45 - City of Kingston

Notice

City of Kingston Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

Prepared for:

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

Prepared by:

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

Date Submitted: March 31, 2016

Contract Number: 65114, Task 5

Points of Contact Authorized for the City of Kingston Microgrid Study:

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

Notice

Abstract

Together with the City of Kingston, Booz Allen Hamilton has completed a feasibility study for a proposed community microgrid, which summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is feasible, though not without challenges. The commercial and financial viability of the project have been analyzed and are summarized in this document. The Kingston microgrid project faces the challenge of high capital costs, but it benefits from an advantageous mix of generation and loads. The project design including a 2 megawatt (MW) combined heat and power (CHP) unit and 250 kilowatt (kW) solar photovoltaic (PV) array will provide reliable, low-emission electricity and steam to customers while providing a proof of concept for a community microgrid in an investor-owned utility's (IOU) territory. Many of the takeaways of the feasibility study may be generalized across the spectrum of NY Prize and community microgrids.

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

Contents

Notice i

Abstract ii

Figures vii

Tables vii

Acronyms and Abbreviations vii

Executive Summary xi

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) 2

2.2.1 Serving Multiple, Physically Separated Critical Facilities 4

2.2.2 Limited Use of Diesel Fueled Generators 4

2.2.3 Local Power in both Grid-Connected and Islanded Mode 4

2.2.4 Intentional Islanding 4

2.2.5 Seamless and Automatic Grid Separation Restoration 5

2.2.6 Standardized Interconnection 5

2.2.7 24/7 Operation Capability 7

2.2.8 Two Way Communication with Local Utility 7

2.2.9 Voltage and Frequency Synchronism When Connected to the Grid 7

2.2.10 Load Following and Frequency and Voltage Stability When Islanded 7

2.2.11 Diverse Customer Mix 7

2.2.12 Resiliency to Weather Conditions 8

2.2.13 Black Start Capability 8

2.2.14 Energy Efficiency Upgrades 9

2.2.15 Cyber Security 10

2.2.16 Use of Microgrid Logic Controllers 10

2.2.17 Smart Grid Technologies 10

2.2.18 Smart Meters 10

2.2.19 Distribution Automation 10

2.2.20 Energy Storage 11

2.2.21 Active Network Control System 11

2.2.22 Demand Response 11

2.2.23 Clean Power Sources Integration 11

2.2.24 Economic Dispatch 11

2.2.25 Storage Optimization 11

2.2.26 PV Monitoring, Control, and Forecasting 12

2.2.27 Protection Coordination 12
2.2.28 Selling Energy and Ancillary Services 12
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
2.3 Distributed Energy Resources Characterization (Sub Task 2.3) 13
2.3.1 Existing Generation Assets 13
2.3.2 Proposed Generation Assets 13
2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics 14
2.4 Load Characterization (Sub Task 2.2) 14
2.4.1 Electrical Load 15
2.4.2 Thermal Consumption 18
2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1) 18
2.5.1 Grid Connected Parallel Mode 19
2.5.2 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 23
2.6.3 Basic Protection Mechanism within the Microgrid Boundary 24
2.6.4 Thermal Infrastructure 24
2.7 Microgrid and Building Control Characterization (Sub Task 2.5) 24
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 28
2.7.7 Resynchronization with CHG&E Power 29
2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6) 29
2.8.1 Existing IT & Telecommunications Infrastructure 30
2.8.2 IT Infrastructure and Microgrid Integration 30
2.8.3 Network Resiliency 30
2.9 Microgrid Capability and Technical Design and Characterization Conclusions 31
3. Assesement of Microgrid's Commercial and Financial Feasibility (Task 3) 31
3.1 Commercial Viability – Customers (Sub Task 3.1) 31
3.1.1 Microgrid Customers 32
3.1.2 Benefits and Costs to Other Stakeholders 32
3.1.3 Purchasing Relationship 33

3.1.4 Solicitation and Registration 34
3.1.5 Energy Commodities 34
3.2 Commercial Viability – Value Proposition (Sub Task 3.2) 34
3.2.1 Business Model 35
3.2.2 New Technology 38
3.2.3 Replicability and Scalability 38
3.2.4 Benefits, Costs, and Value 39
3.2.5 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 47
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 50
3.4.4 Permitting 51
3.5 Financial Viability (Sub Task 3.5) 51
3.5 1 Revenue, Cost, and Profitability 51
3.5.2 Financing Structure 53
3.6 Legal Viability (Sub Task 3.6) 54
3.6.1 Ownership and Access 54
3.6.2 Regulatory Considerations 55
3.7 Project Commercial and Financial Viability Conclusions 56
4. Cost Benefit Analysis 57
4.1 Facility and Customer Description (Sub Task 4.1) 58
4.2 Characterization of Distributed Energy Resource (Sub Task 4.2) 60
4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3) 63
4.3.1 Peak Load support 63
4.3.2 Demand Response 63
4.3.3 Deferral of Transmission/Distribution Requirements 63
4.3.4 Ancillary Services 64
4.3.5 Development of a Combined Heat and Power System 64
4.3.6 Environmental Regulation for Emission 64
4.4 Project Costs (Sub Task 4.4) 66
4.4.1 Project Capital Cost 66
4.4.2 Initial Planning and Design Cost 69
4.4.3 Operations and Maintenance Cost 70

4.4.4 Distributed Energy Resource Replenishing Fuel Time 71
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 73
4.6 Services Supported by the Microgrid (Sub Task 4.6) 73
4.7 Industrial Economics Benefit-Cost Analysis Report 74
4.7.1 Project Overview 74
4.7.2 Methodology and Assumptions 75
4.7.3 Results 76
5. Summary and Conclusions 86
5.1 Kingston Lessons Learned and Areas for Improvement 86
5.1.1 Kingston Lessons Learned 86
5.1.2 Statewide Replicability and 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 the City of Kingston 92
5.2.3 Benefits to Residents in and around Kingston 92
5.2.4 Benefits to Healthcare Customers 92
5.2.5 Benefits to New York State 93
5.3 Conclusion and Recommendations 93
Appendix 95
Typical 24-Hour Health Alliance (Broadway Ave) Load Profile .... **Error! Bookmark not defined.**
Typical 24-Hour Health Alliance (Mary Ave) Load Profile .... **Error! Bookmark not defined.**
Typical 24-Hour Kingston Fire Department Load Profile .... **Error! Bookmark not defined.**
Typical 24-Hour Kingston DPW Load Profile .... **Error! Bookmark not defined.**
Typical 24-Hour Kingston City Hall Load Profile .... **Error! Bookmark not defined.**
Typical 24-Hour Kingston High School Profile .... **Error! Bookmark not defined.**
Kingston Microgrid Operation One-Line: Black Start .... **Error! Bookmark not defined.**
Kingston Microgrid Operation One-Line: Island Mode .... **Error! Bookmark not defined.**
Kingston Microgrid Operation One-Line: Transient State (from Islanded Mode to Grid Connected Mode) .... **Error! Bookmark not defined.**
Kingston Microgrid Operation One-Line: Grid Connected Mode .... **Error! Bookmark not defined.**

Figures

Figure ES- 1. Schematic of Microgrid with Facilities and DERs ... xii
Figure 1. Map of Microgrid Coverage Area ... **Error! Bookmark not defined.**
Figure 2. Kingston Equipment Layout ... 16
Figure 3. Typical 24-Hour Cumulative Load Profile ... 17
Figure 4. Kingston One-Line Diagram ... 22
Figure 5. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate) ... 77
Figure 6. Present Value Results, Scenario 2 (Major Power Outages Averaging 4.5 Days/Year; 7 Percent Discount Rate) ... 84

Tables

Table ES- 1. Prospective Microgrid Facilities ... xi
Table ES- 2. Proposed and Existing Generation Assets ... xii
Table 1. Microgrid Capabilities Matrix ... 3
Table 2. New York State Interconnection Standards ... 6
Table 3. City of Kingston List of Prospective Microgrid Facilities ... 7
Table 4. Potential EE Upgrades to Microgrid Facilities ... 9
Table 5. Proposed Generation Assets ... 14
Table 6. Kingston's 2014 Microgrid Load Points ... 17
Table 7. Kingston's Distributed Switches Description ... 20
Table 8. Kingston's Network Switch Description ... 21
Table 9. Kingston's Server Description ... 21
Table 10. List of Additional Components ... 23
Table 11. Microgrid Customers ... 32
Table 12. Kingston Microgrid SWOT ... 36
Table 13. Benefits, Costs, and Value Proposition to CHG&E ... 39
Table 14. Benefits, Costs, and Value Proposition to DER Owners ... 40
Table 15. Benefits, Costs, and Value Proposition to City of Kingston ... 41
Table 16. Benefits, Costs, and Value Proposition to Industrial Facilities ... 41
Table 17. Benefits, Costs, and Value Proposition to Other Commercial Entities ... 42
Table 18. Benefits, Costs, and Value Proposition to Larger Kingston-area Community ... 42
Table 19. Benefits, Costs, and Value Proposition to New York State ... 43
Table 20. Project Team ... 45
Table 21. Project Team Roles and Responsibilities ... 46
Table 22. Savings and Revenues ... 52
Table 23. Capital and Operating Costs ... 52
Table 24. Available Incentive Programs ... 53
Table 25. Facility and Customer Detail Benefit ... 59
Table 26. Distributed Energy Resources ... 62
Table 27. Distributed Energy Resource Peak Load Support ... 63
Table 28. Emission Rates ... 66
Table 29. Capital Cost of Jansen Substation ... 67
Table 30. Capital Cost of Proposed Generation Units ... 68

Table 31. Initial Planning and Design Cost 69
Table 32. Fixed Operating and Maintaining Cost 70
Table 33. Cost of Generation during a Power Outage 72
Table 34. Critical Services Supported 73
Table 35. BCA Results (Assuming 7 Percent Discount Rate) 76
Table 36. Detailed BCA Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate) 78
Table 37. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 4.5 Days/Year; 7 Percent Discount Rate) 85

Acronyms and Abbreviations

AC	Alternating Current
AMI	Advanced Metering Infrastructure
BCA	Benefit Cost Analysis
BEMS	Building Energy Management Systems
BTU	British thermal unit
CAIDI	Customer Average Interruption Duration Index
CHG&E	Central Hudson Gas and Electric
CHP	Combined Heat and Power
DC	Direct Current
DER	Distributed Energy Resources
DNP3	Distributed Network Protocol
DPW	Department of Public Works
DR	Demand Response
EDRP	Emergency Demand Response Program
EE	Energy Efficiency
EMS	Energy Management System
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
Hz	Hertz
ICCP	Inter-Control Center Communications Protocol
IEc	Industrial Economics
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor Owned Utility
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
MMBTU	One Million British Thermal Units
$MMTCO_2e$	Million Metric Tons CO_2 Equivalent
$MTCO_2e$	Metric Tons CO_2 Equivalent
MW	Megawatt
MWh	Megawatt-hour
NFPA	National Fire Protection Association
NPV	Net Present Value
NYISO	New York Independent System Operator
NYPSC	New York Public Service Commission

NYS DEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
OPC	Open Platform Communication or OLE (Object Link Embedded) Process Control
OPF	Optimal Power Flow
PCC	Point of Common Coupling
PPA	Power Purchase Agreement
PV	Photovoltaic
RAID	Redundant Array of Independent Disks
REV	Reforming the Energy Vision
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCOPF	Security Constrained Optimal Power Flow
SOA	Service Oriented Architecture
SOW	Statement of Work
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 City of Kingston, New York. This deliverable presents the findings and recommendations from the previous four tasks, discusses the results and lessons learned from the project, and lays out the environmental and economic benefits for the project. The design demonstrates the City can improve energy resiliency with intentional and emergency island mode capabilities, stabilize energy prices by relying on its own energy generation assets when statewide electricity demand is high, and comply with the greater New York REV (Reforming the Energy Vision) program by constructing 2.25 MW of clean energy generation capability. The study concludes the technical design is feasible.

The Kingston microgrid project will tie together five critical facilities (per NYSERDA's definition) and one important facility into a community microgrid. ES- lists all the facilities under consideration for the microgrid concept at this time.

Table ES- 1. Prospective Microgrid Facilities

Table lists the facilities in the City of Kingston's proposed microgrid, including their classifications as public, health, or school. The table also denotes critical and important facilities.

Facility #	Property	Classification
F2	**City of Kingston (City Hall)**	Public*
F3	**Kingston Fire Department**	Public *
F6	**Department of Public Works (DPW)**	Public*
F4	**Health Alliance: Benedictine Hospital**	Heath*
F6	**Broadway Campus Hospital**	Health*
F1	**Kingston School District (High School)**	School**
		* Critical Facility ** Important Facility

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

- One existing 100 kW backup natural gas generator at City Hall (420 Broadway).
- One proposed 2 MW natural gas combined heat and power (CHP) reciprocating generator at Benedictine Hospital.
- One proposed 250 kW PV array system at City Hall.

Table ES-2 lists all of the proposed and existing distributed energy resources (DERs) and Figure ES- 1 shows their locations in the City of Kingston.

Table ES- 2. Proposed and Existing Generation Assets

Table describes three existing generation assets in the City of Kingston and the fuel source, capacity, and address of each system.

Name	Description	Fuel Source	Capacity (kW)	Address
DER1	New CHP at Benedictine Hospital	Natural Gas	2,000	105 Mary's Ave
DER2	New solar PV system at City Hall	Sun Light	250	420 Broadway
DER3	City Hall (backup generation)	Natural Gas	100	420 Broadway

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

Figure ES-1 shows the proposed microgrid and the locations of facilities and DERs.

