermined set points. They can also be manually overridden by the MCS or a human operator. The control system host servers continuously poll these logic controllers for data using discrete or analog signals. Resulting data is processed by the IEDs connected to control elements.
- Automated Pad-Mounted Equipment (PME) (Siemens 7SJ85 multi breaker control relay or equivalent) – The PMEs, which include switches and fuses, are updated via remote control relay and are capable of controlling internal switches.

- Automatic Transfer Switch (Siemens 7SJ85 multi breaker control relay or equivalent) – The ATS is capable of current sensing and multi breaker control and is equipped with remote control relay.
- PV Inverter Controller (OEM Fronius, or equivalent) – This component will control PV output 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.

2.7.2 Grid Parallel Mode Control

When the microgrid operates in grid-connected mode, every generator will synchronize its voltage (magnitude and angle) and frequency with the voltage (magnitude and phase) and frequency of the electrically closest main grid point. After 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.

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

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

2.7.4 Islanded Mode Control

The transition to island mode can be either unintentional or intentional. Unintentional islanding is essentially the main microgrid controller's programmed response to an outage at the distribution system or transmission level. An outage at the distribution system level can occur within or outside the microgrid, and the microgrid islanding scheme must be able to handle either situation. Microgrid control system relays at the PCC will recognize low voltage, and applicable switches at the PCC will open automatically (disconnecting the microgrid from the larger grid). Any existing 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 reciprocating generator's black-start capabilities (and those of other spinning generators if necessary), the MCS will commence island mode operation. The main generator will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. After the reciprocating generator is on-line and power flow through the microgrid is stable, the main microgrid controller will synchronize output from the solar arrays (voltage and frequency) and bring them on-line. In steady state, their phases will be different, similar to grid-connected steady state operation.

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

- The Con Ed grid has an expected outage that could potentially affect transmission power to Cortlandt substations.
- The Con Ed grid needs to perform network maintenance work, thereby isolating loads in the Cortlandt 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, including spinning backup generators (as necessary). Once the available power sources are synchronized, the system is considered ready to implement islanded operation and will begin opening the incoming utility line breakers.

Please refer to 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. 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. It should be noted that low-priority loads may be disconnected in order to maintain the N+1 power assurance.

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

- Generators that do not start.
- Generators that trip off unexpectedly during microgrid operation.
- Switchgear that fails to operate.
- Switchgear that fails to report status.
- Loss of power from the natural gas generator (or spinning backup generators).
- Loss of power from the solar arrays.

The EMS will optimize the microgrid's operation by managing generation assets and prioritizing critical loads according to operational requirements. Proposed DERs will provide stable, sustainable, and reliable power. The MCS will continuously balance generation and load in real-time, monitoring relevant variables (i.e., system frequency and voltage) and adjusting generator output as necessary. The main microgrid controller will first deploy energy from renewable generation assets and adjust output from spinning generators to match remaining electricity demand. The microgrid design relies on fast ramp rates from spinning generators to compensate for changing output from the solar arrays. 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 Cortlandt's microgrid system. The analysis considered the potential of using storage for three purposes:

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

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

2.7.6 Black Start

The proposed 100 kW reciprocating generator will be equipped with black-start capabilities. The existing backup generators in Cortlandt may also be outfitted with black-start capabilities to provide system redundancy in grid outage scenarios. If the Cortlandt grid unexpectedly loses power, the main microgrid controller will initiate island mode by orchestrating the predefined black-start sequence. The microgrid then will begin an unintentional transition to island mode. A DC auxiliary support system is an essential part of each generator’s black-start capabilities. Each battery system must have enough power to start the generator multiple times.

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

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

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

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 Typical 24-Hour St. Columbanus School Load Profile in the Appendix for the control scheme sequence of operations.

2.7.7 Resynchronization to Con Ed Power

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

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

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

2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6)

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

2.8.1 Existing IT & Telecommunications Infrastructure

Cortlandt 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

The data transmitted throughout the proposed Cortlandt microgrid will be encrypted, but several additional intrusion protection measures can easily be implemented. One simple and inexpensive method is to disable any 65,535 TCP ports not being used to make the microgrid system work. Depending on final configuration, only a few TCP ports will need to be active. More TCP ports will need to be active if 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 that certain events (e.g., failed login attempts) are recorded. The SCADA security portion (software that resides on the SCADA servers) will be configured so that only operators and engineers with specific login credentials will be allowed to access and control the microgrid.

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

Because the logic controllers will be located at or near loads, the distributed equipment will take the IT system to the "edge," where it is potentially more vulnerable to hackers. A practical tool to prevent unauthorized access into the IT network is a program called Sticky media access control (MAC), used to monitor the unique address of the device and its designated network port, and if the device is ever disconnected, the program will disable that port and prevent an unauthorized device from entering the IT system.[8]

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. However, long periods of separation from the network will hamper SCADA controls, historian logging, and firmware updates from upstream servers.

2.9 Microgrid Capability and Technical Design and Characterization Conclusions

After thorough examination of existing utility infrastructure and energy demand requirements, the Project Team has provided a reliable microgrid design. Control components will efficiently manage the real-time operation of the microgrid by communicating with distributed intelligent electronic devices. The proposed design is resilient to forces of nature and cyber threats and

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

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, there are several barriers to project completion, which are outlined below.

- New distribution lines must be constructed.
- Funding for the project's capital costs must be obtained.
- The utility (Con Ed) must agree to the new interconnection and electrical distribution network because it will incorporate Con Ed lines and switches.
- The Town Hall/Police Department complex and Cortlandt Healthcare must agree to host the proposed reciprocating generator and solar arrays, and they must support the interconnection of their existing backup generators to the microgrid.
- The existing and proposed generation assets and microgrid components must be available for maintenance at all times.

The team is working with the facilities to ensure they will allow a third party to service the generation assets and microgrid components located on their land. These facilities have considerable incentive to support the project because construction and interconnection will guarantee a reliable power supply and possibly provide DER asset owners with new sources of revenue. The Project Team therefore expects these operational challenges to be resolved by the time of construction.

The microgrid design will require a new medium-voltage distribution line to connect the proposed facilities (see Figure 1). Existing natural gas infrastructure in the Town will be adequate for the continuous operation of the proposed natural gas reciprocating generator.

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:

- Investors will have sufficient interest in the project to provide necessary capital for the construction of new DERs and electricity distribution infrastructure.
- The solar arrays will value electricity at the average commercial retail rate through net metering agreements with Con Ed.
- Con Ed will purchase electricity from the new reciprocating generator at the utility's average supply price of electricity.[9]
- A third party, or Con Ed, will serve as the microgrid operator.

[9] ~$0.073/kWh. Calculated as the average Market Supply Charge (MSC) from 2013-2015 plus the average MSC Adjustment for Con Ed's Westchester Zone. Data obtained from https://apps.coned.com/CEMyAccount/csol/MSCcc.aspx and http://www.coned.com/documents/elecPSC10/MSCAdjCurrentPSCNo10.pdf

- Backup generators will come online only when the microgrid is in island mode and the proposed generators are not producing sufficient electricity to meet aggregate demand.

Preliminary analyses indicate that cash flows from energy sales and participation tariffs will not be sufficient to recover initial capital outlay. The proposed DERs will be eligible for approximately $240,000 in incentives from the NY Sun Program and $215,000 from the Federal Incentive Tax Credit (ITC).[10] However, public investors (such as the Town of Cortlandt) are not eligible for the Federal ITC, and tax incentive programs will be limited to the portion of the project owned by taxable entities. Regardless of investor eligibility for federal assistance, the Cortlandt microgrid will struggle to yield positive returns even with a Phase III NY Prize award.

3.1 Commercial Viability – Customers (Sub Task 3.1)

The Cortlandt microgrid design includes three facilities: Cortlandt Healthcare, St. Columbanus School, and the Town Hall/Police Department complex. The project will operate under an ownership model in which a single SPV owns the microgrid's DERs and components/control infrastructure. Private investors and the Town will provide the majority of the capital for the SPV, and the connected facilities may participate at their discretion.

The facilities will provide critical services (as defined by NYSERDA) to the Town during emergency situations. Cortlandt Healthcare will provide health services to the community, the Town Hall/Police Department complex will maintain law enforcement, and the school can serve as a shelter. Both Cortlandt Healthcare and the Town currently own backup generators that will be connected to the microgrid; however, these generators will only come online if the proposed reciprocating generator and solar arrays are not generating enough electricity when the microgrid is islanded to meet load requirements. To connect the proposed facilities, new power distribution lines will be required. Because the three facilities to be connected are close to each other, the Project Team forecasts the total length of new lines to be around 2,600 feet.

The project will affect several groups of stakeholders in the Cortlandt community that are not physically connected to the microgrid, and the benefits and challenges to these stakeholders are discussed further in this section.

3.1.1 Microgrid Customers and Investors

Three new DERs will generate electricity throughout the year: a 100 kW natural gas-fired reciprocating generator, a 60 kW solar array, and a 350 kW solar array. The microgrid will have the technical ability to enter island mode for economic reasons (to participate in DR programs), but it is unlikely to do so regularly.

In their day-to-day operations, each of the connected facilities serves the Cortlandt community, and most will make their services available to an even larger group of stakeholders during emergency outages. For example, by providing shelter in times of emergency, St. Columbanus

[10] 30% of the installed cost of each solar array; http://energy.gov/savings/business-energy-investment-tax-credit-itc

School may extend its immediate customer count beyond students and teachers to include the greater Cortlandt population.

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

Table 10. Microgrid Customers

Table provides a list of facilities that will be connected to the microgrid, their addresses, classifications, and scenarios during which they will purchase microgrid services.

Property	Address	Classification	Critical Service	Back-up Generation	Normal vs Island Mode
Cortlandt Healthcare	110 Oregon Rd	Healthcare	Yes	Yes	Both
St. Columbanus School	122 Oregon Rd	School	Yes	No	Both
Town Hall and Police Facilities	1-2 Heady St	Government	Yes	Yes	Both

Cash flows from electricity sales will consistently cover variable costs of operating the microgrid. The Federal ITC and NY Sun Program will recover much of the capital cost of the solar array for private investors. However, the generators are relatively small in scale and will produce proportionately small revenue streams, which will not recover initial capital expenditure costs.

The project would require NYSERDA NY Prize Phase III to approach a breakeven financial position. As a result, it may be in Cortlandt's best interest to consider a phased approach to energy security by first adding rooftop solar to the Town Hall and Police complex, enhancing energy efficiency projects and further considering solar at Cortlandt Healthcare.

3.1.2 Benefits and Costs to Other Stakeholders

Prospective stakeholders in the Cortlandt microgrid extend beyond direct investors and facilities to include other Con Ed customers, existing generation asset owners, and residents of the areas surrounding Cortlandt. Direct benefits will accrue to the Town, proposed DER asset owners, connected facilities, and Con Ed, the local utility. The surrounding communities and larger State of New York will enjoy indirect benefits from the microgrid (further discussed in Section 5.2).

During an emergency power outage, the microgrid will maintain power to three critical facilities, facilitating availability to residents inside and outside Cortlandt. Cortlandt Healthcare will continue to provide medical services to residents of the Town and surrounding communities in the event of a long-term grid outage, the Town Hall/Police Department complex will maintain law enforcement and centralized emergency management and communication for the community. The new reciprocating generator and solar arrays together possess a maximum generation capacity of 510 kW, which represents 100 kW of continuous load reduction for the larger Con Ed grid during both peak demand events and normal periods of operation and 410 kW of variable production solar PV. The design currently incorporates backup generators at

Cortlandt Healthcare and the Town Hall/Police Department complex into the microgrid to provide additional load support in islanded operation.

The negative effects and challenges faced by external stakeholders are relatively few. The primary costs will be purchasing and installing the necessary microgrid equipment and proposed generation assets. However, these costs will not directly impact community members not involved in the microgrid. The relatively small size of the spinning generation means noise and space concerns should be minimal.

3.1.3 Purchasing Relationship

Private and public investors will own the DERs and microgrid infrastructure including control equipment, distributed intelligent electronic devices, and new distribution lines. A third party operator such as Con Ed Solutions or Constellation, or the utility will operate and maintain the microgrid components and controls. DER owners will sell electricity from the reciprocating generator to Con Ed under a buy-back agreement or other long-term power purchase agreement (PPA), while solar energy will be valued at the average commercial rate according to a net metering agreement. During outages, DER owners will sell electricity from the backup generators directly to connected facilities.

DER owners will sell electricity to Con Ed and may realize additional revenue from ancillary service sales to the New York Independent System Operator (NYISO). The volume of electricity purchased from the reciprocating generator will depend on electricity output (dictated by microgrid controllers), system demand, and agreements between the owners and Con Ed.[11] Unfortunately, the minimum required capacity for participation in most NYISO ancillary service markets is 1 megawatt (MW), which represents approximately 1000% of the generator's maximum output. The Project Team therefore expects the microgrid will *not* participate in NYISO ancillary service markets and do not include any value streams associated with ancillary services in the assessment. Solar energy produced by the proposed arrays will be valued at the average commercial rate under a net metering agreement (volume = total generation minus on-site consumption).[12]

DER owners will receive revenues from electricity sales, and infrastructure owners will receive revenues from new tariffs associated with microgrid connection or islanded operation service. Revenues will first be committed to covering operation costs and debt payments. Investors will then receive a share of the remaining cash flow that corresponds to their initial investment. Because Cortlandt Healthcare, the Town, and the school can purchase shares in the proposed SPV, some of the microgrid's connected facilities may receive revenues from energy sales and microgrid operation.

The utility-purchaser relationship will remain largely unchanged because electricity will flow through the existing system and rates will be captured though the existing billing mechanism. All

[11] This electricity will most likely be valued at Con Ed's average supply charge ($0.0729/kWh in Zone I, Dunwoodie).
[12] This electricity is valued at the local commercial retail rate.

generated electricity will be sold into the Con Ed main grid, and the facilities will continue to draw their electricity from Con Ed and pay their standard electricity rates; the facilities will see no difference in their electricity procurement and billing procedures during normal operation. See Figure 5 and Figure 6 for visual representations of normal and islanded purchasing relationships.

Figure 5. Normal Operation Purchasing Relationship

Figure provides a visual representation of the purchasing relationship during normal operation.