The existing and proposed generation assets will provide 100% of the average aggregate loads of the listed important and critical facilities during emergency outage conditions, but the microgrid peak load may exceed the total generation limit of the microgrid, even with the natural gas-fired backup generator running. Non-critical loads may be dropped in these situations to maintain the integrity of the microgrid. The backup power supplied by the microgrid will ensure essential services remain accessible during long-term grid outages, providing relief for residents in and around Kingston. In addition, the CHP unit will sell steam to the Benedictine Hospital during both grid-connected and island mode, lowering the steam procurement costs and greenhouse gas (GHG) emissions of the facility, and it will sell electricity into the Central Hudson Gas and Electric Corporation (CHG&E) grid during normal operation. The PV array will also operate in islanded and grid-connected mode to further improve the local energy mix.

A hybrid ownership model is envisioned for the Kingston microgrid, in which components of the microgrid will be owned by two separate special purpose vehicles (SPVs). The Project Team believes this hybrid model offers the greatest benefits and flexibility to the utility and customer base within the City.

The first SPV will own the distributed energy resource assets, and the second will own the distribution infrastructure and microgrid components and control infrastructure. The majority stake in the SPV for the distributed energy resource assets will be held by private or municipal investors, and it is assumed that these parties will finance the SPV through a combination of debt and equity. The SPV is expected to pay rent to the hospital for the land on which the CHP is built. The majority stake in the second SPV for the microgrid components and control infrastructure may be owned by CHG&E or by a third party operator. CHG&E may wish to own the new infrastructure in order to maintain control and operation of all systems leveraging their existing distribution system.

The microgrid will incur initial capital costs of $5.6 million as well as yearly operation, maintenance, and fuel costs totaling $1.1 million per year. Overall revenue streams from the project are estimated at $1.3 million per year and will be captured primarily through the sale of electricity from the generation units to CHG&E and the sale of thermal resources to the hospital. Other revenues from the proposed microgrid will include tax credits, incentives, and demand response (DR) programs.

Two major challenges currently face the microgrid project. First, CHG&E will need to support the proposed interconnection, electrical distribution design, and ownership of the microgrid distribution assets. At present, they have not consented to the use of spare lines as part of the microgrid. While the design was reviewed at length with CHG&E it is unclear whether they will support the final proposal at this time due to existing system resiliency. Second, the hospital will need to allow the CHP to be located at their facility and purchase steam from the system. The value proposition to the hospital to participate in the project is strong, and as such it is expected that the hospital will want to participate.

1. Introduction

The City of Kingston is seeking to develop a community microgrid to improve energy service resiliency, accommodate distributed energy resources, stabilize energy prices, and reduce greenhouse gas emissions. Working with Kingston and CHG&E, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary community microgrid concept that will connect six critical and important facilities with two new generation assets and an existing backup generator. The design proposes a new 2 MW CHP unit to be located at the Benedictine Hospital, a new 250 kW solar PV array on the premises of City Hall, and the incorporation of an existing 100 kW natural gas generator at City Hall. Section 2 of this document describes the configuration further, and provides the full scope of the proposed design and its component parts.

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

2. Microgrid Capabilities and Technical Design and Configuration

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

2.1 Project Purpose and Need

The Kingston microgrid will improve the resiliency of the local electricity grid in emergency outage situations, accommodate distributed energy generation, stabilize energy costs to CHG&E during peak events, and reduce reliance on high emission assets during peak demand events. Kingston is typical of many communities in Upstate New York, with a relatively concentrated cluster of critical and important facilities in the core of the City surrounded by residential and other commercial customers. The City is also accustomed to the range of weather events that face Upstate New York, including torrential rain, snow, and wind, all of which may impact the ability of the grid to safely, reliably, and efficiently deliver services to customers. However, CHG&E has historically provided highly reliable service to customers in the Kingston area; thus, the primary reliability benefits from the microgrid will only be realized when the larger grid loses power. Kingston has experienced several such situations in recent years (Tropical Storm Lee, Hurricane Irene, and Hurricane Sandy), all of which resulted in prolonged interruptions to energy service. In the aftermath of Hurricane Sandy, for example, more than one third of the CHG&E service territory was without electricity. Flooding and falling branches destroyed power lines and interrupted delivery of electricity to the City's critical facilities. Many of the critical government, health, and public facilities in Kingston do not have backup generation, so these prolonged grid outages create a potentially hazardous situation for all of the City's residents. Finally, the microgrid's generation assets will reduce the amount of current that must be transmitted to the City. CHG&E expects direct cost savings to be minimal at present; however, as electricity demand across New York State grows and increases pressure on the State's transmission and distribution system, congestion costs will increase and more critical congestion points will appear. The microgrid therefore represents a valuable investment in both the City and New York State's energy future.

1. The City of Kingston provides a unique opportunity to examine the prospects of a replicable, modular microgrid solution. New York State has experienced severe longstanding congestion at critical points on the transmission system linking upstate and downstate New York, some of which could be eliminated by building microgrids with intentional island mode capability. The project will therefore serve as a model that could be replicated at critical congestion points throughout the state.
2. There are several existing generation sources in the City of Kingston. The City has already made significant progress towards their Climate Action Plan and has met the goal of purchasing (or generating) at least 20% of the City's energy from renewable sources. The microgrid will provide another avenue for developing renewable energy generation in the City of Kingston, which could propel the City to leadership status among the New York cities that aim to achieve the state's REV goals.

The City of Kingston and its residents seek to improve resiliency of energy service, stabilize costs, and lower their environmental footprint. Utilizing the CHP by generating power at the Hospital on Mary's Avenue while producing high quality steam is one way the Hospital is seeking to stabilize their steam generation costs as currently they use No. 2 oil.

CHGE would also benefit from being able to remotely monitor the microgrid and the Jansen Avenue Substation. This is a concept that CHGE has been interested in for quite some time. It is important to note that the automated system will have flexibility and expansion capabilities for CHGE to add additional electrical and gas distribution elements outside of the microgrid but related to the City of Kingston if they desire. The microgrid could serve as a catalyst for CHGE's vision to remotely monitor and control their system in Kingston.

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

The NYSERDA statement of work (SOW) 65114 outlines 15 required capabilities and 18 preferred capabilities each NY Prize microgrid feasibility study must address. Table 1 summarizes required and preferred capabilities met by the proposed microgrid design in greater detail. The proposed microgrid design meets all required capabilities and most of the preferred capabilities.

Table 1. Microgrid Capabilities Matrix

List of NYSERDA required and preferred capabilities and annotations of whether or not the Kingston microgrid will meet these criteria.

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

* Capability is characterized as preferred by NYSERDA but is a required component in this design

The remainder of this section demonstrates how the design concept meets the required capabilities provided by NYSERDA in the SOW 65114.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

Kingston and the Booz Allen Team have identified five critical facilities and one important facility to be tied into the microgrid, including a school (which could be used for shelter during a natural disaster). See Table ES-1 for a full list of prospective critical and important facilities to be tied into the microgrid.

In total, six facilities are proposed for the microgrid. All loads are within a 0.5 mile radius, interconnected via medium voltage (13.8 kV) distribution owned by Central Hudson. These facilities will communicate with each other via Kingston's existing IT network, which will allow the microgrid to serve multiple, physically separated critical facilities. Kingston's existing IT network will require upgrades to achieve microgrid functionality. New systems will reflect industry standard protocols such as Distributed Network Protocol (DNP3), Modbus, IEC 61850, and others as required, to enable remote monitoring and control of the physically separated critical facilities. The microgrid design is also flexible and scalable to accommodate the addition or expansion of critical facilities.

2.2.2 Limited Use of Diesel Fueled Generators

Kingston currently has natural gas at the proposed CHP (Hospital, Mary Ave.) location. In addition to CHP, Kingston is interested in installing a 250 kW solar PV array in the parking lot behind the Town Hall building.

2.2.3 Local Power in both Grid-Connected and Islanded Mode

The microgrid will provide on-site power in both grid connected and islanded mode with the capability to switch from grid to islanded mode either manually by an operator or automatically based on grid disruptions and programmed logic. The microgrid will optimize on-site generation and automatically shed non-critical loads as needed to maintain the stability and reliability of the microgrid. While in grid connected mode (paralleling with the grid), the microgrid will optimize the use of available assets to reduce energy costs when possible and export to the connected grid when and if economic and technical conditions align. For example, a solar PV system could operate in parallel with the grid under normal operation, reducing Kingston's dependence on grid power. In islanded mode, the solar PV system would function alongside the other generators to meet critical load needs as well. The CHP system will run continuously year-round in both grid connected mode and in islanded mode.

2.2.4 Intentional Islanding

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

The MCS will automatically start and parallel the generation assets. Once the available power sources are synchronized with the grid (and each other), the system is considered ready to begin islanded operation, and it will begin by opening the incoming utility line breakers. Once in islanded mode, the microgrid controls must maintain the voltage and frequency between acceptable limits and perform load following.

2.2.5 Seamless and Automatic Grid Separation Restoration

The microgrid will automatically disconnect from the main grid and seamlessly reconnect to it after main grid conditions have stabilized using synchronization and protection equipment. The switching will be done by the operator or when monitored operational variables satisfy predetermined conditions. Synchronization is accomplished by having the generation assets' output voltage reference taken from grid voltage using a phase-locked-loop circuit.

2.2.6 Standardized Interconnection

This microgrid feasibility study will be governed by the NYPSC interconnection standards. Table 2 outlines the most significant state interconnection standards that apply to this microgrid project. Any additional local utility or local building codes or interconnection standards will also be incorporated. Given the broad support for microgrid development in Kingston, local standards and regulations have not been identified as a significant barrier to project feasibility. There are several interconnection standards with direct applications to the microgrid, particularly the distributed energy resource components.

Table 2. New York State Interconnection Standards

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

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

2.2.7 24/7 Operation Capability

The project concept envisions the proposed CHP reciprocating generator to be the main generation source and thermal host for the community microgrid. Existing natural gas pipelines at the CHP location will enable the 24/7 operation capability to be met.

2.2.8 Two Way Communication with Local Utility

Kingston currently has no bidirectional communication components with the main grid. The new automation solution will serve as a protocol converter to send and receive all data available over the City's network using industry standard protocols such as DNP3, as well as OPC, Modbus, IEC 61850, ICCP (IEC 60870-6). The flexibility of the proposed system allows for expansion to enterprise-level for Central Hudson to view and control the microgrid remotely via a wide area network (WAN) remote connection (workstation).

2.2.9 Voltage and Frequency Synchronism When Connected to the Grid

Power generated either by the rotating sources, such as turbine generators, or inverter-based energy sources, such as PV, will be frequency and phase synchronized with the main CHGE grid. Synchronization is accomplished by comparing the output voltage, frequency, and phase of the three generation assets using a phase-locked-loop circuit. The synchronization is critical to allow power to be generated by multiple power sources.

2.2.10 Load Following and Frequency and Voltage Stability When Islanded

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

2.2.11 Diverse Customer Mix

Too much industrial or electronics-based loads can negatively affect power quality and supply stability. To avoid power quality challenges, the proposed Kingston microgrid will balance loads with a variety of customer classes. The microgrid power management system will allow for an acceptable mix of commercial, governmental, and hospital customers.

Table 3 lists all the facilities currently considered in the microgrid concept design, and Figure 1 shows them on a map. There are six total facilities that will be tied into the microgrid.

Table 3. City of Kingston List of Prospective Microgrid Facilities

List of properties, addresses, classifications, and number of load points for each facility proposed for the Kingston microgrid.

	Property	Address	Classification
1	**City of Kingston (City Hall)**	420 Broadway	Public
2	**Kingston Fire Department**	32 E O'Reilly St	Public
3	**Department of Public Works**	25 E. O'Reilly St	Public
4	**Kingston School District (High School)**	403 Broadway	School
5	**Broadway Campus Hospital**	396 Broadway	Health
6	**Health Alliance: Benedictine Hospital**	105 Mary's Ave	Health

Figure 2. Schematic of Microgrid with Facilities and DERs

Shows the proposed microgrid and the locations of facilities and DERs.

2.2.12 Resiliency to Weather Conditions

Typical forces of nature affecting the City of Kingston include, but are not limited to, torrential rain, snow, ice, wind, and even EF1 tornados that could cause falling objects and debris to disrupt electric service and damage equipment and lives. Ways to harden the microgrid resiliency include, but are not limited to, implementing line fault notifications and deploying other sensors to ensure the network is as resilient as possible to storms and other unforeseen forces of nature. Positioning proposed equipment in topographically higher areas of the town not prone to flooding is also important. Ideally the natural gas pipeline will be underground to protect it from severe weather. Some generators can also be located inside buildings or sheds to protect them from rain, snow, strong winds, or falling trees.

2.2.13 Black Start Capability

When grid power goes out in Kingston, islanded mode is initiated by distributed energy resource's black start capability. This mode of operation will require the generators being used for black start to have black start capability. They must have at a minimum a direct current (DC) auxiliary support system with enough power to start the generator multiple times in case it fails to start the first time. This will require the proposed natural gas CHP and existing natural gas generator to be equipped with black start capabilities.

2.2.14 Energy Efficiency Upgrades

Energy efficiency (EE) is critical to the overall microgrid concept. City facilities and the Hudson Valley Hospitals have both benefitted from energy savings performance contracts. There are still opportunities to reduce overall and peak demand at these facilities through additional EE upgrades. Kingston High and Middle Schools are undergoing major renovation projects, which will result in more efficient buildings. EE upgrades to microgrid facilities are estimated to result in an approximately 160 kW reduction in peak load.

The project implementation team will work with facility owners to identify upgrades that could result in additional significant load reduction. The project implementation team will also seek to qualify microgrid facilities for EE programs funded by CHGE and NYSERDA, including the Commercial Existing Facilities Program. Table 4 provides a list of potential EE upgrades that will help achieve this targeted reduction.

Table 4. Potential EE Upgrades to Microgrid Facilities

Provides an overview of the potential EE upgrades at the following facilities: HAHV Hospitals, Kingston High and Middle School, City Hall, Fire Department, and Department of Public Works.

Facility	Potential EE Upgrades	Existing CHGE EE Program (✓)
HAHV Hospital Broadway Campus	- Complete lighting upgrade to light-emitting diode (LED), including outpatient beds	✓
HAHV Hospital Mary Ave Campus	- Upgrade HVAC compressors - Replace parking lot lights with LED	✓ ✓
Kingston High/Middle School	- T12 fluorescent lighting and motion sensors in classrooms and hallways - Replace parking lot lights with LED - Building envelop improvements	✓ ✓ ✓
Kingston City Hall	- Indoor lighting and control upgrades - Replace parking lot lights with LED - Building envelop improvements	✓ ✓ ✓
Kingston Fire Department	- Indoor lighting and control upgrades - Building envelop improvements - Window upgrades	✓ ✓
Kingston Department of Public Works	- Indoor lighting and control upgrades - Building envelop improvements - Window upgrades - EMS and HVAC controls upgrade	✓ ✓

2.2.15 Cyber Security

To enhance the cyber security of the microgrid, the management and control system network data will be fully encrypted when stored or transmitted. In addition, the microgrid will be protected from cyber intrusion and disruption through network segmentation broken down by function and through network firewalls and continuous monitoring. The microgrid management and control system will be set up to provide authorized personnel access to the automation system via the control center while unauthorized persons are denied access. Security logs may also be activated and analyzed. As a rule, the operating system and firewall can be configured to ensure certain events, such as like failed login attempts, are recorded.

The logic controllers will be located at, or near, loads. This means the generation equipment will take the IT system to the edge of the Kingston network where it is potentially more vulnerable to hackers. A program called sticky media access control (MAC) will be used to prevent unauthorized access into the network. Every network-attached device has a unique media access control MAC interface. The sticky MAC program monitors the unique address of the device and its designated network port. If the device is disconnected, the sticky MAC program will disable the port and prevent an unauthorized device that may have malicious code from entering the IT system.

2.2.16 Use of Microgrid Logic Controllers

Microprocessor-based RTUs serving as microgrid logic controllers are described below in Section 2.7.1. The role of the RTU is to provide monitoring and control capabilities at or near the object being controlled.

2.2.17 Smart Grid Technologies

The microgrid will offer a distributed network architecture allowing smart grid technologies including distributed energy resources and associated hardware and software to connect to the grid via multiple protocols including DNP3, OPC, Modbus, IEC 61850, ICCP (IEC 60870-6), and more as required. For the microgrid system to enable fully automated control, smart grid technology will be required.

2.2.18 Smart Meters

Kingston has AMI meters installed in areas across its coverage area including within the microgrid footprint. These meters and other smart technologies will be able to connect via the industry standard protocols as required.

2.2.19 Distribution Automation

The automated solution outlined in this study for the City's microgrid includes electrical distribution-level and substation-level automatic isolation/switching, and automatic circuit breaker controls. In addition to automatic switching and controls, the microgrid's automated solution also provides monitoring and control of other utility elements and serves as the catalyst for CHGE's future automation expansion of their utility system for remote monitoring and control. After the installation of microgrid components including IT network integration, host servers, and application servers outlined herein, adding additional network-attached control elements is relatively easy once the automation system is already in place.

2.2.20 Energy Storage

At this time, battery storage technologies have not been identified as optimal energy solutions for Kingston due to their high cost. Despite this, the microgrid EMS will be equipped with the capability to fully utilize and optimize the storage resources—including charging and discharging cycles for peak demand shaving—in the event these technologies become more economic in the future.

2.2.21 Active Network Control System

All smart grid technology components on the microgrid will communicate bi-directionally with the MCS via MODBUS, OPC, DNP3 TCP/IP, or others protocols as required. Additionally, Ethernet switches will be required at all remote locations for the RTUs to connect to the City of Kingston's IT network. The IT network will operate over Kingston's existing fiber optics backbone.

2.2.22 Demand Response

The microgrid EMS has the capability to utilize demand response programs by maximizing renewable on-site generation and combining it with consumer demand by monitoring trends and predicting consumption patterns to change the price of electricity over time. While CHGE does have demand response programs the Kingston microgrid project does not fall within the program's targeted area.

Given the lack of opportunity on the utility level, the microgrid team will seek out opportunities to participate in one or more of NYISO's DR programs, including the Emergency DR Program and the Day Ahead DR Program.

2.2.23 Clean Power Sources Integration

Kingston's microgrid is envisioned to include a natural gas-fired CHP unit and one solar PV array as distributed energy resources.

2.2.24 Economic Dispatch

The City's microgrid footprint is expected to be fairly small, with only two to three generation resources. Economic dispatch will comprise of the pre-determined priority list, which will take into account generation availability, balancing run-times, and fuel costs. The microgrid EMS will utilize the optimum output of generation sources at the lowest cost in an approach that includes fuel cost, maintenance, and energy cost as part of security constrained optimal power flow (SCOPF).

2.2.25 Storage Optimization

Energy storage is not financially viable for Kingston. If, in the future, it becomes economically viable then it would include the intelligent controls necessary to work in unison with the microgrid controls.

2.2.26 PV Monitoring, Control, and Forecasting

The PV system inverters will be tied into the MCS and can be controlled to reduce output, either to match load or to better align with simultaneous generation from the diesel of gas units. The microgrid EMS will fully optimize the PV resources currently installed and proposed as well as provide recommendations for additional PV resources if applicable. The microgrid power management includes the ability to integrate high resolution solar forecasting, increasing the value by firming up the PV and smoothing out ramping.

2.2.27 Protection Coordination

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

2.2.28 Selling Energy and Ancillary Services

It is unclear whether the microgrid will be permitted to back-feed through the City of Kingston's main substation into the broader Central Hudson transmission systems. If allowed, the microgrid will sell excess solar energy back to CHGE. The proposed CHP will also potentially sell ancillary services, like providing frequency response, spinning/operation reserve to CHGE grid.

2.2.29 Data Logging Features

The microgrid EMS and SCADA systems include an historian database server to maintain data logs and trending.

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 who 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. 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 and will continue to engage with all parties to understand their specific needs and constraints. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.4.

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As discussed above, the proposed microgrid will leverage one existing back-up generator and two new DERs to power the Kingston microgrid. This section will discuss the benefits of the proposed resources and how they will meet the microgrid's demand in greater detail.

2.3.1 Existing Generation Assets

Kingston currently has limited generation resources, with only a single 100 kW natural gas-fired back-up generator at City Hall. Kingston also has two diesel back-up generators (2,000 kW at Broadway Hospital and 500 kW at St. Mary's Hospital) that cannot be used by the microgrid due to National Fire Protection Association (NFPA) safety code regulations for hospital back-up generation assets. The St. Mary's Avenue Hospital is in the final stages of approving the purchase of three new 500 kW back-up diesel generators to bring the facility in compliance with the latest emergency power requirements in hospital building codes.

When deciding whether or not an existing back-up generator shall be included in the microgrid, several factors determine the outcome. The first factor is generator capacity, the second is generator emergency power functionality (i.e., whether or not the generator is intended to serve emergency power mandated by code), and the third is the generator's location with respect to the loads it can serve from a power distribution standpoint. It is also important not to interfere with the emergency backup generators in place for life-safety set forth by NFPA codes and regulations. For this reason, the hospital's proposed diesel backup generators (three 500 kW generators) will not be included in the microgrid as generation assets. Furthermore, there could also be emissions implications depending on the diesel generators' use under the microgrid system, since most of these back-up units are installed as exempt emergency-only generators. Additionally, these units were not designed for continuous duty.

The existing 100 kW natural gas generator at City Hall will be included in the microgrid. Grid paralleling switchgear will be required for this unit to be included in the system. The generator is currently on a maintenance program with Generac.

2.3.2 Proposed Generation Assets

The two proposed generation assets include a 2 MW natural gas-fired continuous duty reciprocating generator and a 250 kW PV array system, shown in Table 5. The CHP facility will be located at Mary's Avenue Hospital and will provide the majority of its year-round thermal energy (for steam and hot water) requirements. The natural gas pipeline infrastructure required for the CHP unit is already present in the mechanical room at the hospital with sufficient volume and pressure.

The proposed 250 kW PV array system will be located just north of City Hall on the roof of a proposed parking deck. The new system will be easily incorporated into the microgrid system with inverters able to synchronize in both normal grid and islanded mode.

Table 5. Proposed Generation Assets

CHP reciprocating generator rating, fuel, and address, as well as solar PV rating and address.

Name	Technology	Rating (kW)	Fuel	Address
Natural Gas CHP Recip.	Recip. generator	2000 kW	Natural Gas	105 Mary's Ave
PV Array	Solar	250 kW	N/A	420 Broadway

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides Kingston with several additional energy resources. In grid-connected mode, the proposed PV array and natural gas CHP unit will operate in parallel with the main grid, exporting power and supporting supplementary power to meet peak demand when necessary. The team assumes the CHP facility will be allowed to interconnect to the CHG&E grid via a standard interconnect agreement as part of a Small Generation Interconnection Application. In islanded mode, the PV arrays and CHP will supply the base load with supplementary power from the existing natural gas generator available to meet peak loads. The CHP unit and natural gas generators are capable of covering the microgrid's demand during island mode, providing power in situations when the solar PV arrays may be offline due to weather or time of day. The proposed natural gas CHP will run in both modes to provide 2 MW of power and also supply approximately 2,800 million British Thermal Units (MMBTU) per month of steam for St. Mary's Avenue Hospital.

Generators will be protected from rain, snow, strong winds, or falling trees by housing units, such as sheds or container facilities.

Each identified DER, whether existing or proposed, will be capable of supplying reliable electricity by providing:

- Automatic load following capability – generation units and controls will be able to respond to load fluctuations within cycles, allowing the microgrid system to maintain system voltage and frequency.
- Black start capability – the diesel and CHP generators will have auxiliary power (batteries) required to start and establish island mode grid frequency.
- Generator controllers – the natural gas CHP can adjust generation output power according to frequency deviation signal to achieve load following.
- Conformance with New York State Interconnection Standards.[1]

2.4 Load Characterization (Sub Task 2.2)

Electricity and steam demand data from Kingston's load points is essential to correctly size new power generation and thermal distributed energy resources. The load characterizations in c 2.3.1 fully describe both the electrical and thermal loads served by the microgrid when operating in

[1] 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.

islanded and parallel modes based on metering data from CHG&E and thermal loads from the facilities. Included are descriptions of the sizing of the loads to be served by the microgrid along with redundancy opportunities to account for downtime, and detailed thermal and electric loads can be found in the Appendix.

2.4.1 Electrical Load

Refer to the Appendix for typical 24-hour load profiles for each of the six microgrid facilities during a typical month in 2014.

Electrical load characterization for the Kingston microgrid consisted of evaluating six primary loads. Kingston's proposed microgrid configuration will incorporate government, commercial, hospital and healthcare facilities, all within close proximity, within ½ square mile, to Central Hudson's Jansen Avenue Substation. Figure 2 provides an illustration of the proposed microgrid design and layout.

Figure 2. Kingston Equipment Layout

Microgrid equipment layout illustrating substations, distributed energy resources, distribution lines, load points, servers and workstations, network switches, and proposed distribution switches.

The 12 months of metering data for 2014 was provided by CHG&E and is summarized below in Table 6. The total peak load in Kingston in 2014 was 2.616 MW, and the monthly average was 1.759 MW.

Table 6. Kingston's 2014 Microgrid Load Points

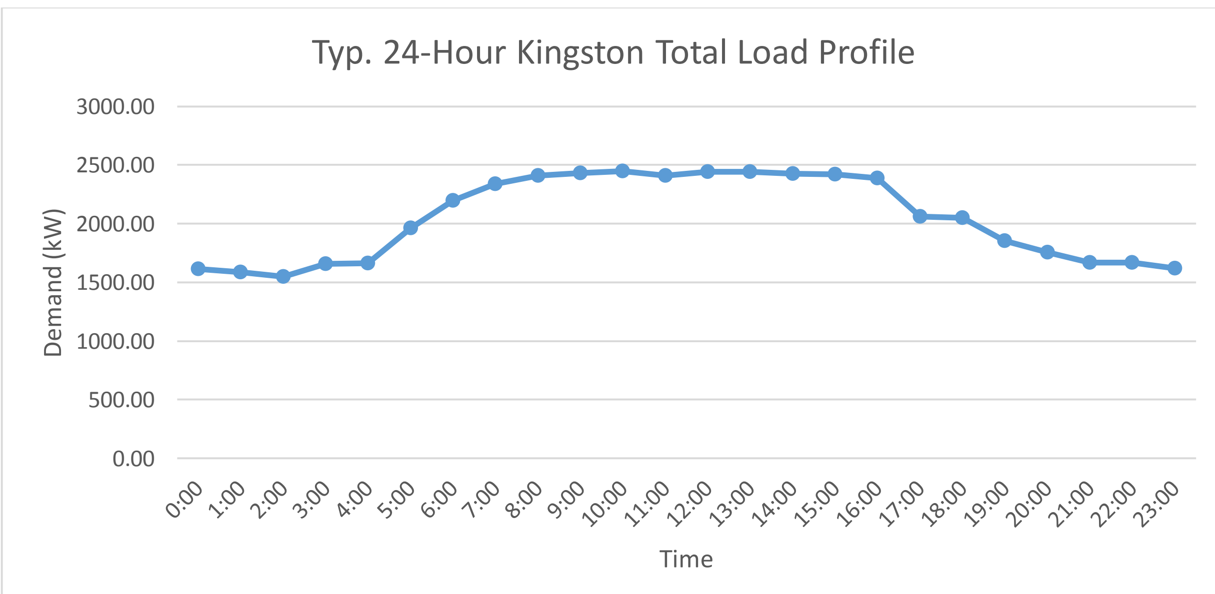
Microgrid electric demand in kW, electric consumption in kWh, and thermal consumption in MMBTU.

	Electric Demand (kW)		Electric Consumption (kWh)			Thermal Consumption (MMBTU) for Steam		
	2014 Peak	2014 Monthly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average
Microgrid Loads	2,616	1,759	15,411,776	1,284,315	298,678	51,000	4,250	988

Figure 3 provides the cumulative hourly load profile of all the loads.