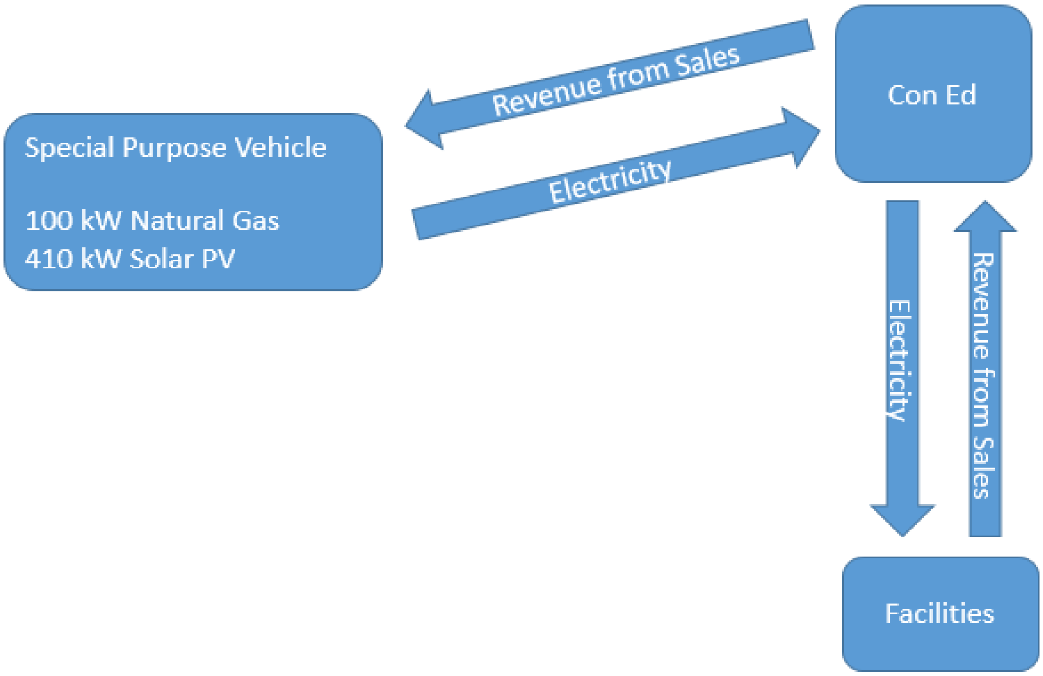
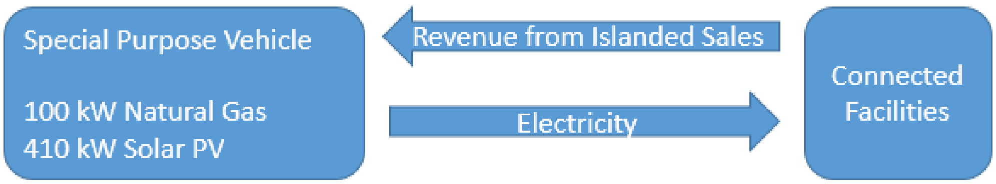


Figure 6. Island Operation Purchasing Relationship

Figure provides a visual representation of the purchasing relationship during island operation.



3.1.4 Solicitation and Registration

The Town and utility will work with identified facilities to join the project as microgrid participants. This outreach will include informal discussions and, ultimately, signed agreements of participation in the microgrid and acceptance of the tariff or fee structure determined by the NY Public Service Commission (PSC). Formal registration with the microgrid will be managed by programming the logic controllers to include or exclude the facility from islanded services based on their agreement with the utility. The Project Team views this registration as an operational feature of the microgrid and not a legal requirement of the PSC.

Electricity purchases during normal operation will follow existing contractual and purchase relationships between the utility and the customers, while electricity sales will follow a new buy-back agreement or PPA. Islanded operation contracts will be established during development and construction and will address the order in which islanded facilities are brought back online following an island event, the order in which facilities will be dropped to maintain N+1 assurance, and the associated cost for participating in the microgrid. All of the aforementioned contracts are proposed and none are currently in-force.

3.1.5 Energy Commodities

The microgrid's generation assets will generate revenue from electricity sales and possible participation in ancillary service or DR programs. Together these DERs will provide up to 510 kW of electricity for the microgrid and the Cortlandt community. The energy will serve the Con Ed main grid during normal operation, and it will directly serve the connected facilities during a grid outage.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to Cortlandt, private investors, Con Ed, direct participants, and the larger State of New York. The proposed reciprocating generator and solar arrays will reduce the Town's greenhouse gas emissions and provide stable energy resources to critical and important facilities in emergency situations. Electricity customers will benefit from a more stable power supply, and DERs will return stable cash flows. Moreover, incremental lessening of the load on the Con Ed system may provide benefits into the future.

3.2.1 Business Model

Microgrid ownership in Cortlandt will follow an ownership model wherein a single SPV owns the distributed energy resources and microgrid infrastructure. This model most efficiently couples the revenues from the DERs with the costs of the microgrid infrastructure. The Town and private investors will be the primary shareholders in the ownership group. Investors will receive revenue from electricity sales to the utility and possibly from minor participation in DR programs. Revenue streams from electricity sales (further described in Section 3.5.1) will accrue to investors and will cover variable generation costs. However, the relatively small scale of the proposed generators forces the project to rely on NY Prize Phase III funding for commercial feasibility, and the Project Team estimates even Phase III support will not be sufficient to ensure positive returns for the project. Private investors would likely finance this project with a mixture of outside debt and equity. The Town of Cortlandt may issue bonds to raise capital. The Town should qualify for a relatively low interest rate on issued debt given its high credit rating (Section 3.3.3). Further, Con Ed, as the local utility, should operate the control infrastructure and seamlessly integrate with the existing grid.

The table below provides an overview of the Cortlandt microgrid project, including an analysis of project strengths, weaknesses, opportunities, and threats (SWOT).

Table 11. Cortlandt Microgrid SWOT

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

Strengths	Weaknesses
• Provides value to investors by selling electricity at the local utility supply charge • Qualifies for several existing incentive programs such as the Federal ITC and NY Sun Program • Connects three critical facilities to reliable sources of backup power, maintaining community access to life-saving equipment and services during emergency outages • Aligns interests of the Town (and therefore community), Con Ed, connected facilities, and private investors in seeing the microgrid succeed • Leverages Con Ed expertise to facilitate load aggregation, following, voltage regulation, and other necessary daily operations	• Overhead distribution lines would cost around $150,000[13] • The project will not likely be able to recover up-front investment • Long-term purchase agreements between DER owners and Con Ed are required to ensure value for DER investors; these are not assured • Insufficient thermal energy demand in Cortlandt prevents incorporation of CHP system into microgrid design
Opportunities	**Threats**
• Serves as a replicable template (most NY communities are served by IOUs) and encourages coordination between local government, private investors, and utility • Experiments with new methods of rate calculation, with the opportunity to revolutionize the role of utilities in electricity generation, distribution, and consumption in New York State • Demonstrates the feasibility of reducing load on the larger grid with distributed energy resources	• Changes in regulatory requirements could impact the proposed business model and stakeholder goals—for example, if utilities are permitted to own generation assets in the future, Con Ed may wish to purchase a larger stake in DERs • If natural gas prices increase, it will significantly raise the microgrid's marginal cost of producing electricity, which may prompt a re-negotiation of Con Ed's purchasing price

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

- **Financial** – The small footprint and load, coupled with the lack of steam demand, makes the business case for the Cortlandt microgrid a difficult one. The proposed generation will support positive operating cash flows but will be unable to recover the capital expenditures. These expenditures, including the microgrid controller and new lines, are a requirement for this footprint. Revenue streams would be improved if the microgrid were able to island for purely economic reasons, such as when grid electricity prices are high or as a single demand response unit to take advantage of DR incentive payments or to sell power at retail rates; however, the Project Team does not consider these viable paths forward under current regulatory conditions.

[13] New distribution lines could cost as much as $1.4 million if built underground.

- **Regulatory** – Current State, NYISO, and utility incentives such as DR are not structured to incentivize microgrids. For instance, current Con Ed DR programs are lucrative and could provide the Cortlandt microgrid with tens of thousands of dollars per year in payments for removing loads. However, islanding the microgrid to shed the loads also sheds generation and provides no net benefit to Con Ed or NYISO, so this revenue is currently not included in calculations. Moving forward, regulatory policy should address the treatment of microgrids in DR programs, as policies currently do not account for the particulars of microgrid operation. Further, the possibility of the microgrid being regulated similarly to a qualifying facility would enhance project economics.
- **Incentives** – The commercial viability of the Cortlandt microgrid currently depends on the Federal ITC, the NY Sun Program, and NYSERDA NY Prize Phase III funding. The NY Sun Program will cover 30% of the installed cost of the 60 kW array, while the Federal ITC will offset 30% of the installed cost of each array (for private investors). Finally, even with these incentives, the loads and proposed generation assets are too small to guarantee recovery of the capital costs.

3.2.2 Replicability and Scalability

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

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

Organizational Replicability. The proposed business model does not present a barrier to project replicability, but the reliance on incentive programs for commercial viability limits the specific replicability of this design (see Section 3.5.1 for details).

The combined benefits of inexpensive capital from municipalities and local expertise from the utility will promote close cooperation between previously separated stakeholders and encourage the adoption of the proposed ownership model. The Federal ITC and NY Sun Program will recover around 60% of installed capital costs for the 60 kW solar array, but the 350 kW solar array exceeds the NY Sun Program's size limitations. The project's commercial viability and overall replicability is therefore not strong due to its capital expense and relatively small size.

Scalability. The microgrid is scalable; however, the local Con Ed feeder network is a primary constraint on how large the microgrid could grow and which new facilities might be included. The Cortlandt microgrid does not rely on AMI meters to remotely disconnect loads that fall within the utility line breakers, meaning any expansion will have to consider either the physical realities of partitioning new power lines from the larger grid or introduce AMI remote disconnect capability to all loads between utility line breakers. Additionally, because the spinning generators (natural gas and diesel) provide only an aggregate 320 kW of power, new generation assets, or battery storage, are prerequisites to expanding the microgrid in the future.

3.2.3 Benefits, Costs, and Value

The microgrid will provide both direct and indirect benefits to a wide range of stakeholders; however, the magnitude of these benefits is limited by the small size of the proposed microgrid. Primarily, the community will have access to healthcare, shelter, and law enforcement during emergency grid outages. Preliminary analysis indicates revenues from electricity sales will cover annual variable generation costs; however, remaining cash flows will not recover initial investment costs. Projected costs and benefits are discussed in Table 12 through Table 17. Except for a marginally increased price of electricity during island mode and minimal microgrid participation fees, the customers and local community will not bear any of the project's costs. This proposal involves a wide group of stakeholders—from local, non-customer residents to the State of New York—and provides value to all involved parties. The tables below provide an overview of the benefits and costs to members of the SPV, direct microgrid customers, citizens of Cortlandt and surrounding municipalities, and the State of New York.

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Distributed Energy Resource Owners	- Investors will receive annual cash flow from solar array net metering and electricity sales from the NG reciprocating generator - Federal ITC and NY Sun Program recover 30-60% of each solar array's cost in the project's first year (for private investors; the Town is not eligible for the ITC) - Entering island mode during peak demand events could qualify the microgrid for Con Ed DR programs. However, Con Ed is unlikely to accept islanding as eligible load reduction - NY Prize Phase III funding could recover up to $5 MM of initial project costs	- Initial capital outlay will be significant, as the SPV must purchase and install its generation assets - Forecasted installed capital costs for the 60 kW solar array, 350 kW solar array, and natural gas reciprocating engine are ~$105,000, ~$610,000, and ~$130,000 respectively[14] - Ongoing maintenance of DERs - Financing costs associated with initial capital outlay will persist for many years	- Baseline operation of natural gas generator and solar arrays provide cash streams. These cash flows may be supplemented by strategic participation in DR programs and/or ancillary services markets - Inclusion in the microgrid will provide generation asset owners with a reliable energy market for generated electricity

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

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Con Ed	- The utility will receive revenue from transmission & distribution (T&D) charges - The utility will continue to sell electricity to direct customers; there may be a slight reduction in prices - The utility will avoid loss of revenues in emergency outage situations - Local generation reduces the amount of power that must be imported from the larger grid; this may defer future T&D investments	- The utility will be responsible for purchasing generated electricity through a long-term PPA. Costs would be recouped through sales to existing Con Ed customers	- The utility can serve as a market connector without the costs associated with constructing and operating distributed energy resource assets - The utility will enjoy improved grid resiliency by integrating local generation assets with local distribution networks - Con Ed will have a new supply of electricity valued at their average supply charge

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Town of Cortlandt	- The microgrid will provide a resilient and redundant energy supply to critical services - Meets energy goals by encouraging DER construction and improving energy resiliency - Reduce GHG emissions - Connect municipal government facilities to a reliable emergency power source	- When the microgrid enters island mode due to a larger grid outage, customers will pay a slightly higher price for electricity than they would for electricity from the larger grid. This cost is offset by enhanced reliability and power quality	- Critical and important services will keep the lights on during outages, allowing the Town of Cortlandt to be an oasis of relief for local citizens and surrounding areas - The microgrid project will serve as a catalyst for customers becoming more engaged in energy service opportunities and will inspire residential investment in DER assets, such as solar PV and battery storage, as citizens see benefits associated with avoiding peak demand hours, producing enough electricity to be independent from the larger grid, and selling electricity in a local market - Generating electricity with solar PV arrays and a natural gas-fired reciprocating generator will reduce the Town's GHG emissions

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Connected Facilities	- Resilient and redundant energy supply to operations—outages cost commercial and residential customers ~$40-60/kWh and ~$5-8/kWh, respectively[15] - Access to a local market for distributed energy generation makes investments in small DERs more attractive to connected facilities	- Slightly higher electricity prices during island mode	- Maintain operations during emergency outages and provide valuable critical services to the Cortlandt community - Potential for partnerships and a local market for excess generation will encourage industrial stakeholders to build large-scale generation assets - Local market for excess energy makes investments in small DERs (such as solar panels) profitable for connected facilities

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Community at Large	- Access to 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	- Future expansion of the microgrid could bring more facilities into the design—however, the Town of Cortlandt will likely need to install widespread AMI to make this feasible

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

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

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

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
New York State	- DER assets will reduce the town's GHG emissions - Indirect benefits (such as outages averted) will demonstrate the benefits of microgrids paired with DER assets to citizens across the state and reduce load on the larger grid - Each microgrid accelerates NY State's transition from old macrogrid technology to newer, smarter, smaller technologies	- Depending on financing plans, growth of microgrid popularity, and increased use of natural gas-fired generators, the state may need to develop additional plans for expanding natural gas infrastructure	- By reducing peak load on the larger grid, every microgrid's DER assets will reduce the state's use of coal- and oil-fired plants during peak demand events—thus reducing GHG emissions and achieving NY State energy goals - Successful construction and operation of a microgrid will demonstrate the tangible value of microgrid projects as investments - Indirect benefits associated with microgrids will encourage and inspire citizens to strive for DERs in their own communities

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 unavoidable climate change, and expand renewable energy in the Town. The proposed microgrid supports the New York State Energy Plan by providing a power distribution platform for locally-owned DER assets. The ownership model has the potential to be extremely successful by leveraging low-cost capital as well as local utility expertise, and it is highly replicable. This project could therefore serve as a valuable example of innovative, profitable cooperation between IOUs, municipalities, and private investors.