Figure 3. Typical 24-Hour Cumulative Load Profile

Illustrates the typical 24-hour cumulative load profile in which the system peaks just before noon.



The proposed 2 MW CHP and 250 kW PV array will operate continuously in both parallel mode, supplying power to the grid, and islanded mode when there is a grid outage or when it makes economic sense to do so during peak cost times. The PV array will not always be able to supply its rated capacity, so the proposed CHP along with City Hall's existing natural gas generator will be available for islanded mode.

The grid paralleling and island mode one-line diagrams can be found in the Appendix.

The yearly average for the microgrid loads is 1,759 kW, and the system peak is at 2,616 kW; therefore, the combined 2.35 (2 + 0.250 + 0.1) MW of capacity is adequate to serve critical loads in the event of an outage. In the event the outage occurs at a time when the demand is greater than the generation of then loads will shed to meet available generation. For typical 24-hour load profiles for each of the six microgrid facilities, refer to the Appendix in this document. The team analyzed all 12 months for the load simulation with respect to the appropriate input constraints, such as type of building or function. CHG&E was unable to provide a 24-hour load profile for these facilities, which is why a simulation was used.

2.4.2 Thermal Consumption

Not all thermal loads can be served by the microgrid. As a result, thermal consumption for this feasibility study can be separated into two main categories: thermal consumption for facility steam usage, which will be served by the microgrid's CHP unit, and consumption for facility heating, which cannot be served by the microgrid so it will not be discussed in this study.

Natural gas and fuel oil have traditionally been used at Mary's Avenue Hospital to generate steam. In 2014, the hospital used 51,000 MMBTU of natural gas, the majority of which was used in the boilers to generate 70 pounds per square inch (psi) pressure steam which was distributed across the campus.

The proposed 2.0 MW CHP unit is capable of producing 2,800 MMBTU per month of 70 psi steam, enough to provide all the hospital's steam needs in the spring and summer months and roughly 48% of the steam required during winter heating season. The unit is sized to minimize steam waste and meet full steam demand in the spring and summer months, however there is no technical reason preventing an upsizing of the CHP unit.

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 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.

Details concerning the infrastructure and operations of the proposed microgrid in normal and emergency situations are described below.

2.5.1 Grid Connected Parallel Mode

In grid parallel (connected) mode the normal mode of operation, the microgrid will be able to operate the proposed 2 MW gas-fired CHP unit, proposed 250 kW solar PV array, and the single 100 kW existing natural gas generator in parallel with the grid. During grid parallel operation, the proposed and existing distributed energy resource assets, together with the main grid power if needed, will supply energy to the entire microgrid. Under normal conditions, only the natural gas generator packaged with a CHP system and PV array will operate in grid parallel mode, since they are built for continuous duty operation. The existing backup generator is not proposed to be used during normal grid connected mode.

When there is a grid outage, the parallel mode control scheme allows for a predetermined amount of active and reactive power to fulfill a pre-specified requirement, such as load shedding. In this event, the microgrid can turn on the other generation resources, including the existing backup generators if needed, and can implement any load shedding or peak shaving with the goal of reducing the power imports and peak demand charges from the CHG&E grid. When in the parallel mode, the microgrid can also export power to the main grid, if allowed by Central Hudson.

If electricity production within the microgrid exceeds the microgrid's demand for power, the microgrid will export power to the main grid pursuant to any regulations and agreements with CHG&E.

2.5.2 Islanded Mode

In islanded, or autonomous mode, the operating strategy is mainly focused on using an appropriate energy management and control scheme to enable the use of the microgrid's DER assets as described in Section 2.7.4 of this document. For a description of assets see Table 10. The system will manage the PV array, natural gas-fired CHP generator, and existing natural gas generator. The existing generator will only be used when necessary, for example, black start, or when the PV array is producing far below its capacity. Real-time response for generation assets is necessary to ensure the microgrid generation is equal to the demand. Refer to the simplified one-line diagram in the Appendix for a detailed device representation showing both existing and proposed generation assets and their utility interconnection points.

2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)

This section describes the electrical and thermal infrastructure of the proposed microgrid. The infrastructure resiliency, the point of coupling, and the proposed utility infrastructure investment are also fully discussed below. Information about electric and thermal loads can be found in the Appendix.

2.6.1 Electrical Infrastructure

Kingston's electricity infrastructure is owned and operated by CHG&E. Electricity enters the Kingston distribution system from the CHG&E-owned 14.4 kilovolt (kV) lines at the Jansen Avenue Substation and then steps down to 13.8 kV to feed the microgrid loads.

The existing 1004 line, described in Figure 4 below, is currently used as a redundant line from Jansen Avenue Substation that feeds the St. Mary's Hospital (the location of the proposed CHP facility). This is a dedicated line with no additional loads; therefore, it is also an ideal conductor for the 2 MW of CHP-generated electricity to flow back to the circuit breakers at Jansen thereby feeding the rest of the microgrid.

The equipment layout in Figure 2 illustrates the microgrid components; Table 7 to Table 9 below describe the microgrid components. More detailed descriptions of the components and their purpose can be found in Section 2.7.1.

Table 7. Kingston's Distributed Switches Description

Outlines all distributed switches with their descriptions, status as proposed, and attached line.

Name	Description	Proposed New/Upgrade	Attached Line
SW1	Load Transfer Switch	Upgrade	L1001, L1022
SW2	Automated Switch	Upgrade	L1002
SW3	Automated Switch	Upgrade	L1002
SW4	Inverter Internal Breaker	New	L1002
SW5	Generator Internal Breaker	New	L1002
SW6	Generator Internal Breaker	New	L1012
SW7	Load Transfer Switch	Upgrade	L1004, L1012
SW8	Automated Switch	New	L1003
SW9	Automated Switch	New	L1003
SW10	Transformer Circuit Breaker	Upgrade	Sub transmission Cable
SW11	Substation Feeder Circuit Breaker	Upgrade	L1001
SW12	Substation Feeder Circuit Breaker	Upgrade	L1002
SW13	Substation Feeder Circuit Breaker	Upgrade	L1004
SW14	Substation Feeder Circuit Breaker	Upgrade	L1003

Table 8. Kingston's Network Switch Description

Outlines all eight network switches with their descriptions, status as existing or proposed, and addresses.

Name	Description	Status	Address
NS1	10/100/1000 Mbps Ethernet Switch	Existing	420 Broadway
NS2	10/100/1000 Mbps Ethernet Switch	Existing	478 Hasbrouck Ave
NS3	10/100/1000 Mbps Ethernet Switch	Existing	467 Broadway
NS4	10/100/1000 Mbps Ethernet Switch	Existing	19 E O'Reilly St
NS5	10/100/1000 Mbps Ethernet Switch	Existing	17 Hoffman St
NS6	10/100/1000 Mbps Ethernet Switch	Existing	111 Jansen Ave
NS7	10/100/1000 Mbps Ethernet Switch	Existing	25 E O'Reilly St
NS8	10/100/1000 Mbps Ethernet Switch	Proposed	105 Mary's Ave

Table 9. Kingston's Server Description

Description of four servers and one workstation, their status as proposed, and the address on 420 Broadway.

Name	Description	Status	Address
Sever1	SCADA Primary	Proposed	420 Broadway
Sever2	SCADA Secondary	Proposed	420 Broadway
Sever3	Energy Management System (EMS) Primary	Proposed	420 Broadway
Sever4	EMS Secondary	Proposed	420 Broadway
Workstation	Operator/Engineer workstation	Proposed	420 Broadway

Kingston's microgrid will have automated switching equipment throughout the distribution grid, enabling different routings of power flows and isolation/bypass of certain areas as needed. Kingston's one-line proposed electrical layout is shown below in Figure 4.

Figure 4. Kingston One-Line Diagram

One-line diagram for Kingston illustrating interconnections and lay-out.

REDACTED PER NDA WITH CHG&E

2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The proposed interconnection points and investments in Kingston for microgrid operation are listed in Table 1010. The proposed Point of Common Coupling (PCC) between the main grid and the microgrid is located at the Jansen Avenue Substation. In order to serve multiple, non-contiguous loads using generators spread across the existing distribution grid, the microgrid will rely on automated isolation switches across the feeders to segment loads by enabling automatic grid segmentation, which is required for precise microgrid control and reliability. This segmentation is critical to provide voltage and frequency control within the millisecond response intervals required for maintaining a stable microgrid. See Section 2.7.1 for further details on components.

Table 10. List of Additional Components

List of all substation components at Jansen Avenue Substation as well as distribution devices.

Jansen Ave. Substation Device	Quantity	Purpose/Functionality
Microgrid Control System (MCS) 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 Transfer Switch (Siemens 7SC80 or equivalent)	2	Single Pole, Two Throw Switch which is remotely controlled to switch Microgrid loads/generation onto the proper distribution bus as well as isolate additional utility feeders (Jensen Ave and Mary's Ave).
Transformer High Side CB (7SJ85 or 7UT85 or equivalent)	1	Disconnects utility Jansen feed from Jansen Substation to initiate Microgrid Mode.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay or equivalent)	3	Upgraded breakers/switches at 2 distribution load feeders. Isolate downstream loads from the Microgrid (High School and Fire Station).
Automated PME (Siemens 7SJ85 multi breaker control relay or equivalent)	2	Pad Mount Enclosure to be updated to be automated with remote control relay capable of isolating downstream loads from the Microgrid and separating Microgrid loads onto different Jansen feeders (City Hall and Broadway).
Jansen Substation Multi Feeder Breaker Control (Siemens 7SC80 with 3 modules for additional breaker control or equivalent)	1	Four feeders at Jansen Substation controlled by one Microprocessor relay. Includes necessary modules to control and protect all 4 feeders.
Generation Controls (OEM CAT, Cummins, etc.) (Load Sharing Woodward or equivalent)	2	Serves as the primary resource for coordinating the paralleling load matching and load sharing of spinning generation.
PV Inverter Controller (OEM Fronius or equivalent)	1	Controls PV output and sends data to SCADA and EMS for forecasting.

Most microgrid devices will require a reliable source of DC power. At each device, or grouping of devices in a similar location, there will be a primary and back-up power supply source. During normal operation, 120 volt alternating current (VAC) power source will be sent through an alternating current (AC)/DC converter to power the microgrid devices and maintain the charge of the DC back-up battery. When normal AC voltage is unavailable, likely due to an issue outside or elsewhere in Kingston's distribution grid, all microgrid devices will be capable of operating on DC power from the battery bank for at least one week. The power supplies shall not exceed 60% power utilization from the device current draw.

2.6.3 Basic Protection Mechanism within the Microgrid Boundary

The power system protection structure senses grid variables such as voltage, current, and frequency, and takes corresponding actions, such as de-energizing a circuit line. Some protection schemes are based on the assumption that power flows in one direction. However, bidirectional power flow during island mode will introduce difficulties for protection coordination because it violates the unidirectional power flow assumption of the existing protection scheme. At a later design stage, the microgrid designer team will perform protection studies accounting for possible bidirectional power flows and very low currents, which can occur when the network operates in island mode. Section 2.8.3 provides further details about security and network resiliency.

The current proposed design includes controls and the necessary hardware and protection scheme to prevent back-feeding power into the CHG&E system, if required by CHG&E. However, it is assumed the CHP will be allowed to sell power into the CHG&E grid via a standard Small Generator Interconnection Agreement.

2.6.4 Thermal Infrastructure

The proposed CHP unit requires access to the natural gas pipeline present in the mechanical room at the hospital with sufficient volume and pressure.

2.7 Microgrid and Building Control Characterization (Sub Task 2.5)

This section provides a more detailed description of the microgrid's different modes of operation. While operating in grid parallel mode, the microgrid will synchronize frequency and phase, and it will sell electricity to CHG&E according to CHG&E's buy-back and net metering guidelines. The microgrid will switch to island mode in emergency outage situations and during economic intentional islanding. In emergency situations, the microgrid will provide power to key facilities through its black start capabilities. The microgrid will also automatically re-synchronize to the CHG&E grid when power returns after an emergency situation.

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

2.7.1 Microgrid Supporting Computer Hardware, Software and Control Components

The proposed system uses a SOA software platform that functions as the messaging and integration platform for monitoring and control of almost any power device or control system from any major vendor. It solves the problem of communication networkability and interoperability between competing vendor systems and allows them to share data. The computer hardware and software required for a fully automated operational microgrid design are as follows:

- SOA software platform – This software functions as the messaging and integration platform for the monitoring and control of virtually any power device or control system from any major vendor.
- Two fully Redundant Array of Independent Disks (RAID) 5 servers (one primary, one backup) for SCADA – SCADA is the human-machine interface component that enables the operator(s) to monitor and control the microgrid in real time from a central location.
- Two fully RAID 5 servers (one primary, one backup) for EMS – The EMS works with the SCADA system to optimize microgrid elements, such as critical loads to be supplied, the use of PV including high resolution solar forecasting, and energy storage charging and discharging. The system combines information on power quality, utilization, and capacity in real time to allow the community and control algorithms to optimally balance the demand and supply.
- One or more Historian Database server(s) – The Historian Database collects data from various devices on the network and logs information to its database.
- One or more applications server(s) – Application servers are very broad in use, and, depending on the preference of the software and hardware vendors, 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 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 to control the microgrid from the SCADA control room or remotely provided they have the proper access rights and permissions to do so.
- Remote Terminal Units (RTUs) – These are microprocessor-based logic controllers in the field at or near loads that are programmed to act on predetermined set points or can be manually overridden by an operator via SCADA. The SCADA host servers continuously poll these logic controllers for values that are processed by the RTUs connected to control elements, such as the utility breakers, switches, and other objects either by discrete (open/close) or analog signals depending on the process.

Layer 3 Gigabit Ethernet switches – These connect the host servers with the logic controllers and other network-attached equipment over the City of Kingston's local area network (LAN).