By coordinating the microgrid as a local distributed system platform (DSP), the Cortlandt microgrid will act as a distributed resource and will provide local grid stabilization through injections and withdrawals of power. As more distributed resources are added throughout the Town, the microgrid can be tuned to provide continual support for these assets (e.g., by providing ancillary services) and will diversify and enhance its portfolio of revenue streams.

The Town of Cortlandt has made considerable progress towards achieving New York State energy goals. The Town is one of six certified Climate Smart Communities in New York State, having addressed all ten elements of the Climate Smart Communities Pledge which includes such goals as decreasing energy demand, supporting a green innovation economy, determining current emissions levels, and setting emission reduction targets. In 2012 Cortlandt committed to a Climate Action Plan for community and government as part of the Northern Westchester Energy Action Consortium (NWEAC), and the Town plans to reduce government and community emissions by replacing vehicle fleets and investing in building energy efficiency. The State Department of Environmental Conservation's Climate Smart Communities program also asks communities to develop action plans for adaptation to unavoidable climate change. As an investment that would greatly improve energy resiliency in the Town of Cortlandt, a community microgrid represents a major contribution towards this goal.

Cortlandt citizens are eligible for the Solarize Westchester campaign, which helps individuals and businesses install solar at a lower cost and provides planning and design support. Expanding distributed energy resources is key to expanding the microgrid. By leveraging incentives, such as the Solarize Westchester program, NY Sun program, and Federal ITC, Cortlandt residents and businesses have the opportunity to expand the community microgrid in the future and make progress towards grid independence.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

The Project Team includes Con Ed, the local Cortlandt government, Booz Allen Hamilton, Siemens AG, and Power Analytics. It may expand to include financiers and legal advisors as the project develops. Details on the Project Team can be found in this section.

3.3.1 Stakeholder Engagement

The Project Team has been engaged in constant communication with local stakeholders from the outset. Booz Allen and its partners in the Town 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 Cortlandt microgrid project is a collaboration between the public sector, led by the Town of Cortlandt, and the private sector, led by Con Ed and Booz Allen Hamilton with significant support from Power Analytics and Siemens. Project partners Pace Energy and Climate Center and Sustainable Westchester are also valuable team members. Each of the private sector partners is exceptionally well qualified in the energy and project management space, and the Town of Cortlandt has strong interest in improving its energy reliability and expanding its clean energy generation capacity. Details about the Project Team are included in Table 18 and Table 19.

Table 18. Project Team

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

<table>
<tr><td>Booz Allen Hamilton</td><td>Headquarters: McLean, VA</td><td>Annual Revenue: $5.5 B</td><td>Employees: 22,700</td></tr>
<tr><td colspan="4">History and Product Portfolio: Booz Allen was founded in 1914. In the ten decades since its founding, Booz Allen has assisted a broad spectrum of government, industry, and not-for-profit clients including the American Red Cross, all branches of the Department of Defense, the Chrysler Corporation, NASA, and the Internal Revenue Service. Booz Allen's energy business includes helping clients analyze and understand their energy use and develop energy strategies, recommending technology solutions to achieve their energy goals, and executing both self- and 3rd party funded projects including energy efficiency, renewable energy, and smart grids.</td></tr>
<tr><td>Siemens AG</td><td>Headquarters: Munich, Germany;
U.S. Headquarters: Washington, DC</td><td>Annual Revenue: €71.9 B</td><td>Employees: 343,000</td></tr>
<tr><td colspan="4">History and Product Portfolio: Siemens AG was founded in 1847 and is now one of the world's largest technology companies. Siemens AG specializes in electronics and electrical engineering, operating in the industry, energy, healthcare, infrastructure, and cities sectors. Siemens AG develops and manufactures products, designs and installs complex systems and projects, and tailors a wide range of solutions for individual requirements. The Siemens Microgrid Team develops comprehensive solutions leveraging the strength of Siemens' portfolio – from generation sources such as gas, wind, and solar, to transmission & distribution products, to control software solutions and services.</td></tr>
<tr><td>Power Analytics</td><td>Headquarters: San Diego, CA</td><td>Annual Revenue: $10-15M</td><td>Employees: 50</td></tr>
<tr><td colspan="4">History and Product Portfolio: Founded 25 years ago, Power Analytics is a privately-held small business that develops and supports electrical power system design, simulation, and analytics software. The Company's worldwide operations include sales, distribution, and support offices located throughout North America, South America, Europe, Asia, and Africa and Australia.</td></tr>
<tr><td>Consolidated Edison, Inc.</td><td>Headquarters: New York, NY</td><td>Annual Revenue: $13 B</td><td>Employees: 14,500</td></tr>
<tr><td colspan="4">History and Product Portfolio: For more than 180 years, Consolidated Edison has served the world's most dynamic and demanding marketplace—metropolitan New York. Con Edison provides electric service to approximately 3.3 million customers and gas service to approximately 1.1 million customers in New York City and Westchester County. The company also provides steam service in certain parts of Manhattan. Con Edison receives yearly operating revenues of approximately $13 BN and owns assets totaling approximately $44 BN.</td></tr>
</table>

Table 19. Project Team Roles and Responsibilities

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

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Consolidated Edison, Inc.	The utility's expertise will be essential in planning microgrid construction. To date, Con Ed has been non-committal about what role they intend to play in the project lifecycle.	Con Ed will oversee any installation of new controls and switches on their existing infrastructure and tie-ins with the grid.	Con Ed can help operate and maintain the microgrid. This may include responsibility for switching to island mode and regulating voltage and frequency across the microgrid's loads in both grid-connected and island mode. Con Ed will also purchase electricity from the reciprocating generator and distribute it to customers in Cortlandt.
Town of Cortlandt	The Town may purchase shares in the SPV. It will serve as the main conduit to representatives of the critical and important facilities and other interests in the Town. This effort is spearheaded by the Town Mayor, who is responsible for local outreach.	As the liaison, the Town will coordinate with all local and state parties as needed. The Town will also provide a share of the capital outlay that corresponds to its ownership of the SPV.	As the liaison, the Town will coordinate with all local, regional, and state parties as required. The Town will also provide a share of necessary services and capital to maintain the microgrid that corresponds with its ownership share of the SPV.
Booz Allen	BAH is responsible for the delivery of the Feasibility Study and its component parts. This includes serving as the central clearinghouse of data, design, and proposal development as well as the key POC for NYSERDA on this task.	BAH will serve in an advisory and organizational role, working in a similar prime contractor capacity to provide overall design, costing, and construction management services.	BAH would serve in an outside, advisory capacity upon completion of the microgrid and during its operation.
Siemens	Siemens is the engineering and technology partner of this project. They will develop the technical design and system configuration in concert with BAH engineers and the Power Analytics team.	Siemens will have primary responsibility for the microgrid construction and installation of hardware and generation assets.	Ensuring proper functioning and maintenance of the microgrid technology components throughout.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Power Analytics	Power Analytics is the partner for energy software solutions. The PA team, in conjunction with Siemens and Booz Allen, is responsible for the design of the SCADA and system software components and controls.	Power Analytics will lead the installation of control and energy management software following hardware installation and in concert with Siemens.	Power Analytics will provide IT systems support and may play an active role in system management through the EnergyNet software platform.
Suppliers	There are no suppliers required during this development phase; however, project partners and suppliers Siemens and Power Analytics are closely involved in feasibility and design portions of the project. BAH is in touch with several additional suppliers of hardware and software, including Duke Energy, Con Ed Solutions, Enel Green Power, Anbaric Transmission, Bloom, and Energize.	Siemens or another engineering and technology firm will be the hardware supplier, including switches and other physical controls. Power Analytics or another software company will be the EMS and SCADA provider, responsible for software and server components.	The installer of the hardware and software will continue to provide maintenance and advisory services as required to ensure proper and efficient functioning of their components. The software provider will work in cooperation with Con Ed to assess the best approach to daily operations of the software system.
Financiers/Investors	Outside finance advisors will be leveraged to assist the potential Cortlandt bond offering and creation of the SPV. The SPV will be created during the project development phase. Investors will provide capital for stakes in the SPV. Investors may include any of the entities mentioned in the rows above as well as private investors not mentioned as part of the Project Team.	Outside financial advisors will be retained to assist the bond offering and drawdown of funds. Debt and equity investors will supply the cash required to complete the construction and installation of generation assets and microgrid controls.	Outside financial advisors will be retained to assist with any issues in bond repayment that may arise. Generation asset owners will realize revenues from the sale of electricity and thermal resources. Microgrid system owners will realize revenues from the microgrid tariff, and Con Ed may realize T&D depending on final financial agreements.
Legal/Regulatory Advisors	Legal and regulatory advice is housed both within Booz Allen and through project partner Pace Climate and Energy Center. Further counsel will be retained as necessary to create the SPV and arrange financing.	Legal and regulatory will be a combination of Booz Allen, the Town, Con Ed, and any investor counsel required.	Legal and regulatory will be the responsibility of the Town, the utility, and any investors in the SPV.

3.3.3 Financial Strength

The principal shareholders in the microgrid project are the DER owners (private investors) and the Town of Cortlandt. Potential private investors that do not publish financial statements are not discussed in this section.

In 2010, Moody's Investor Service gave the Town of Cortlandt's $3.3 million general obligation bond series a long-term credit rating of Aa2 (its third highest ranking) and published a positive opinion on the Town's future credit outlook. An obligation rated as "Aa" indicates that the obligation is "judged to be of high quality and [is] subject to very low credit risk." Moody's has not issued a credit rating for the Town of Cortlandt since 2010, indicating that the town has not incurred significant obligations. The Town should therefore qualify for relatively low interest rates should it choose to finance the microgrid project with debt.

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

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

3.4.1 Microgrid Technologies

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

A solar PV array and a natural gas system were chosen as generator technologies to reduce GHG emissions and enhance the reliability of the power supply. The natural gas unit will be capable of automatic load following, responding to load fluctuations within cycles, allowing the microgrid to maintain system voltage and frequency, black starts, and adjusting generation output. The unit will reduce the need for diesel generation in emergency outage situations and will be capable of providing some ancillary services to the macrogrid, potentially creating another revenue stream for the microgrid. The natural gas unit will be placed inside some form of shelter or container to protect it from natural elements. The solar PV system will provide a renewable component to the microgrid generation mix and represents a more appropriate addition than an expanded CHP unit. It will provide emission-free electricity during daylight hours, move Cortlandt and New York State closer to the renewable generation goals set forth in the New York State Energy Plan, and allow the NY PSC to regulate the microgrid as a Qualifying Facility (QF) instead of an electricity corporation (see Section 3.2.4 for further discussion). However, PV generation will face the same problems in Cortlandt as it does elsewhere in the State with a low capacity factor and only intermittent generation.

The Cortlandt microgrid includes numerous components that have been previously used and validated. Solar PV and natural gas reciprocating engines are both widely used technologies, with more than six gigawatts of solar PV installed in 2015 in the United States. The switch components are all industry standard and are widely used in utilities worldwide, and the intelligent electronic devices, which are robust and safe via embedded electrical protections, are similarly standard across the industry. Siemens microgrid technologies are recognized worldwide for their flexibility, reliability, and expandability—successful examples of Siemens microgrid technology at work include the Parker Ranch and Savona University microgrids.[16]

3.4.2 Operation

All SPV investors will contribute funds to operate and maintain microgrid infrastructure and generation assets. As the project's subject matter expert, Con Ed will provide advice regarding the logistics of day-to-day operation. All members of the SPV will be responsible for the continued and successful operation of the component pieces of the grid, including software, switches, servers, generation, and AMI meters, but they will have ongoing assistance from Siemens, Power Analytics, and others. Regular maintenance and checks of equipment will be conducted based on manufacturer or installer recommendations and will ensure the proper function of all grid elements. The microgrid is a classic shared value entity; the utility, Town, and investors will benefit financially, and the continued success of the grid requires support and collaboration from all three.

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

This analysis assumes Con Ed will purchase electricity from the SPV and distribute it across its grid. The facilities will continue to be billed for electricity via the regular Con Ed billing mechanism and cycle. Con Ed's revenue should be sufficient to cover the supply cost of electricity (from the DERs) as well as Con Ed-imposed delivery and capacity charges. Additional fees may be imposed upon microgrid participants as a percentage of their electricity cost. However, given the extremely limited amount of time forecasted in island operation and the commensurately limited time that the customers will need to rely on the microgrid, the added fee will be no more than one or two percent of the retail rate of islanded electricity usage.

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—new distribution lines alone could cost up to $2.3 million if they are placed underground. Assuming the DERs will sell electricity to Con Ed at their current supply charge, the microgrid will produce positive net

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

income from year to year. However, after discounting future cash flows, annual net income does not provide sufficient revenue for a stand-alone positive net present value (NPV) business case.

The small loads in Cortlandt are also a barrier to completion. The matched generation size to the loads, and the small size of the loads means that sales of electricity to Con Ed are unable to adequately offset capital expenditures.

3.4.4 Permitting

The Cortlandt microgrid may require certain permits and permissions depending on the ultimate design choices. Distributed energy resource assets will require zoning variances. Cortlandt is not in any EPA criteria pollutant nonattainment zones; however, the natural gas 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 Con Ed under net metering and buy-back tariff or power purchase agreement. These assets will require significant initial capital outlay as well as annual operation and maintenance costs. The Project Team expects that microgrid infrastructure in Cortlandt will require considerable investment and will play a major role in final project NPV. The Town of Cortlandt may issue municipal bonds to finance its relatively minor share in proposed DERs and microgrid infrastructure. This section will discuss the revenues, costs, and financing options associated with the microgrid project in more detail.