2.7.2 Grid Parallel Mode Control

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

The proposed CHP unit is capable of providing ancillary service to the NYISO grid to enhance the reliability of the system and will be included in scheduling, system control, and dispatch in the energy market operations to the extent that it does not impact microgrid operations. It can also provide reactive power and frequency response service. These services contribute to the stability of system frequency while improving the generation flexibility to follow uncertain demand.

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

2.7.3 Energy Management in Grid Parallel Mode

The proposed microgrid is designed to operate as an integrated system of software and hardware to ensure the highest levels of reliability and performance in all operating modes. This integrated system will filter information through the microgrid executive dashboard, which will include information on the current operating strategy as well as performance metrics for SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), and CAIDI (Customer Average Interruption Duration Index), all adjusted to reflect the high sampling frequency of the system. In addition, the dashboard metrics include power interruptions (defined as 50% variance of predicted voltage to measured voltage for 10 minutes or longer), voltage violation (defined as variance of actual voltage to predicted voltage for 5 minutes), and frequency violations (defined as variation to predicted frequency of more than 0.2 Hz for more than 10 minutes). All of these metrics include daily, weekly, and monthly rolling totals.

When the Kingston microgrid is connected to the CHG&E grid, the focus of operating the microgrid is to maximize the deployment of renewable generation and to manage local generation and curtailable loads to offset electrical demand charges.

2.7.4 Islanded Mode Control

The microgrid will switch to intentional islanding when there is a larger grid outage that would leave the whole City of Kingston without power. The intentional islanding most likely will occur to meet a demand response event or in the event of notice from Kingston about an imminent grid outage.

During the intentional islanding operation, the microgrid will receive the operator's command to prepare to enter island mode of operation. The microgrid will then automatically start and parallel the generation assets. Once the available power sources are synchronized with the grid and each other, the system is considered ready to implement islanded operation and will begin opening the incoming utility line breakers. Under intentional islanding, the transition into the islanding operation is seamless (it does not require black start). Once in islanded mode, the microgrid controls must maintain the voltage and frequency between acceptable limits and perform load following.

In this mode, all interconnecting lines outside of the City will be opened along with utility breakers at the substation level to fully isolate the area controlled by the microgrid system. All available generation will be connected and the supported load will be incorporated in the distribution network. At each step of the process for entering islanded mode, contingencies related to non-operational or non-responsive equipment will be considered, with appropriate actions specified.

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

2.7.5 Energy Management in Islanded Mode

Once in islanded mode, the EMS will perform a series of operational tests to ensure the microgrid is operating as expected in a stable and reliable condition. Power flow, short circuit, voltage stability, and power system optimization studies will be performed using an N+1 (Component [N] plus at least one independent backup component) contingency strategy to determine if 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 the shedding of low-priority loads may occur in order to maintain the N+1 power assurance.

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

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

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

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

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

The results of the analysis indicated that storage was not needed to resolve system reliability issues due to the flexibility in ramp rates of the other generators in the microgrid. The high cost of battery storage and absence of time-of-use energy rates challenged the economics of using storage to shift generation or extend island mode operation.

2.7.6 Black Start

It is envisioned that the CHP unit and the existing natural gas generator will be equipped with black start capabilities. When the grid power goes out for Kingston, the microgrid controller initiates island mode by orchestrating the predefined black start sequence. The microgrid then enters unintentional islanding mode. For this mode of operation, the generators must have a DC auxiliary support system with enough power to start the generator multiple times in case it fails to start the first time.

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

1. The PCC breaker opens (anti-islanding protection).
2. The microgrid controller waits a preset amount of time, approximately 30 seconds (in case CHG&E power comes back).
3. The microgrid controller EMS calculates the expected load.
4. The microgrid control system then automatically starts to synchronize generation by operating the breakers at the generation switchgear and the distribution bus at the substation level. After this, the system begins closing main switches across the distribution network to safely and sequentially configure the microgrid distribution system based on load priority order and available generation.

The EMS will manage contingencies in case the breakers do not respond to trip commands and the Kingston grid does not properly isolate from CHG&E utility power. Contingency algorithms will handle the case if one or more generators do not start as expected during a utility outage. If possible, the microgrid will still be formed but with only critical loads satisfied.

The EMS will allow operators to designate certain generators as unavailable for participation in the microgrid, for example, if they require maintenance, in order to ensure the generator dispatch and load shedding algorithms can accommodate a reduced available capacity.

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

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

2.7.7 Resynchronization with CHG&E Power

When CHG&E power comes back, a safe and orderly transition to obtaining power from the grid is coordinated by the microgrid controller. The system first waits a predefined configurable time period and then commences resynchronization to CHG&E power supply.

While in emergency island mode, the system will constantly monitor the status of the utility feed at the Jansen Avenue Substation and determine when it is restored. When power is restored, the control system will synchronize and parallel the microgrid generation with the utility service through the utility circuit breakers at the Jansen Avenue Substation. The PV system will be disconnected. Before the microgrid system starts paralleling with the utility, it will balance the generation and load to not exceed both minimum or maximum export limits and time durations set forth in the utility interconnection agreement. Once the Jansen Avenue Substation is restored, generation breakers for the natural gas generator will trip automatically. The Jansen Avenue Substation will be connected in re-synchronized mode. Consequently, the PV will be synchronized back to the grid automatically by inverters.

Please refer to the Kingston 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 Kingston has the bandwidth capacity to support the proposed microgrid. The presence of this network is conducive to the addition of an automated microgrid. The team has received ample support from the Network Administrator in Kingston regarding the network switch locations and knowledge about integration to the existing network. The microgrid hardware will seamlessly integrate with the IT system using a minimal amount of additional hardware (i.e., the network switches, servers, and computers required to manage a microgrid).

2.8.1 Existing IT & Telecommunications Infrastructure

Kingston already takes advantage of its existing fiber optic backbone ring and existing Ethernet switches for reliable internet and LAN activities, making convergence quite feasible.

2.8.2 IT Infrastructure and Microgrid Integration

Though the IT infrastructure is reliable and available for the expansion of the proposed automated microgrid system, additional microgrid hardware and software is needed. Section 2.7.1 outlines the required hardware and software. Seven main components are 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 optic or Ethernet cables), and the SOA software that functions as the messaging and integration platform for the monitoring and control of virtually any power device or control system from any major vendor. All these critical parts work together and serve specific roles.

2.8.3 Network Resiliency

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

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

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

Because the logical controllers will be located at or near loads, the distributed equipment will take the IT system to the "edge" of the Kingston network, where it is potentially more vulnerable to hackers. Sticky MAC is an inexpensive and practical program that can help prevent unauthorized access and protect the Kingston network. Every network attached device has a media access control MAC interface that is unique to it and will never change. The Sticky MAC program is configured to monitor the unique address of the device and its designated network port. If the device disconnects, the program disables the port and thus prevents an unauthorized device that may have malicious code from entering the IT system.

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

2.9 Microgrid Capability and Technical Design and Characterization Conclusions

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

In conclusion, at this stage in the assessment the project appears technically feasible. However, two significant items remain in order for Kingston's microgrid to become a reality. The utility (CHG&E) must support the proposed interconnection and electrical distribution, and the Hospital (Mary's Avenue) must approve the CHP be located at their facility.

CHG&E has indicated a potential willingness to support the microgrid; however, they would need to approve the automated distribution switches on the feeder lines, the automated circuit breakers at the substation, and allow the designer to perform a protection coordination settings test and power flow study in the next phase of the study.

The Hospital has also expressed interest in housing a CHP facility. As the largest thermal off-taker of the CHP, the system is most technically and financially viable if the hospital houses the unit at their facility. Operators of the microgrid would also require regular access to the CHP for routine maintenance.

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

3.1 Commercial Viability – Customers (Sub Task 3.1)

The Kingston microgrid will include a mix of government, public service, and healthcare facilities. Ownership and operation will follow a hybrid model wherein CHG&E or a third party operator will own and operate the microgrid infrastructure, controls and hardware while private investors own the distributed energy resource assets. The project will affect several groups of stakeholders in the Kingston community not physically connected to the microgrid—the benefits and challenges to these stakeholders are discussed further in this section.

3.1.1 Microgrid Customers

Customers of the Kingston microgrid can be identified by two groups: critical and important. These customers (listed in Table 11 below) will all maintain electric service in case of an intentional islanding of the microgrid. When the larger CHG&E grid experiences an outage or a severe disturbance, a command from the microgrid operator will catalyze an automated sequence that will seamlessly disconnect the microgrid's DERs and loads from the larger grid. The Kingston microgrid will then be in island mode, and each of the facilities included in the microgrid design will benefit by remaining online and available in emergency situations. By providing critical services to the community, these facilities extend their immediate customer counts beyond direct employees and residents. The larger population served by these facilities includes stakeholders described in Section 3.1.2.

Table 11. Microgrid Customers

Table provides a list of facilities that will be connected to the microgrid, their addresses, classifications, and the availability and type of backup generation.

Property	Address	Classification	Critical Service	Back-up Generation	Normal vs Island Mode
City of Kingston (City Hall)	15 W. State St	Public	Yes	Yes (Natural Gas)	Both
Kingston Fire Department	32 E. O'Reilly St	Public	Yes	No	Both
Department of Public Works	25 E. O'Reilly St	Public	Yes	No	Both
Kingston School District (High School)	403 Broadway	School	No	No	Both
Broadway Campus Hospital	396 Broadway	Health	Yes	Yes* (Diesel)	Both
Health Alliance: Benedictine Hospital	105 Mary's Ave	Private	No	Yes* (Diesel)	Both
*Generators will not be connected to the microgrid					

3.1.2 Benefits and Costs to Other Stakeholders

Stakeholders in the Kingston microgrid extend beyond the direct purchasers of services and the utility. Stakeholder groups also include the existing generation asset owners, residents of the areas surrounding Kingston, and CHG&E customers not captured by the six facilities included in the microgrid.

Distributed energy resource asset owners and the system operator will receive cash flows from the microgrid project through energy sales and microgrid tariffs, while Kingston and surrounding community will benefit from a more resilient energy supply and the availability of services during an outage. Although Kingston is not considered a critical congestion point on the larger NYISO system, peak load support from proposed generation assets could reduce congestion costs to NYISO, the system operator and/or CHG&E, and electricity customers. During a power outage, the microgrid will supply power to critical and important facilities that are equally accessible and available to residents both within and outside Kingston. These facilities provide shelter, healthcare, law enforcement, and fire control/emergency services in the event of a grid outage. Because the microgrid is designed to operate in island mode indefinitely, as long as the natural gas supply to the CHP facility is uninterrupted, sufficiently long-term services can be provided in case of an outage. The microgrid may be able to participate in demand response programs through economic islanding (see Section 3.2.5). However, the policies on demand response program participation do not address the loss of associated generation from the larger electric grid. We expect policies to change in the near future to exclude microgrid DR participation when loads and generation are both isolated.

Stakeholders will face relatively few negative effects and challenges. The primary external cost imposed will be for private investors and CHG&E to purchase and install the new generation assets, if chosen, and necessary components of the microgrid. The community at-large will bear no cost for the installation, operation, and maintenance of the new generation or microgrid assets except to the extent that the City may have an ownership in the new assets.

3.1.3 Purchasing Relationship

The microgrid will be owned by a consortium of private investors and will be operated by CHG&E. The direct customers will be the listed critical and important facilities from Section 2. The utility-customer relationship will largely remain the same as it is currently because electricity will still flow through the same system and rates will be captured though the same billing mechanism. The owners of the CHP unit will sell electricity to CHG&E under a buy back agreement or unique procurement model settled with CHG&E. The utility wishes to avoid power purchase agreements (PPAs) because they may cause a reduction in credit ratings and thus result in a higher cost of capital. Solar PV generated electricity will enter the distribution system under a net metering arrangement.

For the CHP unit, the relevant facility will have a two-way electricity provision relationship with CHG&E. The facility will purchase services from the Kingston grid as they do at present, and CHG&E will purchase electricity back from the SPV. The solar generated electricity sold back to CHG&E will be total generation less on-site consumption. The CHG&E purchased volumes will depend on electricity output from the generators as dictated by the microgrid controllers, system demand, and agreements between the generation owners and CHG&E. Benedictine Hospital will directly off-take the steam from the CHP unit in a transaction between the hospital and the owner(s) of the CHP unit. It will not require the direct involvement of CHG&E. Depending on generator performance and the City's demand for electricity, the microgrid's generation assets may also be able to sell ancillary services on the NYISO frequency capacity market. See Section 3.2.1 for a detailed description of the business model.

Generation asset owners stand to benefit directly from the sale of electricity, while CHG&E will receive revenue from T&D, microgrid tariffs, the difference in purchased electricity price to sale price, and tariffs associated with islanded operation. CHG&E does not have any growth-related capital investments planned in the Kingston area, meaning it will not immediately benefit from deferred capital investments. The microgrid will have the ability to provide ancillary services to CHG&E and NYISO, which would make the microgrid more profitable and stabilize NYISO's electricity network. However, most NYISO ancillary service programs require a capacity commitment of at least 1 MW. The microgrid's generation assets, which have a combined nameplate capacity of 2.25 MW, will rarely be capable of committing at least 1 MW of generation to an ancillary service market while maintaining power to microgrid facilities. The programs available below 1 MW of dedicated capacity are limited to spinning and non-spinning reserves and have payments that are well below the amount at which electricity can be sold to CHG&E.

3.1.4 Solicitation and Registration

The City and utility will work with the facilities listed in Table 2 to encourage their participation in the microgrid project. This outreach will include informal discussions and, ultimately, signed agreements of participation in the microgrid and tariff or fee structure determined by the NYPSC. Formal registration with the microgrid will be managed by programming the logic controllers to include or exclude the facility from islanded services based on their agreement with the utility.

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

3.1.5 Energy Commodities

The microgrid's generation assets will produce electricity and thermal energy year round. The CHP and solar array will produce electricity while exhaust heat from the CHP's electricity turbine will be converted into steam. Steam greatly enhances the efficiency of the CHP unit and improves the overall commercial feasibility of the microgrid project. Benedictine Hospital will purchase 100% of produced steam and CHP-produced steam will provide for approximately 60% of the hospital's thermal energy demand, which is currently satisfied by a natural gas-fired boiler. There is also potential for participation in ancillary service and demand response programs, such as frequency regulation or NYISO's Special Case Resources (SCR); however, participation is subject to generator capacity that is unlikely to be available.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to direct participants, non-customer stakeholders, CHG&E, and the State of New York. The 250 kW solar array and 2 MW natural gas-fired CHP plant will provide cleaner sources of peak energy supply and stable energy resources to critical facilities in emergency situations. Electricity customers will benefit from a more resilient power supply that is protected against grid outages and loss, while Benedictine Hospital will reduce usage and wear on its existing steam generation assets and defer new boiler investments. Two of the three hospital boilers, representing 87% of their steam capacity and $540,000[2] of replacement cost, are beyond their intended life, and the CHP steam will negate the need for the full cost replacement. CHG&E will also receive stable fees from the T&D of microgrid electricity and management fees, and the generation asset owners will be able to monetize the power production through sales to the utility. The benefits, costs, and total value of the microgrid project are discussed in detail below.

3.2.1 Business Model

The City of Kingston is served by Central Hudson Gas and Electric Corporation and is well positioned to adapt a hybrid microgrid ownership model. Separate Special Purpose Vehicles will own the different components of the Kingston microgrid: 1) distributed energy resource assets and 2) distribution infrastructure and microgrid components/control infrastructure. Private or municipal investors will own majority stakes in distributed energy resource assets. Outside investment will own the majority stake in the proposed CHP unit through a mixture of debt and equity. The City of Kingston will presumably own the majority stake in the proposed solar array, as the array will be located on the roof of City Hall (420 Broadway Ave). The City may even provide 100% of the solar array's capital outlay because it can raise capital with low interest bonds. Creditors and investors will be reimbursed from the revenue streams produced by the generation assets (described in Section 3.5.1). The utility will retain ownership of the local distribution infrastructure and will purchase a majority stake in the microgrid components/control infrastructure. If necessary, the utility will finance this project with a mixture of outside debt and equity. The Project Team believes this hybrid model provides the greatest benefits and flexibility to both the utility and the customer base within the City, while allowing the utility to maintain full control of their lines and distribution infrastructure. Table 12 address the strengths, weaknesses, opportunities, and threats surrounding the Kingston microgrid project.

[2] Communications with Joe Puetz at the Health Alliance in Kingston.

Table 12. Kingston Microgrid SWOT

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

Strengths	Weaknesses
• Disaggregates cost burden so no single actor is responsible for the full project cost • Allows for the use of existing transmission and distribution (T&D) infrastructure, thereby reducing the potential cost burden of constructing duplicative assets • Ability to tie AMI infrastructure into existing utility metering mechanisms • Aligns the interests of many actors in seeing the microgrid succeed • Leaves load aggregation and following in the hands of the utility • Solar array can participate in a Net Metering program. Its electricity is therefore valued at the retail rather than the wholesale rate	• Requires collaboration amongst multiple actors, each with different motivations for participation • Potential tariff structures often favor the utility over the generator, excluding net metering arrangements • Utilities are only allowed to own generation assets under exceptional circumstances; thus, the project will need to separate ownership of generation assets from owners of microgrid components. Though an organizational complication, this separation is an aim of REV • Long-term purchase agreements between DER owners and utility are required to ensure value for DER owners, but PPAs may negatively impact utility/aggregator credit ratings
Opportunities	**Threats**
• Replicable model as most communities are served by Investor Owned Utilities (IOUs) • Experiment with new methods of rate calculation and/or new business models, with the opportunity to revolutionize the role of utilities in New York State electricity generation, distribution, and consumption • Demonstrate the feasibility of reducing load on the larger grid; this data could be used to target critical congestion points on the larger grid for future projects • Expand Kingston microgrid to include existing assets, including a 6 MW solar PV array	• Changes in regulatory requirements could impact the proposed business model and stakeholder goals • Low wholesale price of electricity in Hudson Valley area could threaten partnership between generator owners and CHG&E; however, future electricity prices are projected to increase • If natural gas prices continue to fall, asset owners may need to reduce steam price accordingly to compete. Steam price has a heavy influence on net project value. • Critical incentives (such as the NYSERDA CHP Performance Program and Federal Business Investment Tax Credit) may expire at the end of 2016; losing these incentives may have a negative impact on the microgrid's commercial viability

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

- **Financial** – Generation asset investors will seek long-term PPAs with CHG&E to guarantee steady future revenue streams, but CHG&E opposes PPAs because they may drive a reduction in credit ratings. Instead, CHG&E may wish to develop a custom procurement model based on fuel source, generator location, and generator size. As long as this custom procurement agreement reliably guarantees fair compensation for generator operation for the lifespan of the generators, investors need be content with flexible compensation rates. Additionally, as new sources of natural gas are tapped and national distribution infrastructure expands, the price of natural gas may fall. This may force CHP owners to reduce the price of steam in order to compete with the hospital's existing boilers; however, this should be offset by the corresponding decrease in CHP fuel costs.
- **Organizational Burden** – The hybrid model requires collaboration among groups of stakeholders that have different motivations for participation in the microgrid project. These goals will be contrary at times, but they can be successfully coordinated by delineating specific roles and responsibilities in the initial contract and seeking arbitration when necessary. Moreover, operational organizational conflict will be reduced to a minimum as each entity agrees to an operating framework to be executed by CHG&E.
- **Regulatory** – Utilities in New York State currently cannot own generation assets unless they can demonstrate why it provides value to their customers. The State of New York wishes to avoid monopolies that could raise electricity prices without a corresponding improvement of service. However, this regulatory landscape may change as the state transitions from large generation assets and an unwieldy macrogrid to distributed energy resource assets connected to smart microgrids. If the regulatory landscape shifts, utilities may wish to own their own generation assets in the future. This could drive CHG&E to renegotiate the terms of the hybrid model. While the regulatory landscape may pose a threat to the hybrid model, the hybrid model itself may provide evidence that privately owned generation assets can successfully sell electricity over a utility-owned power distribution platform. By providing this evidence, the hybrid model could ensure continued preference for special purpose vehicles over vertically integrated generation and distribution.
- **Incentive Expiration** – The NYSERDA CHP Performance Program and Federal Business Incentive Tax Credit currently provide $2.1 million to offset investment costs over the first three years of microgrid operation. This represents approximately 45% of total microgrid investment costs and has a comparatively high value because it is received early in the project lifecycle. Expiration of these incentives may have a significant negative effect on the microgrid's commercial viability.

3.2.2 New Technology

Kingston will need to install AMI meters on the grid connected facilities. While the microgrid feeders will not serve any non-customer loads during normal operation or island operation, AMI meters will allow remote disconnect of loads in an emergency outage situation if needed to maintain redundant generation. Though NYS law currently prohibits remote disconnection in cases of non-payment, NYSERDA has included remote disconnect capabilities as a potentially useful component of the microgrid, implying the legality of such a system. The SCADA and SOA architecture is not new, but its integration with the smart controls and switches in the manner proposed is not widespread.

3.2.3 Replicability and Scalability

The Kingston 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 existing AMI meter infrastructure, and the attendant remote disconnect capability that will soon be installed, is the only physical component of the microgrid that is unique. The remaining components, including the proposed generation infrastructure, switches, SCADA, and EMS, are widely available and can be installed in any given location. All interconnections with the CHG&E grid are industry standard.

Further, an appropriately sized and located steam off-taker is required to replicate this project, since CHP is not a viable generation solution without a customer for the thermal resources.

Organizational Replicability. The hybrid model may encounter difficulties due to rules governing ownership of distributed energy resource assets and other system components, but these rules will be largely the same across different IOUs. As long as the utility does not have a majority ownership in any of the generation assets (and CHG&E will not in Kingston), this does not present a replicability problem. The specific arrangement of a utility-led SPV owning the microgrid and one or more ownership groups owning the generation assets is both replicable and scalable, limited by the utility's desire to participate and investor desire to construct new generation units. This model may promote innovations in rate calculations and change the basket of services IOUs are expected to provide, and its replicability expands the potential market for innovations to include the greater part of New York State. As such, this project presents a valuable opportunity for NYSERDA to examine the changing role of the IOU in energy generation and distribution.

Scalability. The microgrid is scalable to the limits of the AMI radio controllers and the ability to physically partition the microgrid from the macrogrid. Scalability is also limited by the existing generation assets; they will already produce at nearly full capacity, so building new generation assets will be necessary to expand the microgrid in the future. As discussed above, CHP generators require large thermal demand to be cost-effective. Thus the presence or absence of thermal energy demand in Kingston may limit the types of generation assets that can be constructed in the future. However, Benedictine Hospital will have an unmet steam demand upon completion of the project. There are no other technical components that should restrain this microgrid concept from serving a larger population.

3.2.4 Benefits, Costs, and Value

The microgrid will provide widely distributed benefits, both direct and indirect, to a multitude of stakeholders. The utility will see stabilized prices and improved grid performance, generation owners will receive steady cash flows from energy sales, customers will see a more resilient grid system, and the community will reap the positive effects of living in and around the microgrid. These costs and benefits are described in Tables 13 through 19. Moreover, except for marginally increased electricity costs during island mode and potential microgrid participation fees, the customers and Kingston community will not bear any of the project's costs. Economic projections indicate that rates will not need to increase to finance the costs of construction and operation, and new revenues from T&D and the microgrid tariff, will be sufficient to cover associated costs.[3] However, the CHP owners may need to lower steam prices below optimal levels to compete with existing natural gas boilers. This proposal involves a wide group of stakeholders—from local, non-customer residents to the State of New York—and provides an excellent value proposition to all involved parties.

Table 13. Benefits, Costs, and Value Proposition to CHG&E

Table describes benefits, costs, and overall value to CHG&E and the owners of the DERs.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Central Hudson	- The utility will realize revenue T&D charges and other microgrid tariffs that support the construction and operation of the microgrid infrastructure, controls, and hardware - CHG&E will avoid total loss of revenues in emergency outage situations - Local generation reduces the power that must be imported from the larger grid; this may defer future transmission & distribution investments	- CHG&E, in conjunction with investors, will provide capital outlay to construct and operate the microgrid controllers and system components, such as switches, cutouts, and radio control of AMIs - CHG&E may also be responsible for buy-back tariffs to generation assets that do not qualify for net metering. Costs would be recouped through sales to existing CHG&E customers	- The utility can serve as a market connector without incurring the costs attendant with constructing and operating distributed energy resource assets - Improved grid resiliency by integrating local generation assets with local distribution networks

[3] This depends on the price CHG&E will pay for electricity from the CHP unit—at the average wholesale rate, the project will have a positive NPV but will rely heavily on incentive programs and depreciation benefits. Increasing the sales price by 10-20% would drastically improve the project's commercial viability.

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

Table shows the benefits, costs, and overall value to private investors.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Distributed Energy Resource Owners	- Generation asset owners/investors will receive revenues from solar array net metering, CHP electricity sales, and CHP thermal energy sales - NYSERDA CHP Performance Program will provide $1.76MM of incentives over the project's first three years - If a non-municipal entity owns the solar array they will for the Federal Investment Tax Credit (ITC) (worth 30% of Capital investment cost) - CHP owners qualify for the Federal ITC (worth 10% of capital investment cost) - By strategically increasing and decreasing output throughout the year, generation asset owners may be able to participate in lucrative demand response programs	- CHP and solar array will require investment costs of $3.2 M and ~$440,000, respectively, with a total capital cost of $5.6 M including microgrid components - CHP will incur scheduled and variable O&M costs as well as the ongoing fuel costs that are necessary for operation - Solar array will require scheduled yearly maintenance - Reserving capacity for demand response programs would negatively impact the ability to regularly sell electricity to CHG&E and sell the full capacity of thermal resources	- Baseline operation of CHP and solar array provide positive cash streams for many years. These cash flows may be supplemented by strategic participation in demand response programs and/or ancillary services markets - Tax credits and incentives will recover up to 55% of investment cost for CHP and 30% of investment cost for solar array - Inclusion in the microgrid should provide generation asset owners with a reliable energy market

Table 15. Benefits, Costs, and Value Proposition to City of Kingston

Table shows the benefits, costs, and overall value to the City of Kingston.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
City of Kingston	- Facilities will receive backup power from proposed generation assets and optimize use of existing backup generation—this will reduce the need for investments in further backup generation capabilities - The microgrid will provide a resilient and redundant energy supply to critical services - Meet NY REV goals - Further integration as a smart community - Reduced emissions during peak demand events	- When the microgrid enters island mode due to a larger grid outage, microgrid 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 - As a customer Kingston will be responsible for the microgrid tariff of 1%	- Critical and important services will keep the lights on during outages, allowing the City of Kingston to be a center of relief for the City and surrounding areas - The microgrid project will serve as a catalyst for customers becoming more engaged in energy service opportunities and will inspire 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 and heat with solar PV arrays and a natural gas-fired CHP plant will offset high-emission peaking assets during peak demand events

Table 16. Benefits, Costs, and Value Proposition to Industrial Facilities

Table shows the benefits, costs, and overall value to industrial facilities.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Industry (future)	- Resilient and redundant energy supply to operations—the EPA estimates that a power outage costs industrial customers ~$50.00/kWh - Future expansion of the microgrid could include integration of industrial facilities - Future microgrid assets could provide both electricity and thermal energy to industrial customers	- As there are no industrial facilities currently included in the microgrid design, industry in Kingston will not bear any costs	- Replacing fuel oil with steam heat could provide significant savings to future industrial customers - Decreased costs of production (from lower energy bill) may encourage other capital investments and expansion of business - PPA based steam purchase model provides for stable steam prices and better cash flow forecasting - Potential for partnerships and a local market for excess generation will encourage industrial stakeholders to build large-scale generation assets

Table 17. Benefits, Costs, and Value Proposition to Other Commercial Entities

Table shows the benefits, costs, and overall value to connected hospitals.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Healthcare	- Benedictine Hospital will reduce emissions by purchasing cogenerated steam produced by the CHP - Resilient and redundant energy supply to critical services (EPA estimates that a power outage costs commercial entities at least $40.00/kWh) - Creation of a local market for excess energy production	- Microgrid tariff of 1% - Will experience slightly higher prices in island mode. However, given that the microgrid will only enter island mode during widespread outages, this cost should be marginal - Benedictine will bear the cost of steam purchases from the microgrid; however, it will be a one-to-one offset from current natural gas fired steam boilers	- Commercial entities will benefit from lower electricity costs and reliable power supply (allowing them to maintain operations and sales during power outages and periods of poor power quality) - Commercial entities that use No. 2 Fuel oil for thermal energy could save up to $14.00/MMBTU on heating bill - The microgrid will provide a local market for excess energy production and an example of the investment value of DER assets—these factors may encourage commercial entities to construct large scale DER assets such as solar PV arrays or wind turbines - Up to $540,000[4] of deferred boiler replacement costs at Benedictine Hospital

Table 18. Benefits, Costs, and Value Proposition to Larger Kingston-area Community

Table shows the benefits, costs, and overall value to the larger community.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Community at Large	- Access to a wide range of critical and vital services during grid outages	- Because the larger community will not be connected to the microgrid, this stakeholder group will not bear any costs	- Potential for reconnect in outage situations if generation assets are out producing the demanded critical and important loads - Future expansion of the microgrid could easily connect more facilities through the use of unique IDs on each AMI meter

[4] Communications with Joe Puetz at the Health Alliance in Kingston.