3.5.1 Revenue, Cost, and Profitability

The microgrid has a number of savings and revenue streams, as outlined in Table 20. The revenues will sum to approximately $110,000 per year, which will exceed the yearly generation costs (estimated to be around $60,000 per year). If new distribution lines must be buried underground, the commercial viability of the Cortlandt microgrid project will depend heavily on NY Prize Phase III funding. See Table 21 for a description of the costs.

Table 20. Savings and Revenues

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

Description of Savings and Revenues	Savings or Revenue	Relative Magnitude	Fixed or variable
Electricity sales from 100 kW system during grid connected mode[17]	Revenue	~$54,000/yr	Variable
Electricity value from 410 kW of total solar PV	Revenue	~$58,000/yr	Variable
Electricity sales to customers during islanded operation	Revenue	~$1,000/yr	Variable
Total Revenue		**$110,000**	Variable

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

Table 21. Capital and Operating Costs

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

Description of Costs	CapEx or Ops	Relative Magnitude	Fixed or Variable
100 kW Natural Gas Recip.	Capital	~$130,000	Fixed
350 kW Solar PV array	Capital	~$610,000	Fixed
60 kW Solar PV array	Capital	~$105,000	Fixed
Microgrid Control Systems	Capital	~$350,000	Fixed
Distributed Equipment	Capital	~$90,000	Fixed
IT Equipment (Wireless stations and cabling)	Capital	~$68,000	Fixed
New distribution lines	Capital	$160,000 (overhead) $1.43 million (underground)	Fixed
Total CapEx		**$1,500,000** (overhead wires)	Fixed
Design considerations and simulation analysis	Planning and Design	$250,000	Fixed
Project valuation and investment planning	Planning and Design	$50,000	Fixed
Assessment of regulatory, legal, and financial viability	Planning and Design	$25,000	Fixed
Development of contractual relationships	Planning and Design	$25,000	Fixed
Total Planning and Design		**$350,000**	Fixed
100 kW NG Recip. Fuel	Operating	$40,000	Variable
100 kW NG Recip. Maintenance	Operating	$10,000	Fixed
350 kW Solar PV array Maintenance	Operating	~$6,700	Variable
60 kW Solar PV array Maintenance	Operating	~$1,000	Variable
Total OpEx		**$60,000 / year**	Variable

The proposed microgrid will qualify for two incentive programs: the Federal ITC and NY Sun Program. Together the programs will recover around 50% of the total DER capital cost (although only private investors are eligible for the Federal ITC). Other possible sources of incentive revenue include NYSERDA Phase III NY Prize funding (up to $5 MM, but will not exceed 50% of total capital costs) and capacity payments for participation in Con Ed DR programs. However, the more lucrative DR programs require 1 MW of generation capacity, which is beyond the scope of the proposed grid. See Table 22 for a list of available incentive programs.

The microgrid could theoretically enter island mode when electricity prices on the spot market rise above the DERs' marginal cost of producing electricity. Con Ed offers several flexible billing plans that could accommodate this capability. For example, business customers are eligible for hourly pricing. Under this billing plan, the hourly price of electricity follows the

NYISO-regulated wholesale market for electricity (specifically the hourly Location-Based Marginal Price, or LBMP). Under the "voluntary time-of-use" billing plan, customers pay different rates during peak and off-peak hours—peak hour prices during the summer months can rise as high as $0.1899/kWh.[18] By subscribing to this program and entering island mode during peak summer month hours, microgrid-connected facilities could save more than 50% on summer electricity bills. However, participation in these programs would still generate only minimal revenue streams due to the small size of the project.

Table 22. Available Incentive Programs

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

Incentive Program	Value	Required or Preferred
NYSERDA NY Prize Phase II	~$1,000,000	Required
NYSERDA NY Prize Phase III	~$5,000,000	Required
NY Sun Program	~$240,000 (total)	Required
Federal ITC (for solar array)	~$215,000	Required

3.5.2 Financing Structure

The development phase is characterized by the negotiation and execution of the construction financing and debt structure and agreements with any equity partners. Awards from Phase II of the NY Prize Community Microgrid Competition will supply most of the funding for project design and development, with all shareholders providing capital for any costs that exceed available NYSERDA funding. Cortlandt and their Project Team will provide needed in-kind services consisting primarily of system expertise and support. Development will conclude with formal contract relationships between the utility and the customers of the microgrid, available and relevant rate and tariff information from the PSC, and firm financing for the construction of the project (described below).

The various investors would ideally leverage Phase III funding from NYSERDA to complete the construction phase and would supplement with capital from municipal bonds, long-term debt, and private equity. Phase III NY Prize funding, which will provide up to $5 million for microgrid and DER equipment purchase and installation, will cover 50% of the total capital costs. The Project Team does not anticipate the project will generate sufficient cash flows to satisfy any debt obligations or financing costs incurred for capital expenditures.

The SPV will occupy a parcel of land from the Town of Cortlandt for the purpose of constructing microgrid infrastructure. Proposed DERs will be placed on both Town land and at Cortlandt Healthcare; access should not be problematic at either location.

[18] http://www.coned.com/customercentral/energyresvoluntary.asp

The operational phase will be characterized by positive operating streams, however principal and interest obligations will not be met. Structured as a typical infrastructure project, the microgrid revenue model will be built for a 20-year period, mirroring the expected lifespan of microgrid infrastructure and generation assets. The project is not expected to generate sufficient cash flows to cover debt service payments and maintenance costs of microgrid infrastructure and generation assets.

3.6 Legal Viability (Sub Task 3.6)

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

3.6.1 Ownership and Access

Legal considerations will include access limitations, franchising, zoning, and permitting. A single SPV will own and operate proposed DERs and microgrid infrastructure. Microgrid equipment will be installed on town-owned land, while generators will be installed at the Town building and at Cortlandt Healthcare. Property rights and access limitations will not be a concern for microgrid infrastructure.

3.6.2 Regulatory Considerations

State and Utility Regulation

Ownership of microgrid infrastructure may qualify the SPV as an electric distribution company. New models of regulatory treatment (currently under discussion in REV proceedings) may also apply if adopted.

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

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

Although the PSC will continue to treat Con Ed as an electric corporation, the SPV may be exempt from much of this regulation if it meets the criteria for a QF under the terms of PSL §2. To be considered a qualifying facility, a microgrid must utilize qualifying forms of generation (co-generation, hydroelectric power, or alternative energy including solar), include no more than

80 MW of generation capability, serve a qualifying number of users, and connect facilities that are located “at or near” generating facilities. The Cortlandt microgrid will include one 350 kW solar PV array, one 60 kW array, and one 100 kW natural generator, will not generate more than 80 MW of power, and will connect facilities located near generators (the generators will be located on-site for both proposed facility clusters). The Project Team does not expect a successful petition for QF status based on the proposal of the natural gas-fired generation

Local Regulation

All zones in Cortlandt are eligible for a special permit public utility facility.[19] The definition of a public utility facility is that it “uses, structures and rights-of-way constructed, altered or maintained by utility corporations, either publicly or privately owned, *or governmental agencies* necessary for the provision of electricity, gas, heat, steam, communication, water, sewage collection or other service. Such uses, structures and rights-of-way shall include poles, wire, mains, drains, sewers, pipes, conduits, cables, alarm and call boxes and other similar equipment, but shall not include office, administration, service or storage buildings”[20] (emphasis added).

This definition would appear to extend to facilities owned by the town of Cortlandt and does not expressly prohibit generation. Express limiting conditions elsewhere in the Code extend only to lot coverage, yardage, fencing, and “additional conditions, including but not limited to increased distance from lot lines, in order to prevent any hazard to the public or noise nuisance to surrounding property.”[21] In the granting of any special permit, the Zoning Board of Appeals may also widely consider any conditions on the permit related to the public welfare.[22]

If microgrid generation is not deemed accessory to the permitted uses of the district and is not granted a special use permit, the project would have to seek a variance. Cortlandt’s Code does not specify standards for obtaining a variance.[23] However, New York State precedent,[24] as well as State law incorporating that precedent, have held that the reasonable use requirements to obtain a zoning variance require the applicant to show that “they cannot realize a reasonable return, provided that lack of return is substantial as demonstrated by competent financial evidence.”[25] This requirement is uncertain to be satisfied for microgrid facilities.

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

[19] Cortlandt Code §307-58.
[20] Cortlandt Code §307-4.
[21] Cortlandt- Code §307-58.
[22] Cortlandt Code §307-42.
[23] Cortlandt Code §307-92 for provisions empowering the Zoning Board of Appeals to review applications for variances.
[24] Otto v. Steinhilber, 282 N.Y. 71 (1939). In that case, the owner of a parcel of property which was located in both a residential and commercial zone applied for a variance enabling him to use the entire parcel for a skating rink, which was a permitted commercial use. The lower court upheld the granting of the use variance, which ruling was affirmed by the Appellate Division. The Court of Appeals, the highest court in the State, reversed these holdings and in doing so, set forth the definitive rules that are still followed today.
[25] General City Law section 81-b(3)(b), Town Law section 267-b(2)(b), and Village Law section 7-712-b(2)(b).

is delivered to the grid versus used on site, and the date of construction. The specific details associated with the proposed natural gas system in Cortlandt 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) c (ICE): 40 CFR part 60 subpart IIII
- NSPS for Stationary Spark Ignition (SI) ICE: 40 CFR part 60 subpart JJJJ

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

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

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

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

3.7 Project Commercial and Financial Viability Conclusions

The microgrid project will include three facilities from the Town of Cortlandt: Cortlandt Healthcare, St. Columbanus School, and the Town Hall/Police Department complex. Each of these facilities is considered critical (as defined by NYSERDA). The project will follow an ownership model wherein a single SPV owns the generation assets and the microgrid infrastructure.

The proposed microgrid's commercial feasibility would depend on NY Prize Phase III funding. Its design includes three DERs: a 100 kW natural gas system, a 60 kW solar PV array, and a 350 kW solar PV array. All SPV shareholders will contribute capital towards the construction of these assets, and each will receive revenues from electricity and thermal energy sales throughout the generator lifespans. The Project Team forecasts yearly revenues of approximately $110,000 from the generators, which should reliably cover yearly generator operation and maintenance costs (forecasted to be approximately $60,000). Revenue from generator operation will not be sufficient to cover capital costs, so the project may require subsidies beyond NY Prize to fully recover initial investment costs.

In addition to revenues from electricity sales, the microgrid will provide indirect financial and non-financial benefits to Cortlandt citizens, SPV shareholders, Con Ed, and the larger Westchester community. Improved energy resiliency enhances the local population's safety and quality of life during emergency outages, and local energy generation reduces the strain on the larger energy transmission and distribution infrastructure. Future expansion of the microgrid could maintain electric service to more facilities in Cortlandt, providing citizens with access to pharmacies, gas, and groceries in outage situations.

Permitting and regulatory hurdles should be reasonably straightforward given Cortlandt's fairly permissive special permit rules. The primary regulatory hurdles will be obtaining permits for the natural gas system under the Clean Air Act and qualifying for an exemption from regulation as an electric corporation under NY PSC law.

The estimates and value propositions in this document are predicated on several assumptions. First, investors must have sufficient interest in the microgrid project to provide capital for construction of the DERs and microgrid infrastructure. Second, the solar array will sell electricity at the average local commercial retail rate through a net metering agreement with Con Ed. Third, Con Ed will purchase electricity generated by the natural gas system at the utility's average supply price of electricity.

4. Cost Benefit Analysis

Section 4 Cost Benefit Analysis is made up of seven sections:

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

4.1 Facility and Customer Description (Sub Task 4.1)

The Cortlandt 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 Table 23 26 for basic statistics on each facility's energy usage. All three of the proposed microgrid facilities belong to the large commercial rate class requiring approximately 1,339 MWh of electricity per year. Additionally the average aggregate demand in 2014 was 0.306 MW and rose as high as 0.435 MW.

There are three kinds of facilities in the microgrid including health, public and educational in the proposed Cortlandt microgrid footprint. The health facility, Cortlandt Healthcare, represents the largest electricity loads, comprising more than 63% of the microgrid's total annual electricity usage. The public facility, the Town Hall and Police Department, and the educational facility, St. Columbanus School, make up the rest electricity usage with 33% and 4% of the total, respectively.

The combination of existing and proposed generation assets included in the microgrid design will be capable of meeting 100% of average aggregate facility energy usage during a major power outage, but may approach their generation limits if several large facilities simultaneously reach peak energy use. In these situations, the backup generators may need to come online to supply additional electricity. Some of the facilities do not operate 24 hours a day, such as the St. Columbanus School, and will only operate at full capacity 12 hours per day during grid-connected mode. However some critical facilities that normally operate less than 24 hours per day may need to operate continuously in emergency island-mode situations; for example, the St. Columbanus School could serve as a shelter in an emergency. This will extend its electricity usage window from 12 hours per day to 24 hours per day. For information on each facility's average daily operation during a major power outage, see Table 23.

Table 23. Facility and Customer Detail Benefit[26]

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

REDACTED PER NDA WITH CONSOLIDATED EDISON

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

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates new and existing DERs, including two existing diesel generators, one existing natural gas generator, a proposed natural gas generator, and two proposed solar PV arrays. The proposed natural gas unit and solar PV arrays will produce an average of 0.1424 MW of electricity throughout the year[27] (including projected capacity factors), and the existing backup generators at Cortlandt Healthcare and the Town Hall will provide up to 0.3 MW of backup generation capacity during emergencies.