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

Table shows the benefits, costs, and overall value to New York State.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
New York State	- Cash flows will provide tangible evidence of a microgrid project's commercial viability - Indirect benefits (such as outages averted) will demonstrate the benefits of microgrids paired with DER assets - Each microgrid accelerates NY state's transition from traditional utility models to newer, smarter, distributed technologies	- State incentives are a crucial part of each microgrid's financial viability—the State will need to pay rebates for construction of new DER assets - 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 - New natural gas generation is likely to require air quality permitting under state regulations and the Clean Air Act	- 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 REV 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 DER in their own communities - Success of the hybrid model aligns with REV goals—this project provides a successful example of investor-owned generation assets selling electricity over a utility-owned power distribution platform

3.2.5 Demonstration of State Policy

The City of Kingston will coordinate plans to develop a community microgrid to provide a platform for the delivery of energy services to the end-use customers. The local utility already offers several energy efficiency incentive programs for residential and non-residential customers, and by expanding generation or curtailing electricity demand during peak events, the microgrid could participate in CHG&E demand response programs. By coordinating the microgrid as the local distributed system platform (DSP), the Kingston microgrid will act as a distributed resource and will provide local stabilization through injections and withdrawals of power from the grid. As more distributed resources are added throughout the City, the microgrid can be tuned to provide continual support for these assets (for example, by providing ancillary services) and will diversify and enhance its portfolio of revenue streams.

The City of Kingston has already made significant progress towards achieving the NY REV goals. The City purchases more than 20% of its energy from renewable sources and has created a Climate Action Plan to guide future development decisions. The microgrid presents an excellent opportunity to expand future renewable energy generation and immediately improve the City's resiliency to extreme weather events. Paired with energy efficiency programs, generation assets in Kingston could shave a substantial electricity load from the larger grid during peak demand events when congestion costs are highest. As only microgrid connected loads will be on the feeders, the microgrid will have the technical ability to island in response to demand response events. This will require load reduction within the microgrid to meet peak summer loads if the grid goes into an economic islanding.

The microgrid provides a local market for excess electricity generated by distributed renewable generation assets, greatly improves resiliency and reliability of local energy supply in extreme weather situations, and encourages citizens within the community to invest in local energy generation and distribution. Kingston's microgrid and generation assets will immediately reduce the need for high-emissions peaking assets, such as coal plants, during statewide peak demand events and will provide a platform for expanding the City's generation capability in the future.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

The Project Team includes Central Hudson Gas and Electric, the City of Kingston, 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 with local stakeholders from the outset. The team has had in-person visits with Central Hudson and City officials, including the project kickoff meeting in Kingston on July 7, 2015, and ongoing communication on various aspects of the microgrid planning and development process. Booz Allen and its City partners have also communicated with each of the critical and important facilities that will comprise the customer base of the microgrid to determine electric demand, gauge the appetite for including existing generation in the project, and discuss other aspects of the project development.

3.3.2 Project Team

The Kingston microgrid project is a collaboration between the public sector, led by the City of Kingston, the local electric and gas utility Central Hudson, and the private sector, led by Booz Allen Hamilton with significant support from Power Analytics and Siemens. Each of the private sector partners is exceptionally well qualified in the energy and project management space, and CHG&E has a long history of providing reliable utility service to their customers across the Hudson Valley. Tables 20 and 21 provide background on these entities and outline their roles and responsibilities.

Table 20. Project Team

Table provides background on Booz Allen Hamilton, Siemens AG, Power Analytics, and CHG&E.

Booz Allen Hamilton	**Headquarters: McLean, VA**	**Annual Revenue: $5.5 B**	**Employees: 22,700**
History and Product Portfolio: Booz Allen was founded in 1914 and in the ten decades since its founding, Booz Allen has assisted a broad spectrum of government, industry, and not-for-profit clients including the American Red Cross, all branches of the Department of Defense, the Chrysler Corporation, NASA, and the Internal Revenue Service. Booz Allen's energy business includes helping clients analyze and understand their energy use and develop energy strategies, recommending technology solutions to achieve their energy goals, and executing both self- and 3rd party funded projects including energy efficiency, renewable energy, and smart grids.			
Siemens AG	**Headquarters: Munich, Germany; U.S. Headquarters: Washington, DC**	**Annual Revenue: $79.9 B**	**Employees: 343,000**
History and Product Portfolio: Siemens AG was founded in 1847 and today is one of the world's largest technology companies. Siemens AG specializes in electronics and electrical engineering, operating in the industry, energy, healthcare, infrastructure, and cities sectors. Siemens AG develops and manufactures products, designs and installs complex systems and projects, and tailors a wide range of solutions for individual requirements. The Siemens Microgrid Team develops comprehensive solutions leveraging the strength of Siemens' portfolio – from generation sources such as gas, wind, and solar, to transmission & distribution products, to control software solutions and services.			
Power Analytics	**Headquarters: San Diego, CA**	**Annual Revenue: $10-15 M**	**Employees: 50**
History and Product Portfolio: Founded 25 years ago, Power Analytics is a privately-held small business that develops and supports electrical power system design, simulation, and analytics software. The Company's worldwide operations include sales, distribution, and support offices located throughout North America, South America, Europe, Asia, and Africa and Australia.			
Central Hudson Gas and Electric	**Headquarters: Poughkeepsie, NY**	**Annual Revenue: $740 M**	**Employees: 939**
History and Product Portfolio: Central Hudson Gas & Electric Corporation is a regulated transmission and distribution utility serving approximately 300,000 electric customers and 78,000 natural gas customers in a defined service territory of New York State's Mid-Hudson River Valley. Central Hudson delivers natural gas and electricity in a defined service territory that extends from the suburbs of metropolitan New York City north to the Capital District at Albany.			

Table 21. Project Team Roles and Responsibilities

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

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Central Hudson Gas and Electric	Central Hudson is responsible to assist with the design and transactional mechanisms that suit the utility and are acceptable to customers and the PSC. They are also responsible to secure the financing required to fund their stake in microgrid components/control infrastructure. CHG&E will not be involved in generation asset planning or construction.	Central Hudson will be responsible for overseeing construction and installation of microgrid components, as well as making the physical and IT connections with existing and proposed generation assets.	Central Hudson will operate the microgrid through the installed MCS, including both the distribution system and remote signaling to generation assets.
City of Kingston	The City is responsible for being the primary liaison with the community and the critical and important facilities. Further, they may take responsibility for construction and ownership of the solar PV array. Depending on available capital, the City may issue bonds to finance the solar array.	The City will coordinate any construction and connections as necessary, and may be responsible to construct generation assets depending on the final design.	The City will have a limited role in operation unless they become a generation asset owner. Absent that, they will continue to relate to the utility-customer relationships as they do at present.
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 advisory capacity upon completion of the microgrid and during its operation.
Siemens	Siemens is the engineering and technology partner of this project. They will develop the technical design and system configuration in concert with BAH engineers and the Power Analytics team.	Siemens may have primary responsibility for the construction and installation of hardware and generation assets.	Siemens would ensure proper functioning and maintenance of the microgrid technology components throughout.
Power Analytics	Power Analytics is the partner for energy software solutions. The PA team, in conjunction with Siemens and Booz Allen, is responsible for the design of the SCADA and system software components and controls.	Power Analytics may lead the installation of control and energy management software following hardware installation and in concert with Siemens.	Power Analytics would provide IT systems support and may play an active role in system management through the Paladin software platform.

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

3.3.3 Financial Strength

Moody's Investor Service rates the local utility, CHG&E, at an A2 credit rating. According to the Moody's rating scale, "Obligations rated [A2] are judged to be of high quality and are subject to very low credit risk". This rating reflects the supportive relationship between CHG&E and the NYPSC as well as the prediction that the utility's cash flows will remain stable in the future.

The local utility, CHG&E, is owned by the Central Hudson Energy Group, which recently merged with Fortis, Inc., a leader in the North American electric and gas utility business. Fortis owns assets worth approximately $28 billion and receives annual revenues of greater than $5 billion. An established parent company such as Fortis provides meaningful stability to smaller utilities like CHG&E, which might make financiers more willing to lend at lower rates with the assurance that Fortis can pay its debts. This could prove important if CHG&E chooses to finance its stake in microgrid components/control infrastructure with debt. The stability of the utility also increases the financial attractiveness to private partners.

Central Hudson is determined to own and maintain their current distribution facilities in and around the City of Kingston, but it is open to discussing a hybrid ownership model wherein outside investors (including the City of Kingston) would own the proposed generation assets while CHG&E would operate the microgrid control system with a majority stake in its ownership. In such a situation, CHG&E would only incur a medium-sized initial investment cost (for microgrid equipment) and a small annual operation and maintenance cost, while the majority of the investment and operation costs would fall to the owners of the proposed DER assets.

Standard & Poor's gives the City of Kingston a long-term credit rating of AA-minus—its fourth highest ranking. An obligation rated as "AA-minus" indicates that "the obligor's capacity to meet its financial commitment on the obligation is very strong". This indicates that the City will qualify for relatively low interest rates should it choose to finance the solar array with debt.

Given the relatively reliable return on investment for CHP units, the proposed CHP should draw significant interest from outside investors given full-time steam and electricity off-takers. For example, Benedictine Hospital, which will use all of the CHP's cogenerated steam, is a likely candidate for ownership in the CHP unit because the unit will be located near the hospital.

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. The Advanced Metering Infrastructure (AMI) in Kingston will support remote connection and disconnection of loads in response to signals from a Supervisory Control and Data Acquisition (SCADA) based control center. The proven efficacy of proposed microgrid components and the extensive AMI and IT infrastructure in Kingston enhance the replicability and scalability of the design in cities with similar existing infrastructure assets. 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, remote connect and disconnect, achieving automatic load following, and developing black start capability. The chosen technologies meet all of the required and most of the preferred capabilities outlined above.

Solar PV and CHP were chosen as generator technologies to enhance the reliability of the power supply and reduce the need for high emission peaking assets (such as coal plants) during peak demand events. Natural gas-fired CHP units are highly efficient and represent a significant improvement over traditional generation technologies, allowing for 75% generation efficiencies as opposed to the traditional 51% average[5]. Further, the CHP unit will produce a cheap and more efficient steam supply, providing a direct replacement for Benedictine Hospital's natural gas-fired boilers. The availability of a proximate steam off-taker is a significant contributing factor to the usefulness of CHP generation and is integral in Kingston. The current CHP nameplate capacity of 2 MW closely matches electricity demand from microgrid facilities and produces about 60% of the hospital's required thermal energy. If the capacity can be spared, the CHP unit will be capable of providing ancillary services to the macrogrid, which could create a new lucrative revenue stream for the Special Purpose Vehicle (SPV) that owns the generator.

The solar PV unit will provide a renewable component to the microgrid generation mix and is a more appropriate addition than an expanded CHP unit because it offsets the CHP unit's emissions and provides maximum energy on hot, sunny days when electricity demand is highest. It will provide emission-free electricity during daylight hours and move Kingston and the State closer to the renewable generation goals set forth in NY REV and the Renewable Portfolio Standards. Solar PV in Kingston faces the same challenges that it does elsewhere: total reliance on daylight and weather conditions.

The Kingston microgrid includes numerous components that have been previously used and validated. Solar PV and reciprocating natural gas CHP are both widely used technologies, with more than 6 gigawatts (GW) of solar PV installed in 2015 in the United States. In NYS alone, there are more than 400 installed reciprocating CHP units with aggregate nameplate generating capacity that exceeds 295 MW.[6] The switch components are all industry standard and widely used in utilities worldwide, and the Intelligent Electronic Devices (IEDs), which are robust and safe via embedded electrical protections, are similarly standard across the industry. Siemens microgrid technologies are recognized worldwide for their flexibility, reliability, and expandability—successful examples of Siemens microgrid technology at work include the Parker Ranch and Savona University microgrids.[7] The only novel application of technology is the radio-controlled automatic connect and disconnect of the quantity of AMIs connected to the Kingston grid. This technology is proven and implemented in smaller scale environments but has not been demonstrated at the level required by the microgrid design.