The natural gas generator has a nameplate capacity of 0.1 MW and will operate nearly continuously. Assuming a capacity factor of 85%, the natural gas unit will produce approximately 745 megawatt hours (MWh) of electricity over the course of the year. If a major power outage occurs, the natural gas unit will produce an average of 2.04 MWh of electricity per day, which would provide an average of 55.5% of the microgrid's average daily demand. The natural gas units use around 9.5 Mcf (1000 ft^3) of natural gas per MWh generated, which amounts to a fuel cost of around $53/MWh to operate.[28]

Limited by weather conditions and natural day-night cycles, the 0.35 MW and 0.06 MW solar PV arrays are expected to produce a combined 502 MWh per year. Because many outages are caused by severe weather events, solar panels cannot be relied upon to provide energy during emergency outages without supplementary battery storage. However, on average the solar arrays will produce a combined 1.38 MWh of electricity per day, which represents 26.8% of average daily electricity demand from microgrid-connected facilities. Maintenance costs for the solar array will be around $8,200 per year,[29] which means the marginal cost of producing solar electricity will be about $34/MWh.[30]

The existing backup generators at Cortland Healthcare and the Town Hall will be used only in emergency situations when the microgrid requires a black start or when the proposed natural gas generator and solar arrays are not producing sufficient electricity to meet aggregate demand. The diesel generator at Cortlandt Healthcare has a nameplate capacity of 0.12 MW, while the diesel and natural gas generators at the Town Hall have nameplate capacities of 0.08 MW and 0.1 MW, respectively. This combined 0.3 MW of backup generation capacity could be vital in emergency situations, or when the solar array or natural gas unit go offline for maintenance. The Booz Allen team forecasts around 2.67 hours of larger grid outage based on Con Ed's Customer Average Interruption Duration Index from 2013,[31] and therefore predicts annual output from backup

[27] 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).

[28] Price of natural gas: $5.74 per Mcf (average CHGE supply price from 2013-2015).

[29] Annual fixed O&M cost: $20/kW per year (NREL, http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html).

[30] Capital cost: $2,200 - $2,400/kw (Siemens estimate).
Variable cost: 30 years of production at a cost of $20/kW per year (Siemens lifecycle estimate, NREL).
Discount rate: 7% (industry standard discount rate; NREL http://www.nrel.gov/docs/fy13osti/58315.pdf).

[31] Grid outage data from DPS 2013 Electric Reliability Performance Report (Con Ed average CAIDI).

diesel generators will be insignificant. The backup diesel generators require around 16.4 gallons of fuel per hour of operation[32], while the backup natural gas generator requires 0.93 Mcf. 33 In the event of a major power outage, the generators could produce up to 7.2 MWh/day.[34] See Table 24 for a detailed list of all proposed and existing distributed energy resources in Cortlandt.

[32] Backup Diesel Generator fuel consumption rate – 16.4 gallons/hour (Prorated from Cummins Power Generation estimation).

[33] NG fired internal combustion engine heat rate: 9.5 MMBTU/MWh (2013 EIA average, http://www.eia.gov/electricity/annual/html/epa_08_02.html).

[34] The Booz Allen team forecasts a 100% level of operation from the backup generator based on historical loads and expected generator output. In 2014, the average load in Cortlandt was 0.306 MW. The natural gas generator and solar arrays can provide an average of 0.1424 MW of generation. Load is expected to exceed the proposed generation's maximum output for approximately 100% of time spent in island mode. Solar output is unreliable, but it should provide significant support on the most irradiated days of the year when peak demand is highest.

Table 24. Distributed Energy Resources

Table lists DERs incorporated in the microgrid, including their energy/fuel source, nameplate capacity, estimated average annual production under normal operating conditions, average daily production in the event of a major power outage, and fuel consumption per MWh generated (for fuel-based DERs). "Normal operating conditions" assumes approximately 2.64 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 - Backup Diesel Generator	Cortlandt Healthcare	Diesel	0.12	0.304	2.88	2.88	82 Gallons	11.35 MMBTUs
DER2 - Solar PV array	Cortlandt Healthcare	Sunlight	0.35	429.2	1.18	2.8[35]	N/A	N/A
DER3- Backup Diesel Generator	Town Hall and Police Facilities	Diesel	0.08	0.203	1.92	1.92	82 Gallons	11.35 MMBTUs
DER4 - Backup Natural Gas Generator	Town Hall and Police Facilities	Natural Gas	0.1	0.227	2.4	2.4	9.26 Mcf	9.5 MMBTUs
DER5 - Solar PV array	Town Hall and Police Facilities	Sunlight	0.06	73.6	0.2	0.48[36]	N/A	N/A
DER6 - Natural Gas Generator	Town Hall and Police Facilities	Natural Gas	0.1	744.6	2.04	2.4	9.26 Mcf	9.5 MMBTUs

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

4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3)

4.3.1 Peak Load Support

The microgrid's proposed generation assets will operate nearly continuously throughout the year, providing a constant level of load support. Although continuous operation will limit the natural gas generator's ramp-up capability during peak demand events, it will also maximize revenue for owner of the microgrid. The existing backup generators will also be available to reduce peak load in cases of extreme demand. See Table 25 for the maximum generation capacities of the proposed and existing DERs.

The proposed solar arrays will be at their most productive on days with peak solar irradiance when peak demand events are common, thus providing peak load support when it is most needed. The solar arrays will provide around 0.0574 MW of load support on average over the course of a year. However, their generation depends on weather conditions and time of day, therefore solar arrays are not a reliable source of peak load support.

Table 25. Distributed Energy Resource Peak Load Support

Table shows the available capacity and impact of the expected provision of peak load support from each DER. Existing 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?
DER2 - Solar PV array	Cortlandt Healthcare	Maximum of 0.35	No
DER5 - Solar PV array	Town Hall and Police Facilities	Maximum of 0.06	No
DER6 – Natural Gas	Town Hall and Police Facilities	Maximum of 0.1	No[37]

4.3.2 Deferral of Transmission/Distribution Requirements

The 0.1424 MW of average local generation produced by the DERs will slightly reduce the amount of electricity imported from the larger NYISO and Con Ed power lines, 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,[38] they can only transmit a limited amount of power. As demand for electricity in Cortlandt 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 investment cost in certain cases (e.g., if the assets are placed in remote locations and thus expensive to connect to the local grid). Although Cortlandt has ample capacity within the town,

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

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

approximately 2,650 feet of new distribution lines will be need to be built to properly connect the microgrid facilities and will require a significant distribution capacity investment.

4.3.3 Ancillary Service

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

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

4.3.4 Development of a Combined Heat and Power System

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

4.3.5 Environmental Regulation for Emission

The microgrid's generation assets will drive a net 59 $MTCO_2e$ (metric tons CO_2 equivalent) decrease in GHG emissions in Cortlandt as compared to the New York State energy asset mix. The proposed generation assets will produce around 1,665 MWh of electricity per year. The proposed natural gas unit and backup generators will emit approximately 545 $MTCO_2e$ per year, 39 while the solar arrays will emit none. The current New York State energy asset mix would emit approximately 604 $MTCO_2e$ to produce the same amount of electricity[40]. The microgrid's generation assets will therefore result in a net decrease in emissions by 59 $MTCO_2e$.

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

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

[40] 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).

natural gas unit is defined as a "small boiler" by NYS Department of Environmental Conservation (NYS DEC) limits (fuel input of 10-25 MMBTU/hour). The NYS DEC is currently developing output-based emissions limits for distributed energy resource assets. These limits on SO_2, NO_x, and particulate matter (to be captured in 6 NYCRR Part 222) should be published in late 2015 or early 2016. The main source of emissions regulations for small boilers is currently the EPA 40 CFR part 60, subpart JJJJJ—however, this law does not include gas-fired boilers.

The natural gas generator will require an operating permit in addition to other construction permits. The costs of obtaining this permit will be in line with the cost of a construction permit and not comparable to the price of emissions allowances. The existing generators are already permitted and therefore will not incur any significant emissions costs.

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

Table 26. Emission Rates

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

Distributed Energy Resource Name	Location	Emissions Type	Emissions Per MWh (Metric Tons/MWh)
DER2 - Proposed Natural Gas Generator	Town Hall	CO_2	0.508
		SO_2	9.09358E-07[41]
		NO_x	0.006309834[42]
		PM	1.19237E-07[43]
DER1 & DER3 – Backup Diesel Generator	Cortlandt Healthcare and Town Hall	CO_2	0.7196[44]
		SO_2	0.1911[45]
		NO_x	2.9074[46]
		PM	0.2046[47]
DER4 – Backup Natural Gas Generator	Town Hall	CO_2	0.508
		SO_2	9.09358E-07[48]
		NO_x	0.006309834[49]
		PM	1.19237E-07[50]

[41] "Natural Gas-fired Reciprocating Engines" – EPA, http://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s02.pdf.
[42] Ibid.
[43] Ibid.
[44] 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).
[45] Michigan Department of Environmental Quality; Environmental Science and Services Division. "Potential to Emit, Diesel Fired Generator Calculation Worksheet".
[46] Ibid.
[47] Ibid.
[48] "Natural Gas-fired Reciprocating Engines" – EPA, http://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s02.pdf
[49] Ibid.
[50] Ibid.

4.4 Project Costs (Sub Task 4.4)

4.4.1 Project Capital Cost

The microgrid design requires the following new pieces of equipment at the substation and across the rest of the microgrid:

- A control system to provide one point of control for operating the microgrid and synthesizing real-time electricity data from the connected facilities.
- Intelligent electronic devices to interface with the 44 kV utility breaker at the substation as well as the smaller 13.2 kV distribution feeders.
- Automated breakers installed throughout Cortlandt to allow the microgrid to isolate and maintain power to the microgrid connected facilities.
- Grid-paralleling switchgear to synchronize each generator's output to the system's frequency.

The total installed capital cost of the distributed equipment is estimated to be $543,000 and $23,000 for the IT infrastructure. There will be an additional cost of $160,000 if the powerlines are installed overhead. The cost for powerlines installed underground is $1.425 million.[51] The Project Team estimates the 0.35 MW and 0.06 solar PV arrays and 0.1 MW natural gas unit carry an installed costs of $770,000, $144,000 and $130,000, respectively.[52] This brings the total installed capital cost to approximately $1.77 million if the powerlines are installed overhead, not including interconnection fees and site surveys. If the powerlines are installed underground the total capital costs will be $3.03 million. Additionally the estimated capital cost does not account for any financial incentives or tax credits that may lower the overall cost of the microgrid. See

See Table 27 and Table 28 below for estimated installed costs for each microgrid component. Table 27 details capital cost of the substation; 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.

[51] Cost estimate provided by Travers Dennis - Con Ed.

[52] Natural Gas Generator Capital Cost: $1,300/kW (Siemens estimate).
Solar PV Capital Cost: $2,200 - $2,400/kw (Siemens estimate).

Table 27. Distributed Equipment Capital Cost

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

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Microgrid Control System	1 Primary	$50,000	7 - 8 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)	1	$30,000	20	Two new/updated breaker/switch at distribution load feeders to enable IED interface with and control by the microgrid.
Automated PME (Siemens 7SJ85 multi breaker control relay)	2	$40,000	20	New multi module relays at Pad Mounted/underground distribution switches. One relay can protect and control multiple switches/breakers at each PME. Isolate the downstream loads, generation, and feeders from the microgrid.
Automatic Transfer Switch (Siemens 7SJ85 multi breaker control relay	2	$20,000	20	ATS needs to be upgraded with microgrid controllable relays capable of current sensing and multi breaker control. Automated logic for switching to available hot feeder with one designated as the preferred. Current sensing on both feeders makes it possible to initiate emergency microgrid mode.
Generation Controls (OEM CAT, Cummins, etc.) (Load Sharing via Basler, etc.)	4	$16,000	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)	2	$8,000	20	Controls PV output and sends data to SCADA and EMS for forecasting.

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
WiMax Base Station	1	$8,000	20	Located near microgrid control cabinet. Communicates wirelessly with WiMax subscriber units for remote control and monitoring of breakers and switches. Should be installed at high location.
WiMax Subscriber Units	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	-	$23,000	-	The configuration and testing of the WiMax hardware.
Installation Costs	-	$34,000	-	Installation of capital components in the microgrid.

Table 28. Capital Cost of Proposed Generation Units

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

Proposed Generation Units				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
0.35 MW PV System	1	$770,000	30	Generation of electricity
0.06 MW PV System	1	$144,000	30	Generation of electricity
0.1 MW Natural Gas Unit	1	$130,000	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.[53] The total installation cost of cabling is approximately $5.65 per foot.[54] The Project Team will use the existing cabling infrastructure to install the communications cables, thereby avoiding the high costs of trenching

[53] Commercially available RJ-45 connectors, $0.30 per connector.
[54] Installation costs for Cat5e: $5.45/ft. Component cost for Cat5e: $0.14/ft (commercially available).

the proposed lines. The estimated total cost for the microgrid hardwired IT infrastructure is around $23,000.[55]

In addition to the microgrid IT infrastructure, the microgrid will need new distribution lines in order to connect the DERs to the microgrid supported facilities. The Project Team has determined the approximate cost of building these new lines is $160,000 for an overhead installation and $1.425 million for an underground installation.[56]

4.4.2 Initial Planning and Design Cost

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

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

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

Table 29. Initial Planning and Design Cost

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

Initial Planning and Design Costs ($)[57]	Cost Components
$250,000	Design considerations and simulation analysis
$50,000	Project valuation and investment planning
$25,000	Assessment of regulatory, legal, and financial viability
$25,000	Development of contractual relationships
$350,000	**Total Planning and Design Costs**

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[55] The Project Team estimated ~3,000 feet of Cat5e.

[56] The Project Team has determined that approximately 2,640 feet of new line is required at the cost of $60/ft for overheard installation and $540/ft for underground installation according to Travers Dennis at Con Ed.

[57] Estimates developed by Booz Allen Project Team and independent consultant.

4.4.3 Operations and Maintenance Cost

The proposed DERs will incur fixed operation and maintenance (O&M) costs, including fixed annual service contracts.

Annual service for the proposed natural gas unit will cost approximately $1,500.[58] The microgrid owner will also incur $10,600/year in total costs for annual fixed system service agreements for the solar PV array and backup generators. [59]

The DER assets will also incur variable O&M costs that fluctuate based on output. These include fuel and maintenance costs outside of scheduled annual servicing. First, the natural gas generator will require capital for fuel, consumable chemicals, and other operating expenses. The average price of natural gas for the microgrid will be $5.74/Mcf, which translates to an average fuel cost of $53/MWh for the natural gas unit.

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

The solar PV arrays will not require fuel to operate, and it should not require service outside of the normally scheduled downtime. Normally scheduled downtime should cost approximately $20/kW per year.[60]

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[61] Table 30 30 outlines all fixed operations and maintenance (O&M) costs associated with normal operation of the DERs.

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[58] $1,500 for natural gas generator (Pete Torres, Prime Power; yearly service for small scale natural gas generator).
[59] $5,000 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").
[60] NREL (projects $0/kWh variable maintenance costs): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
[61] O&M for non-DER microgrid components: $70,000/year (Siemens).

Table 30. Fixed Operating and Maintenance Cost

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

Fixed O&M Costs ($/year)	Cost Components
$8,200 (total)	Solar PV System Service Agreements – Annual costs of maintenance and servicing of unit
$1,500	Natural Gas Generator Service Agreement – Annual costs of maintenance and servicing of unit
$1,500	Backup Natural Gas Generator Service Agreement – Annual costs of maintenance and servicing of unit
$920	Diesel Generator Service Agreement – Annual costs of maintenance and servicing of unit
$70,000	Non-DER Microgrid Components Service Agreement - Annual costs of maintenance and servicing of components

4.4.4 Distributed Energy Resource Replenishing Fuel Time

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

At full operation, the 0.12 MW and 0.08 MW diesel generators will require 16.4 gallons of diesel fuel per MWh at full load. The Cortland Healthcare and the Town Hall have 300 and 80 gallon diesel storage tanks installed,[62] so at a 100% level of output the Cortlandt Healthcare generator can operate for 30.5 hours while the Town Hall generator can operate for 12.5 hours without replenishing their fuel supply.

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

Table 31. Maximum Fuel Operating Time for Distributed Energy Resource

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

Distributed Energy Resource	Location	Energy Source	Maximum Operating Time in Islanded Mode without Replenishing Fuel (hours)	Fuel Consumption During this Period	
				Quantity	Unit
DER1 - Backup Diesel Generator	Cortlandt Healthcare	Diesel	30.5	300	Gallons

[62] Used comparable generators to determine most likely tank size (http://www.dieselserviceandsupply.com/Used-Generators/).

Distributed Energy Resource	Location	Energy Source	Maximum Operating Time in Islanded Mode without Replenishing Fuel (hours)	Fuel Consumption During this Period	
				Quantity	Unit
DER2 - Solar PV array	Cortlandt Healthcare	Sunlight	N/A	N/A	N/A
DER3- Backup Diesel Generator	Town Hall and Police Facilities	Diesel	12.5	80	Gallons
DER4 - Backup Natural Gas Generator	Town Hall and Police Facilities	Natural Gas	N/A	N/A	N/A
DER5 - Solar PV array	Town Hall and Police Facilities	Sunlight	N/A	N/A	N/A
DER6 - Proposed Natural Gas Generator	Town Hall and Police Facilities	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 natural gas generator will be the most reliable and productive of the DERs, providing an average of 0.085 MW to the microgrid at any given time. Because the natural gas generator will use natural gas via pipeline as fuel, disruptions to its fuel source are unlikely. The natural gas generator can generate on average 2.4 MWh per day, using approximately 22.2 Mcf (22.8 MMBTU) of natural gas. The natural gas generator will not require startup or connection costs in order to run during island mode and should not incur any daily variable costs other than fuel.

The solar array will be available for backup generation during a power outage, but its production is too inconsistent for it to qualify as a true backup generator. Extreme weather is responsible for many emergency outages in New York State, and such weather will greatly reduce the output of the solar panels. However, when high state-wide electricity demand on the most irradiated days of summer causes outages, the solar panels will be at their most productive and could provide up to 0.41 MW of load support to the Cortlandt microgrid. Table 32 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

The backup generators will only come online when the natural gas unit and solar array do not provide sufficient power to the islanded microgrid. Because the natural gas generator can produce 0.1 MW of power at full capacity and the microgrid's loads had an average power demand of 0.306 MW during 2014, the natural gas generator and solar arrays should be capable of satisfying the microgrid's power demand in all situations with the assistance of the backup generators. The backup generators will be necessary for about 100% of total outage time. At

100% operation the combined 0.3 MW of generation would produce an average of 7.2 MWh per day. The backup generators will require around 69.5 gallons of diesel and 22.3 Mcfs per day. One-time startup costs or daily non-fuel maintenance costs for either of the diesel generators are not anticipated.

Table 32. Cost of Generation during a Power Outage

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

Location	Distributed Energy Resource	Energy Source	Nameplate Capacity (MW)	Expected Operating Capacity (%)	Avg. Daily Production During Power Outage (MWh/ Day)	Fuel Consumption per Day		One-Time Operating Costs ($)	Ongoing Operating Costs per day – Fuel and variable O&M
						Quantity	Unit		
Cortlandt Healthcare	DER1 - Backup Diesel Generator	Diesel	0.12	100%	2.88	47.2	Gallons	N/A	$145[63]
Cortlandt Healthcare	DER2 - Solar PV array	Sunlight	0.35	14%[64]	1.18[65]	N/A	N/A	N/A	$20[39]
Town Hall and Police Facilities	DER3- Backup Diesel Generator	Diesel	0.08	100%	1.92	31.5	Gallons	N/A	$100[66]
Town Hall and Police Facilities	DER4 - Backup Natural Gas Generator	Natural Gas	0.1	100%	2.4	22.2	Mcf	N/A	$130
Town Hall and Police Facilities	DER5 - Solar PV array	Sunlight	0.06	14%[40]	0.2[67]	N/A	N/A	N/A	$3.30[42]
Town Hall and Police Facilities	DER6 - Proposed Natural Gas Generator	Natural Gas	0.1	100%	2.4	22.2	Mcf	N/A	$130

[63] = Daily fuel cost during an outage (gallons/day) + (Yearly O&M/365).
[64] NREL PV Watts Calculator.
[65] This output assumes that the PV arrays are still operational after an emergency event. In the case that the PV arrays are damaged, the microgrid will use the natural gas generator as the key source of emergency power.
[66] = Daily fuel cost during an outage (gallons/day) + (Yearly O&M/365).
[67] This output assumes that the PV arrays are still operational after an emergency event. In the case that the PV arrays are damaged, the microgrid will use the natural gas generator as the key source of emergency power.

4.5.2 Cost to Maintain Service during a Power Outage

There are no costs associated with switching the microgrid to island mode during a power outage other than the operational costs already accounted for Table 32. Please refer to Table 32 for one-time and ongoing costs of microgrid generation per day. The proposed microgrid has the capacity to support all the connected facilities, which means even those facilities with backup generators will not have to rely on or pay for on-site backup power. Facilities not connected to the microgrid will experience power outages and may need emergency services depending on the severity of the emergency event. Any other cost incurred during a wide spread power outage will be related to the emergency power (i.e. portable generators) rather than electricity generation costs.

4.6 Services Supported by the Microgrid (Sub Task 4.6)

Most of the facilities to be connected to the microgrid are municipally owned buildings that serve the entirety of the population in Cortlandt (such as the Town Hall and Police Department). Others, like the St. Columbanus School, serve a smaller population for most of the year, but provide critical services to the entire population during emergency situations. For estimates of the population served by each critical facility, see Table 33.

Backup power supplied by the microgrid should provide 100% of each facility's electricity demand during outage situations. However, if backup power from the microgrid is not available, the critical services provided by these facilities will be severely hampered. Some critical services do not require electricity (e.g. driving a police car to the scene of a crime), while others are completely dependent on a stable power supply (e.g. 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 36 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 33. Critical Services Supported

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

Facility Name	Population Served by This Facility	Percentage Loss in Service During a Power Outage[68]	
		When Backup Power is Available	When Backup Power is Not Available
St. Columbanus School	~ 230[69]	0%	> 75%
Cortlandt Healthcare (Assisted living)	~ 140[70]	0%	> 75%
Cortlandt Manor Police Department and Cortlandt Town Hall	~ 42,700	0%	50 - 75%

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 Cortlandt microgrid was delivered to the Project Team on February 12, 2016.

4.7.1 Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the Town of Cortlandt has proposed a microgrid that will combine existing generation capabilities with new solar power facilities. To assist with completion of the project's NY Prize Phase I feasibility study, IEc conducted a screening-level analysis of the project's potential costs and benefits. This report describes the results of that analysis.

Cortlandt is a community of approximately 41,000 residents located on the Hudson River in the northwest corner of Westchester County. The proposed microgrid would serve three key customers:

- Town hall and police station
- Assisted living facility (Cortlandt Healthcare LLC)
- Small private school serving pre-K through 8th grade students (St. Columbanus)

The project design involves two new solar photovoltaic arrays with a combined capacity of 0.41 MW, complemented by a new 0.1 MW natural gas generator, which would be located at the

[68] 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).

[69] Relevant statistics for St. Columbanus School (http://www.privateschoolreview.com/school_ov/school_id/20012).

[70] Relevant statistics for Cortlandt Healthcare (http://nursing-homes.healthgrove.com/l/9079/Cortlandt-Healthcare-L-L-C).

police station. For additional resiliency, the microgrid would also incorporate three existing backup generators, two of which (one diesel, the other natural gas) are located at the police station, the third (a diesel unit) at the assisted living facility. The project would allow 24-hour service for all three participating facilities in the event of a large power outage such as that experienced during Superstorm Sandy.

4.7.2 Methodology and Assumptions

In discussing the economic viability of microgrids, a common understanding of the basic concepts of benefit-cost analysis is essential. Chief among these are the following:

- *Costs* represent the value of resources consumed (or benefits forgone) in the production of a good or service.
- Benefits are impacts that have value to a firm, a household, or society in general.
- *Net benefits* are the difference between a project's benefits and costs.
- Both costs and benefits must be measured relative to a common *baseline* - for a microgrid, the "without project" scenario - that describes the conditions that would prevail absent a project's development. The benefit cost analysis (BCA) considers only those costs and benefits that are *incremental* to the baseline.

This analysis relies on an Excel-based spreadsheet model developed for NYSERDA to analyze the costs and benefits of developing microgrids in New York State. The model evaluates the economic viability of a microgrid based on the user's specification of project costs, the project's design and operating characteristics, and the facilities and services the project is designed to support. Of note, the model analyzes a discrete operating scenario specified by the user; it does not identify an optimal project design or operating strategy.

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[71] 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

[71] 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 (PSC) guidance for benefit-cost analysis, the model relies on temporal projections of the social cost of carbon (SCC), which were developed by the U.S. Environmental Protection Agency using a three percent discount rate, to value CO_2 emissions. As the PSC notes, "The SCC is distinguishable from other measures because it operates over a very long time frame, justifying use of a low discount rate specific to its long term effects." The model also uses EPA's temporal projections of social damage values for SO_2, NO_x, and PM2.5, and therefore also applies a three percent discount rate to the calculation of damages associated with each of those pollutants. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.]

return, which indicates the discount rate at which the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2014 dollars.

With respect to public expenditures, the model's purpose is to ensure that decisions to invest resources in a particular project are cost-effective; i.e., that the benefits of the investment to society will exceed its costs. Accordingly, the model examines impacts from the perspective of society as a whole and does not identify the distribution of costs and benefits among individual stakeholders (e.g., customers, utilities). When facing a choice among investments in multiple projects, the "societal cost test" guides the decision toward the investment that produces the greatest net benefit.

The BCA considers costs and benefits under two scenarios:

- Scenario 1: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).
- Scenario 2: The expected frequency and duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under Scenario 1.[72]

4.7.3 Results

Table 34 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for these scenarios. The results suggest that if no major power outages occur over the microgrid's assumed 20-year operating life, 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 exceed approximately 7.3 days per year (Scenario 2). The discussion that follows provides additional detail on the findings for these two scenarios.

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

Economic Measure	Expected Duration of Major Power Outages	
	Scenario 1: 0 Days/Year	Scenario 2: 7.3 Days/Year
Net Benefits - Present Value	-$4.34 million	$57,600
Benefit-Cost Ratio	0.3	1.0
Internal Rate of Return	N/A	8.3%

[72] 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 7 and Table 35 present the detailed results of the Scenario 1 analysis.

Figure 7. Present Value Results

(No Major Power Outages; 7 Percent Discount Rate)

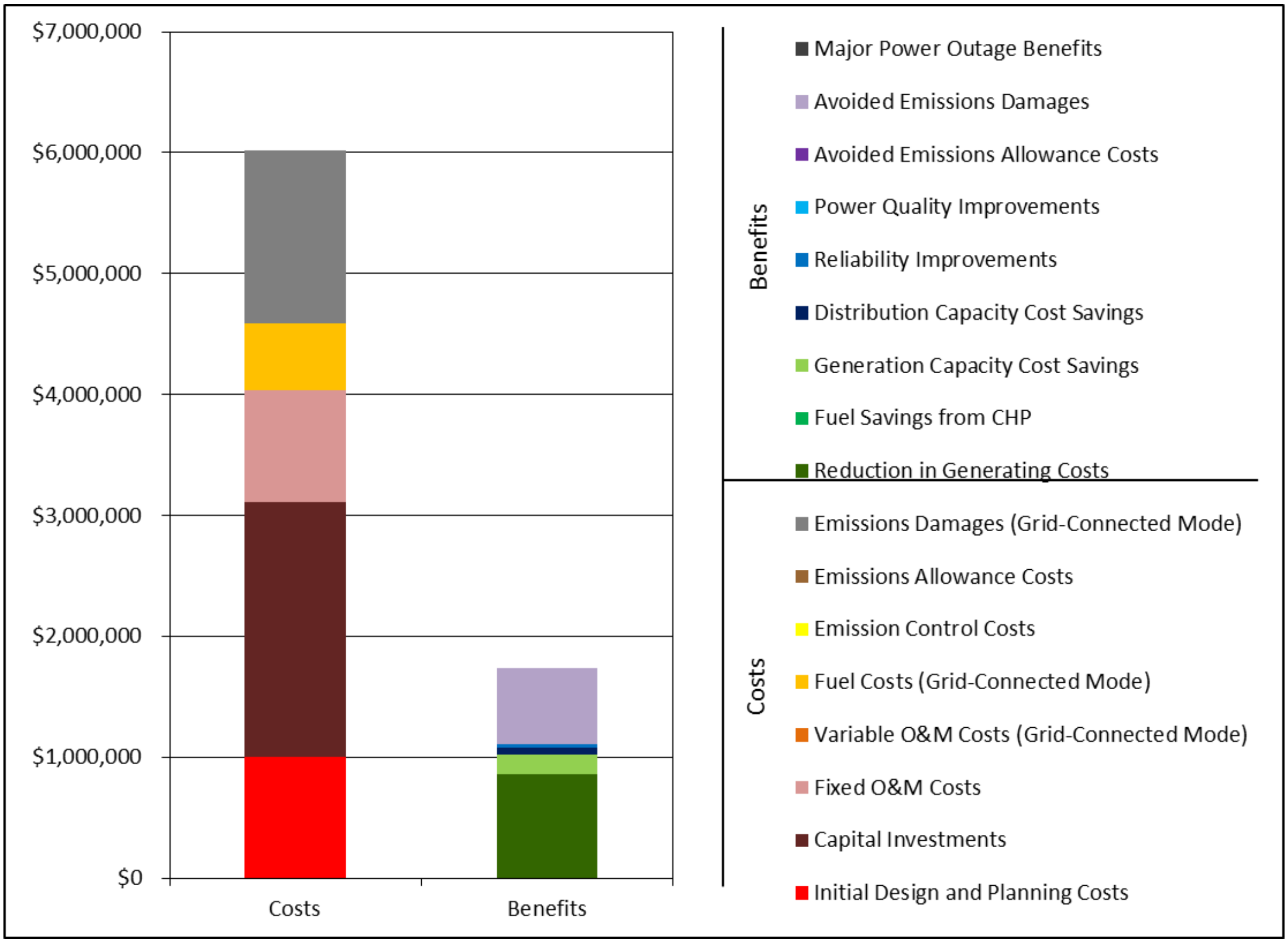


Table 35. Detailed BCA Results

(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	$2,110,000	$170,000
Fixed O&M	$931,000	$82,100
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$548,000	$48,300
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$1,430,000	$93,300
Total Costs	**$6,020,000**	
Benefits		
Reduction in Generating Costs	$860,000	$75,900
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$163,000	$14,400
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$23,300	$2,060
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$423	$37
Avoided Emissions Damages	$629,000	$41,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$1,670,000**	
Net Benefits	**-$4,340,000**	
Benefit/Cost Ratio	**0.3**	
Internal Rate of Return	**n/a**	

Fixed Costs

The BCA relies on information provided by the Project Team to estimate the fixed costs of developing the microgrid. The Project Team's best estimate of initial design and planning costs is approximately $1.0 million. The present value of the project's capital costs is estimated at approximately $2.1 million, including costs associated with installing a microgrid control system; equipment for the substations that will be used to manage the microgrid; the IT infrastructure (communication cabling) for the microgrid; the new 0.1 MW natural gas unit; two photovoltaic arrays totaling 0.41 MW; and the power lines needed to distribute the electricity the microgrid would generate. Operation and maintenance (O&M) of the entire system would be provided under fixed price service contracts, at an estimated annual cost of $82,100. The present value of these O&M costs over a 20-year operating period is approximately $931,000.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's primary generator. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the Project Team and projections of fuel costs from New York's 2015 State Energy Plan (SEP), adjusted to reflect recent market prices.[73] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $548,000.

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 $93,000 annually. The majority of these damages are attributable to the emission of CO_2 and NO_x. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $1.4 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 Cortlandt's proposed microgrid, the primary source of cost savings would be a reduction in demand for electricity from bulk energy suppliers, with a resulting reduction in generating costs. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $860,000. These reductions in demand for electricity from bulk energy suppliers would also avoid emissions of CO_2, SO_2, NO_x, yielding emissions allowance cost savings with a present value of approximately $400 and avoided emissions damages with a present value of approximately $629,000.[74]

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.[75] 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 0.1424 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 $163,000 over a 20-year operating period.

[73] 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.

[74] Following the New York Public Service Commission's (PSC) 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.

[75] 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 ancillary services, in the form of black start support, to the New York Independent System Operator (NYISO). Whether NYISO would select the project to provide these services depends on NYISO's requirements and the ability of the project to provide support at a cost lower than that of alternative sources. Based on discussions with NYISO, it is our understanding that the market for black start support is highly competitive, and that projects of this type would have a relatively small chance of being selected to provide support to the grid. In light of this consideration, the analysis does not attempt to quantify the potential benefits of providing this service.

Reliability Benefits

An additional benefit of the proposed microgrid would be to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $2,000 per year, with a present value of $23,300 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:[76]

- System Average Interruption Frequency Index (SAIFI) – 0.11 events per year.
- Customer Average Interruption Duration Index – 181.2 minutes.[77]

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.[78] 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.

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

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.3; i.e., the estimate of project benefits is approximately 30 percent that of project costs. Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

Scenario 2

Benefits in the Event of a Major Power Outage

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[79,80]

As noted above, the Town of Cortlandt's microgrid project would serve three facilities: Cortlandt Healthcare LLC (assisted living); the town hall and police station; and St. Columbanus, an elementary school. The project's consultants indicate that at present, the police station and assisted living facility are equipped with backup generators. Specifically, Cortlandt Healthcare maintains a diesel generator, while the police station is equipped with two generators, one burning diesel and the other burning natural gas. The level of service these units can support is approximately half the ordinary level of service at the facilities. Operation of these units costs approximately $1,700 per day.

Should the backup generator units fail, the team indicates that all three facilities (Cortlandt Healthcare, the police station, and the school) could maintain operations by bringing in portable diesel generators with sufficient power to maintain all services. The operation of the portable units would cost approximately $4,600 per day. In the absence of backup power – i.e., if the backup generator failed and no replacement was available – all three facilities would experience at least a 75 percent loss in service capabilities.

[79] 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.

[80] As with the analysis of reliability benefits, the analysis of major power outage benefits assumes that development of a microgrid would insulate the facilities the project would serve from all outages. The distribution network within the microgrid is unlikely to be wholly invulnerable to service interruptions. All else equal, this will lead the BCA to overstate the benefits the project would provide.

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

- Cortlandt Healthcare would rely on its existing backup generator, experiencing a 50 percent loss in service capabilities while the generator operates. If the backup generator fails, the facility would experience a total loss of service.
- The police station and town hall would rely on its existing backup generators, experiencing a 50 percent loss in service capabilities while the generators operate. If the backup generators fail, the police department would experience a 100 percent loss in service effectiveness.
- St. Columbanus would rely on a portable generator, experiencing no loss in service while this unit is in operation. If the portable generator fails, the school would experience a total loss of service.
- In all three cases, the supply of fuel necessary to operate the backup generator would be maintained indefinitely.
- At each facility, there is a 15 percent chance that the portable or backup generators would fail.

The economic consequences of a major power outage also depend on the value of the services the facilities of interest provide. The analysis calculates the impact of a loss in the town's police services using standard FEMA values for the costs of crime, the baseline incidence of crime per capita, and the impact of changes in service effectiveness on crime rates. The impact of a loss in service at other facilities is based on the following value of service estimates:

- For Cortlandt Healthcare, a value of approximately $45,000 per day. This figure is based on an estimate of the facility's capacity (120 beds) and state data on the average rate for nursing home care in the area ($377/patient/day).[81]
- For St. Columbanus school, a value of approximately $2,700 per day. This figure is based on tuition per student, scaled to an average daily value, multiplied by the number of students. Based on personal communication with school office (December 18, 2015), the school has 196 K-8 students and 36 preschool students. Separate tuition rates are applied for these two categories of students.[82]

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

[82] Tuition rates are based on information provided at http://www.st-columbanus.com/admissions-tuition.html, accessed on December 18, 2015. The rates applied reflect those charged to a family with a single K-8 child ($4,334 per year) or those with a full-time pre-K child ($4,158 per year). Note that this value is at best a rough approximation of the social welfare loss

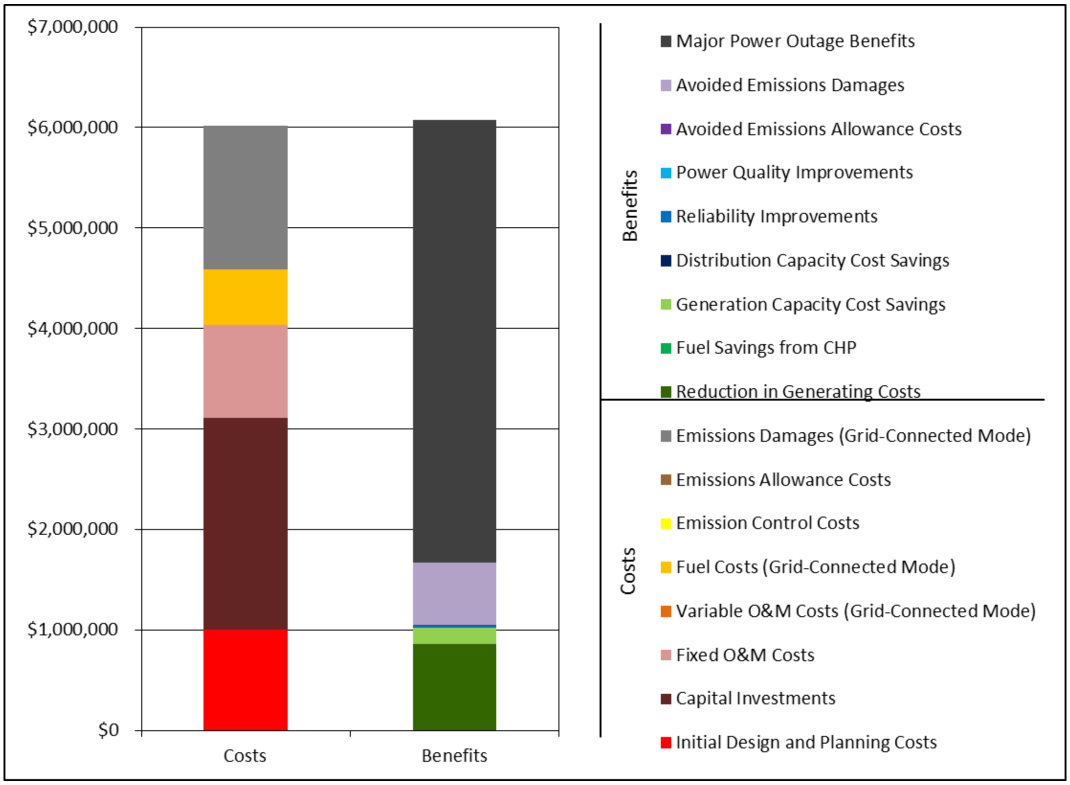
Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the three facilities is approximately $53,300 per day.

Summary

Figure 8 and Table 36 present the results of the BCA for Scenario 2. The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 7.3 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

Figure 8. Present Value Results, Scenario 2

(Major Power Outages Averaging 7.3 Days/Year; 7 Percent Discount Rate)



attributable to a loss of power at the school, as it does not account for the potential to reschedule lost school days when power is restored; the impact of disruptions in schedule on the productivity of teachers, school administrators, or children's caregivers; the cost of operating and maintaining the school; and other factors that would more accurately characterize the impact of a loss of service during an extended outage.

Table 36. Detailed BCA Results, Scenario 2

(Major Power Outages Averaging 7.3 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	$2,110,000	$170,000
Fixed O&M	$931,000	$82,100
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$548,000	$48,300
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$1,430,000	$93,300
Total Costs	**$6,020,000**	
Benefits		
Reduction in Generating Costs	$860,000	$75,900
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$163,000	$14,400
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$23,300	$2,060
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$423	$37
Avoided Emissions Damages	$629,000	$41,000
Major Power Outage Benefits	$4,400,000	$389,000
Total Benefits	**$6,070,000**	
Net Benefits	**$57,600**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**8.3%**	

The Project Team assumed an electricity sales price of $0.073 per kWh in Cortlandt. This is the supply cost for Con Ed, the average amount spent by Con Ed to import electricity into their distribution system. On a long term, fixed volume PPA, the Project Team believes this to be the most accurate pricing model. Industrial Economics modeled the location-based marginal price (LBMP) for the local NYISO zone to price electricity sales. The LBMP is effectively the average spot market price, peaking on summer afternoons and dropping to nearly zero in low demand hours. While the LBMP would be an appropriate price for intermittent and unreliable grid sales, the proposal herein supports reliable, continuous electricity injections into the Con Ed grid. In Cortlandt, the Dunwoodie LBMP is $39.16 per MWh[83], or $0.039 per kWh, a more than 45% reduction in price from the supply cost. The benefits allowed for capacity cost reductions do not bring the electricity prices to parity. This has a predictable influence on the economics of the projects and is the driving force behind the divergent cost benefit analyses developed by the

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

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

5. Summary and Conclusions

5.1 Lessons Learned and Areas for Improvement

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

5.1.1 Cortlandt Lessons Learned

The development of the Cortlandt microgrid proposal yielded several important issues to be addressed moving forward and lessons that can inform future microgrid development in the community.

First and foremost, as discussed elsewhere in this document, the small size of Cortlandt's loads and proposed generation assets create financial hurdles for the project. Without direct power sales from the generation assets to microgrid customers at all times, there is no manner by which the insufficient revenues may be mitigated short of expanding the size of the generation. The addition of storage would provide an opportunity to engage in demand response, load shifting, and time of use billing, however the assets would need to belong to a specific facility and a specific meter. It is unclear how the benefits of the storage might migrate out to the microgrid at-large and the Project Team is unaware of any precedent in New York State for community microgrid linked battery storage that primarily services the grouping of facilities and not a single, specific facility.

In terms of challenges, the costs of a community microgrid complete with on-site generation and a full suite of new control and network infrastructure are quite high. If the local intention for distributed energy resource assets is to serve a large number of facilities, the capital expenditure may become burdensome. Without relatively larger generation assets and commensurate microgrid loads, minimum economies of generation may not be reached, and the costs of the control infrastructure may not be recovered. In the absence of the NY Prize, the financial case for Cortlandt relies on capital rebates and incentives that may not be available in the long term, and operational subsides that do not currently exist.

The Cortlandt microgrid, as proposed in this document, exists with the consent and support of Con Ed and within the Project Team's understanding of current regulatory and legal considerations. The proposed microgrid exists as a set of generation assets that will sell electricity to Con Ed via a long-term power purchase agreement (PPA), selling power to Con

Ed's main grid. This structure was proposed because it is viable under current policy[84]; however, slight changes in the New York PSC's PSL §§ 2(2-d) and the Federal Public Utility Regulatory Policies Act could support a business model to facilitate behind-the-meter operation that is economically more advantageous and in line with the intent of the NY Prize and NYSERDA effort to develop community microgrids. The financial viability of many community microgrids would be significantly enhanced if the PSC were to include community microgrids as eligible for Qualifying Facility (QF) designation or, absent that change, if the PSC were to provide affirmatively lightened regulation[85] for primarily natural-gas fired projects.

A behind-the-meter microgrid would provide significantly stronger returns to investors, propel NY State in the direction of a "grid of grids," and provide more opportunities for load support and demand response across the state. This solution would allow generation assets to load follow the facilities within the microgrid, selling power closer to retail rates to the associated facilities, which would result in greater revenues. Excess power may be sold to Con Ed when the locational-based marginal price (LBMP) is greater than the variable cost of production, and additional revenue may potentially be generated through participation in demand response programs. This solution, we believe, requires the microgrid to be treated as a QF. At present, the Cortlandt microgrid is not eligible as a QF and would instead be subject to regulation as an electric utility (perhaps under lightened regulation, but nonetheless a significant administrative burden given the scope of the footprint). The Project Team endeavors to work with the PSC and other relevant State bodies to move this issue forward because it believes even small clarifications may enhance microgrid viability.

5.1.2 Statewide Lessons Learned

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

Technical. The existing electrical and natural gas infrastructure, along with the permissiveness of the utility in feeder modifications, are the chief determinants of what is possible. In Cortlandt, the possible was somewhat narrow given the placement of critical facilities relative to the electrical feeder system and Con Ed's preference for a small footprint. The Cortlandt system design relies on new distribution lines between the Town Hall / Police Department Complex and Cortlandt Healthcare and St. Columbanus; while linking multiple feeders with new lines is not the ideal solution, the proposal satisfies both the NYSERDA requirements to connect multiple critical facilities with different owners, and the Con Ed electrical system requirements. In general, for reasons of power flow, redundancy, and general system operations, connecting

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

[85] CHP, hydro, PV, fuel cells, etc. are already qualifying generation for a QF. Standalone natural gas (turbine or recip.) is currently excluded and many locations cannot leverage steam loads and may not have the space available for sufficient PV installations. It provides a reliable baseload and is more flexible than any of the currently included generation types.

feeders is not the first choice but given the support of the utility it can be an effective one. These constraints limit the number and diversity of facilities that may be connected in the microgrid, as the feeders do not always follow expected alignments. Further, and with good reason, utilities generally required proposed microgrids to be placed on the ends of feeders. The practical reason for this is to avoid isolating non-microgrid facilities downstream of the microgrid, which could cause power supply problems for the non-connected facilities and therefore be a liability for the utility. This is an understandable concern, and while it will necessarily limit the footprint of many microgrid proposals, the workaround in Cortlandt may serve as an example of selective facility connection absent AMI meters.

Lastly, 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 and the tie-in of existing diesel backup, given the high costs of storage and biomass and the larger footprints required for wind. Because solar generation is intermittent and has a low capacity factor in New York State (approximately 15%), solar installations of a few hundred kW do not provide reliable generation for an islanded microgrid. Natural gas-fired generation, on the other hand, provides high reliability baseload, is relatively clean and efficient, and allows for cogenerated steam sales if there is a proximate off-taker. Moreover, solar requires several orders of magnitude more space than containerized natural gas units, rendering large solar generation infeasible in suburban or urban settings. Cortlandt has moderate space available for solar PV, however it is insufficient for the construction of enough solar PV to independently serve the microgrid.

Financial. Across the portfolio of communities managed by the Project Team, natural gas availability, steam off-takers, and overall project size are the leading elements of financially viable projects. Simply, natural gas generation is more cost efficient, and provides highly reliable revenue streams through electricity sales, and offers steam sales as an added revenue stream unavailable to a system that relies on PV. Unfortunately, there is no steam off-taker in Cortlandt to justify the construction of a CHP unit, and the project financial feasibility reflects this absence of steam revenue. Moreover, the small overall loads and generation assets (peak loads of ~400 kW and proposed generation capacity of 510 kW) do not provide for revenue sufficient to cover operation and maintenance costs. This is a common feature of very small projects and to the extent that microgrid controllers are required, they will continue to financially hamstring projects below a certain kW threshold.

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

Policy. State policy does not currently address microgrids in a cohesive or holistic manner, nor have utility programs adequately recognized microgrid operations in their policies. DR is a potentially lucrative revenue stream in New York; however, current policies do not address community microgrid DR participation, and the lack of certainty of DR payment levels in the future make potential finance partners hesitant to rely on these revenue streams. For instance, interpretations of the existing NYISO DR programs suggest that microgrids could receive payments for islanding in times of high demand on the macrogrid. This scenario, while advantageous from a load shedding perspective, would also remove the microgrid connected generation simultaneously, leaving the macrogrid in a net-neutral position. While the nature of DR payments in such situations is not clear, the Project Team suggests explicit guidance from the Public Service Commission (PSC) and the various utilities regarding their respective policies. Moreover, during the Cortlandt Feasibility Study, Con Ed informally communicated they did not expect DR payments to be available for microgrids that simultaneously shed load and generation from the grid. Due to this lack of clarity, DR revenue has generally been excluded from the Project Team's revenue analysis.

Local community involvement is an important contributor to microgrid design success. Though even the most robust community engagement may not overcome highly unfavorable infrastructure, it is nonetheless imperative for steady forward progress. In Cortlandt, the Project Team has had a working relationship with officials from the community that satisfied the requirements to complete this feasibility study. This type of engagement is necessary to build support among prospective facilities and to engage on ownership models, generation options, and other considerations directly affecting the feasibility of the proposal. In communities with relatively little engagement, it is somewhat difficult to make firm recommendations, and the Project Team runs the risk of suggesting solutions that are, for whatever reason, unpalatable to the community.

Scalability. Scalability is governed by three factors. The structure of the electrical infrastructure, as defined in the technical lessons learned section above, is a key factor determining whether the microgrid can be expanded. At some point of expansion, it becomes necessary to link multiple feeders, which means having proximate feeders of the same voltage and connected to desirable facilities is also important. Though this proposal connects two feeders, there is an upper limit to how extensively Con Ed, or any utility, will allow a microgrid to rewire their system. Second, widespread AMI infrastructure makes expansion less complicated and allows facilities that are not microgrid participants to be disconnected selectively. There are no AMI meters in the Cortlandt footprint, making new lines necessary and excluding the possibility of immediately including several intermediate loads. Lastly, the larger the microgrid grows, the more switches and controls will need to be installed, connected, and maintained to allow for a smooth islanding and grid-reconnect process. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are likely to push back if microgrids grow to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the utilities to find acceptable footprints that both meet the goals of NYSERDA while respecting the operational concerns of local utilities that the NY Prize footprints remain somewhat contained.

5.1.3 Stakeholder Lessons Learned

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

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 owner utilities in the Project Team's portfolio, including Con Ed in Cortlandt, were uniformly against allowing a third party operational control of utility-owned infrastructure. While this view is understandable, 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 duplicative 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 two areas. First, research into a relatively small grid system with multiple generators (some spinning, some inverter-based), temporally and physically variable loads, and multidirectional power flows may inform better designs and more efficient placement of generation and controls relative to loads.

The second is optimizing financial structures for collections of distributed energy resources and control infrastructure. To date, most microgrids in the United Stated have been campus-style developments, in which the grid serves a single institution and it can be easily segregated from the macrogrid. Community microgrids consisting of multi-party owned facilities and generation are a new concept, and literature on how best to own and operate such developments is not yet robust.

Communities. Engaged communities are important, but so too are realistic expectations of what a microgrid might include. Many communities 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 1 feasibility studies, providing a wide canvas for jumpstarting microgrid development in the state but also placing administrative burdens on the utilities and on NYSERDA itself. As NYSERDA is aware, the timelines for receiving information from utilities were significantly delayed compared to what was originally intended, and this has impacted the ability of the Project Team to provide deliverables to NYSERDA on the original schedule. As mentioned in the Utilities Lessons Learned above, better communication between the State and the utilities may have preemptively alleviated this bottleneck.

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

5.2 Benefits Analysis

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

5.2.1 Environmental Benefits

New York State's normal energy portfolio is very clean, with primary energy sources being hydropower and nuclear. Therefore, having a microgrid powered by a natural gas-fired reciprocating generator will increase the overall emissions per kWh. However, the natural gas generator is cleaner than many peaking assets, which come online when statewide demand is high, and is significantly cleaner than the existing diesel backup currently in place in the microgrid footprint. 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 Local Government

The Town government will benefit from the expansion of local, distributed energy resources that will help create a more resilient grid in the area. In the short term, the proposed microgrid will supply electricity to three facilities that provide critical and important services to the community, including the Town Hall / Police Department complex, Cortlandt Healthcare, and St. Columbanus. The availability of these facilities in an emergency situation will provide numerous public safety benefits to the Town. The Project Team spoke with the community on March 10, 2016 to provide a final summary update of the project outcomes and provide a recommended path forward.

5.2.3 Benefits to Residents of Cortlandt

Residents of Cortlandt stand to gain from access to shelter and emergency and municipal services during an outage on the grid. In addition, emergency medical services at Cortlandt Healthcare may be enabled by microgrid support in times of emergency outages, and maintaining a functioning municipal government and public safety element is an important consideration. At present, these services are partially or wholly unavailable during outages; the proposed microgrid provides for unencumbered electrical service to the aforementioned facilities during a grid outage.

5.2.4 Benefits to New York State

New York State will benefit from the continued localization of energy resources, reducing load and congestion on the grid. Moreover, the expansion of distributed energy resources will further the goals of REV and provide a more resilient overall grid. A successful implementation of the Cortlandt microgrid will provide a proof of concept of ownership and operation of microgrids in IOU service areas. It would further make the case for the flexibility associated with microgrids that are not restricted to a single feeder in a sequential arrangement. In addition, the lessons learned described in Section 5.1 are widely applicable to the further development of REV and future NY Prize efforts into Phase II and 3. Tasks 2 and 3 also illustrate the support provided by demonstrating how the microgrid proposal, and its lessons learned, support to the REV proceedings.

5.3 Conclusion and Recommendations

The Project Team has concluded the proposed Cortlandt microgrid is technically feasible, and it is financially feasible with the award of the Phase III NY Prize and additional operational support. This report has detailed the capabilities of the microgrid; its primary technical design; the commercial, financial, and legal viability of the project; and the costs and benefits of the microgrid. The microgrid meets all of the NYSERDA required capabilities and most of its preferred capabilities as outlined in the Statement of Work (SOW) for this contract.

The primary risk of the Cortlandt microgrid project is financial; without substantial grant funding or a change in regulatory treatment, project economics are unfavorable. The current proposal with three facilities was developed in conjunction with Con Ed to minimize disruption to the Con Ed network while also meeting the NYSERDA required project elements. However, the small scale means there is commensurately less generation revenue to offset the installation of control infrastructure and lines. This microgrid project will help accelerate New York State's transition from traditional utility models to newer and smarter distributed technologies. It will help achieve the REV goals of creating an overall more resilient grid, reducing load and congestion, expanding distributed energy resources, reducing GHG emissions, and constructing more renewable resources. It will also encourage citizens within the community to invest and get involved in local energy generation and distribution and will foster greater awareness of these issues.

Finally, the project will demonstrate the widely distributed benefits of microgrids paired with distributed energy resource assets. The utility will see increased revenues and grid performance, customers will see stabilized electricity provided by a more reliable grid system, and the community will reap the positive benefits of living in and around the microgrid.

Path Ahead

Beyond New York Prize, Cortlandt has several options available to improving energy resilience in the community through energy efficiency, distributed energy resources, and advanced technology such as microgrid controllers. The community has done an exceptional job with energy efficiency and other environmentally beneficial, resilient programs. The Town formed a Green Team executive board to guide future EE upgrades. As a Climate Smart Community, Cortlandt has adopted a green procurement policy and a green building code for residential or commercial construction.

In addition to previously implemented efficiency measures, the Project Team estimates the reduction potential for the three facilities to be approximately 25 kW.[86] This is a conservative estimate that may be exceeded by more aggressive efficiency investments, such as a new high-efficiency chiller at Cortlandt Healthcare. Leveraging existing Con Edison EE programs to reduce load at existing facilities and seeking to qualify facilities for NYSERDA funded EE programs could bring significant subsidies to the community.

NYSERDA also maintains additional resources, such as the NYSERDA Economic Development Growth Extension (EDGE). The contractor for this effort in Westchester is Melissa Herreria at Courtney Strong, Inc. They have hosted a number of webinars and information sessions about NY-Prize in the Mid-Hudson region to encourage municipalities to apply for benefits. Their role is to raise awareness of NYSERDA programs and help utility customers, including municipalities, apply to those programs.

The lack of immediate microgrid potential does not mean that distributed energy resources, which may exist without microgrid controls and switches, are infeasible in the community. Larger solar generation on municipality-owned land, coupled with purchase agreements guaranteeing prices for a decade or more, would move Cortlandt further along towards a less costly and more resilient energy future. Small roof-mounted solar across the community would enhance collections of individual homes and, if coupled with increasingly cost effective battery storage, could provide a significant energy resource within the community. Linking this effort with Westchester's move towards community choice aggregation and other wide scale renewables programs would provide another lever to expand local renewables. For example, leveraging NY-Sun Initiative resources can provide a basis for affordable residential and commercial solar. All of the facilities in the microgrid footprint can and should independently pursue rooftop solar, and the resulting savings may be used to seed any number of energy efficiency projects. At a community level beyond the microgrid, decreasing grid-demanded loads immediately improves local resilience.

In addition, the proposed natural gas generator may be installed as currently sized, or decreased to match a single facility's load, to support baseload electricity demand. The leveled cost of production is competitive with retail prices from the grid, and provides for resilient, on-site generation. Either of these generation solutions can be implemented without the expense of a full microgrid control infrastructure. In the future, as state policy or the economics of electricity and outages change, the community will be better postured for a microgrid.

[86] EnergyStar estimates between 10-30% commercial building energy efficiency savings on average. As some investments have been previously made and the Project Team does not have total visibility on opportunities, a conservative estimate for available kW reductions is ~25 kW. https://www.energystar.gov/buildings/about-us/how-can-we-help-you/improve-building-and-plant-performance/improve-energy-use-commercial

Appendix

Metering data for typical 24-hour load profiles were provided by Con Ed. They are included in this feasibility study to show which facilities have highest and lowest load demands at different times of the day. Analyzing these load demand curves has allowed the team to develop a better overall understanding of the generation capacity needed to sustain the microgrid. Con Ed does not provide interval data for loads less than 500 kW, so the Project Team used a simulator to profile typical 24-hour load curves for these facilities. However, the Project Team was able to secure interval data for the healthcare center directly from Cortlandt Healthcare. The load profiles for other Cortlandt facilities are simulated.

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