3.4.2 Operation

CHG&E will be required to maintain the proper functioning of local Kingston electricity distribution systems, as described below. The utility must also retain a critical mass of registrations to ensure that it can continue to purchase electricity from the proposed DER assets far into the future. The microgrid is a classic shared value creation; the utility will benefit financially, investors will receive reasonable rates of return, and customers of the microgrid will benefit in the event of an outage.

---

[5] US EPA, http://www3.epa.gov/chp/basic/methods.html.
[6] US DOE, https://doe.icfwebservices.com/chpdb/state/NY.
[7] Siemens case studies; available from http://w3.usa.siemens.com/smartgrid/us/en/microgrid/pages/microgrids.aspx.

CHG&E, or a third party owner/operator, will operate the microgrid and will have ultimate decision making authority for all questions surrounding the grid (that are not automatic elevations to the State or PSC). The logic controllers and microgrid control system will automatically decide proper levels of generation from local assets pursuant to purchase agreements, load following, and other similar issues. 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 between the generation assets, the microgrid switchgear, and the CHG&E grid will be automatically governed by the microgrid controllers.

As the majority owner of microgrid components and control infrastructure, CHG&E will be technically responsible for the continued and successful operation of the component pieces of the grid, including software, switches, servers, generation, and AMI meters. The utility will have ongoing assistance from the microgrid hardware and software vendors as needed. 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 utility will also be responsible for maintaining an ample supply of natural gas to the CHP unit as the local gas utility. The CHP will be installed at a location with existing gas infrastructure, so hookup costs are expected to be minimal.

The utility will be responsible for the collections component of grid operation, with the utility-customer relationship and billing mechanisms staying largely the same. The principal difference will be the source of the utility's electricity. Purchasers of electricity services will be charged through their regular bills, and the utility will pass on a percentage of this revenue to generation asset owners pursuant to purchase agreements established with asset owners. This is an opportunity for CHG&E to lead innovations in rate construction, an essential component of REV. Additional fees for microgrid participation may be imposed; however, these will be determined by contract and with the approval of the PSC. Metering will continue as normal through the installed AMI meters. Steam sales to industrial off-takers will be billed on the industry standard cycle and format, or as otherwise agreed upon by the parties, and metered at the point of delivery by industry standard gauging equipment.

Project financing will require regular payments on the debt issued to support construction. Depending on the final financing structure, Kingston, Benedictine Hospital, and CHG&E may bear some financing costs. However, revenues are expected to cover debt costs (see Section 3.5.2).

3.4.3 Barriers to Completion

The barriers to completion for generation asset investors are primarily financial. The high capital costs and relatively long payback make the investment a difficult one, but the combination of revenues from electricity sales, thermal sales, ancillary services, and rebates/subsidies allow for a positive net present value (NPV) business case. Although lack of incentives is not currently a barrier to market entry, it may become one in the near future. Many NYSERDA incentive programs have limited budgets and operate on a "first come, first serve" basis, meaning that funds may be unavailable to future communities interested in building microgrids. Access to capital is a potential barrier to entry for most private investors. These investors may need to rely on outside financing (some mix of debt and equity) to provide sufficient capital. Because Kingston can issue bonds on the municipal market, raising capital for the solar array should not present a significant barrier.

Electricity customers on the Kingston microgrid face limited barriers to entry. Some may need to install AMI technology. However, the microgrid design ensures sufficient load capacity for each of the identified critical and vital facilities. There will be costs associated with connection to the microgrid, but they are not intended to be prohibitive and should not preclude participation based on cost. The CHP will be located nearby its only off-taker, which will limit the necessary investment in steam transmission infrastructure. CHG&E, or another system operator, would also be responsible for the installation and operation of new steam infrastructure, which is planned to coincide with the construction of the CHP unit. In conclusion, the microgrid's design leaves customers with few barriers to connection to the microgrid.

3.4.4 Permitting

The Kingston microgrid may require certain permits and permissions depending on the ultimate design choices. Distributed energy resource assets may require zoning variances depending on the exact placement and the current zoned land use. Kingston is not in any EPA criteria pollutant nonattainment zones; however, the CHP unit will require air quality permits pursuant to the Clean Air Act.

3.5 Financial Viability (Sub Task 3.5)

The distributed energy resource assets included in the microgrid design will produce significant revenue streams from electricity sales to CHG&E, steam sales to Benedictine Hospital, and possibly from ancillary services sales to the NYISO. These assets will require significant investment costs as well as fuel (CHP) and normal operations and maintenance costs. The microgrid project qualifies for several NYSERDA and federal incentives that will partially offset the initial investment costs. Private investors will provide the majority of the required capital outlay for the project construction phase from a mixture of debt and equity. This section will discuss the revenues, costs, and financing options associated with the microgrid project in more detail. Tables 25, 26, and 27 below detail the savings and revenues, costs, and available incentives respectively.

3.5.1 Revenue, Cost, and Profitability

The current projected revenues are described in Table 22 below and sum to approximately $1,600,000 per year. The projected costs are described in Table 23 and sum to approximately $4,100,000 in capital expenditures and $1,100,000 per year in operating expenses. Table 24 describes the available incentives rebates from State and Federal programs.

Table 22. Savings and Revenues

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

Description of Savings and Revenues	Savings or Revenue	Relative Magnitude	Fixed or variable
Electricity sales from 2 MW natural gas-fired CHP [8]	Revenue	$1,150,000/yr	Variable
Electricity sales from 250 kW solar PV array[9]	Revenue/ Savings	$50,000/yr	Variable
Electricity sales to customers during islanded operation	Revenue	~$1,000/yr	Variable
Thermal sales from 2 MW natural gas-fired CHP[10]	Revenue	$430,000/yr	Variable
Ancillary services sales to NYISO[11]	Revenue	$0	Variable
Revenue from participation in Demand Response Programs (NYISO)	Revenue	$10,000/yr	Variable
Microgrid participation tariff	Revenue	1%	Variable
	Total	**$1,600,000/yr**	

Table 23. Capital and Operating Costs

Table describes all costs expected to be incurred during construction and operation of the microgrid.

Description of Costs	CapEx or OpEx	Relative Magnitude	Fixed or Variable
2 MW CHP	Capital	$4,400,000	Fixed
250 kW Solar PV	Capital	$600,000	Fixed
Breakers and IEDs	Capital	$160,000	Fixed
Microgrid Controls	Capital	$350,000	Fixed
Microgrid Control Updates[12]	Capital	$100,00	Fixed
	Total CapEx	**$5,610,000**	
Generator Fuel	Operating	$950,000/yr	Variable
CHP Maintenance	Operating	$100,000/yr	Variable
Solar PV Maintenance	Operating	$5,000/yr	Variable
	Total OpEx	**$1,100,000/yr**	

[8] Sold at $0.078/kWh to CHG&E. This is the rate paid by CHG&E to its suppliers as described on their website and quantified on their supply cost sheet http://centralhudson.com/rates/supplypricehistory.aspx.
[9] Sold at average retail rate through net metering, $0.079/kWh in Kingston.
[10] Sold at $13.00/MMBTU to St. Mary's Hospital, which is the hospital's current cost of steam via onsite, natural gas fired boilers.
[11] Most NYISO Ancillary Services markets require at least 1 MW of capacity—because the CHP unit will operate at a high baseline level, it will not have sufficient capacity to participate.
[12] Microgrid control update costs account for hardware and software upgrades during the life of the microgrid, and are not costs that will be incurred with initial construction but are included for conservatism.

Table 24. Available Incentive Programs

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

Incentive Program	Value	Required or Preferred
NYSERDA NY Prize Phase III	$5,000,000	Required
NYSERDA CHP Performance Program	$1,760,000	Preferred
Federal Business Energy Incentive Tax Credit (ITC) for solar array[13]	$130,000	Preferred
Federal Business Energy Incentive Tax Credit (ITC) for CHP	$320,000	Preferred

3.5.2 Financing Structure

The financial structure of the Kingston microgrid project will include two Special Purpose Vehicles established to hold assets related to the microgrid, as well Kingston in its capacity as the owner of the solar PV array. The first SPV will own the microgrid DERs and controls, hardware and software would be owned by CHG&E and outside investors. These entities will provide the required financing for the installation of the microgrid systems through a combination of equity and debt contributions commensurate with their percentage of vehicle ownership. During development, the microgrid ownership SPV will be established through the coordination of CHG&E and other relevant actors. Before construction commences, the entity will be formalized and will have the required financing in place to support the construction of its component of the project.

The second SPV will own the CHP unit at Benedictine Hospital, and it will be owned by outside investors. These entities will provide financing for the installation of the CHP unit with a combination of debt and equity contributions commensurate with their percentage of vehicle ownership. This entity will be formalized during development and will have the required financing in place to support construction of the CHP. The City of Kingston will own and finance the proposed solar PV array at City Hall. This will be completed through a bond offering, leveraging Kingston's ability to issue bonds on the municipal bond market at relatively low rates. Any bonds issued by Kingston on the municipal market will need to address the following issues during negotiations with creditors:

1. Limits of the basic security
2. Flow-of-funds structure
3. Rate (or user-charge) covenant
4. Priority of revenue claims
5. Additional-bonds tests
6. Other relevant covenants

[13] The Solar ITC will be inapplicable if the municipality wholly owns the array due to their lack of a Federal tax burden.

The total amount to be financed through debt versus equity is dependent on the participating investors, but it will sum to the total cost of construction less the $5 million Phase III NY Prize grant. The funds attached to the NY Prize award will be distributed based on the total cost of construction for each component of the grid. For example, if 20% of the cost is controllers, 50% of the cost is the CHP, and 30% of the cost is the solar PV array, then the $5M would be distributed accordingly to subsidize construction. Rebates from NY State and Federal tax incentives will accrue to the relevant ownership group. It is important to note that if the City assumes ownership of the solar array, there will be no opportunity for Federal tax credits because the municipality has no tax burden. In a similar vein, if the solar or CHP ITCs or the NY State CHP rebate expire, it will negatively impact project economics.

Revenues will accrue to each SPV based on the revenue stream associated with it. The CHP ownership group will realize returns through the sale of electricity to CHG&E and thermal resources to Benedictine, the solar PV ownership will realize returns through net metering, and the microgrid ownership will realize returns through participation tariffs and, depending on the arrangements within the SPV, a percentage of T&D and microgrid fees captured by CHG&E. Each of these respective revenue streams will be distributed based on the stake of ownership in the particular SPV.

3.6 Legal Viability (Sub Task 3.6)

The Kingston microgrid will be compliant with all regulatory requirements and will have a robust and accessible set of connected assets. The primary regulatory issues that must be addressed during project development will be the siting of the CHP unit (as it will require a zoning variance) and air quality permits related to the CHP installation. The former will be adjudicated on a local level by Kingston, and because they are a partner in this project, this should not provide an insurmountable hurdle. The air quality permits will be coordinated with the New York Department of Environmental Conservation and should not be prohibitive.

3.6.1 Ownership and Access

The microgrid controllers will be owned by CHG&E, or a third party investor, the generation will be owned by private or municipal interests through an SPV, and distribution infrastructure will be owned by CHG&E. Central Hudson will need to formalize agreements with CHP owners to ensure the necessary site access and will need to stand up a trilateral operating agreement alongside. The agreement will be between CHG&E, or the SPV that owns the microgrid infrastructure, and the SPV that owns the CHP (for operation of the CHP unit). There will be no special agreement required with CHG&E for operation of the solar array as it will be a standard net metering arrangement. These are necessary to ensure seamless integration of the assets with each other, with the microgrid systems, and with the CHG&E grid. The data network upon which the microgrid logic units and controllers will interact with system components is owned by Kingston and should provide no hurdles to access.

We expect that the CHP ownership will pay rent to Benedictine Hospital for the land on which the CHP is built. The terms of this lease agreement will be adjudicated by the parties, but it should minimally include site access contingencies for operation and maintenance of the CHP unit.

3.6.2 Regulatory Considerations

State & Utility Regulation

Regarding electricity generation, Central Hudson must generally comply with New York Public Service Law, as well as CRR-NY Title 16, Chapter II, Electric Utilities (see further discussion below). Specific to customer privacy, Central Hudson must comply with the customer privacy protections outlined in 16 CRR-NY 6-2.1-11. Building and safety codes are adopted on a state level by the State of New York, and localities have the option to further modify these codes. As of December, 2010, New York State has adopted the 2008 *National Electrical Code* for both residential and non-residential construction. New York State and New York City have adopted the 2009 IECC for residential construction and the 2012 IECC for commercial applications

Per New York State Standardized Interconnection Requirements, distributed energy resource units up to 2 MW may be interconnected to the utility system. Systems under this threshold may take advantage of Net Metering programs. It should be noted that the 2015 REV Order directs the implementation of a process to raise the threshold to 5 MW, meaning that sources under 5 MW would be able to net-meter their output.[14]

Central Hudson provides a Net-Energy Metering program which allows for a variety of technology types, with a 2 MW project cap. Specifically regarding solar projects, Central Hudson specifies that "in order to satisfy the statutory 2,000 kW limit applicable to photovoltaic generating equipment, each solar array of not more than 2,000 kW must:

(a) be separately metered and interconnected to the utility delivery system; and,
(b) be located on a separate site; and,
(c) be independently operated from any other project."

Customers may designate a Satellite Account to receive the benefits from the Host Account; however, the Satellite Account may not also be net-metered independently. Net-metering is addressed in Leaf 163.5.6 and Leaf 163.5.11 of the Central Hudson electric rate tariffs.[15]

Local Regulation

Local zoning regulations do not specifically allow for generation systems; instead, the regulations allow for a special permit to be granted under §405.32 of the City of Kingston Code. Similarly, use of distribution wires/poles is granted via special permit under the same section. The Code specifies such permits shall be granted by the Planning Board, which shall take into

[14] Interconnection of Distributed Generation in New York State: A Utility Readiness Assessment, NYSERDA, September 2015, Report Number 15-28.
[15] http://www.centralhudson.com/dg/netmetering.aspx.

consideration the public health, safety, and welfare of the community and shall prescribe the appropriate limitations to the permit.[16]

Air Quality

CHP units may be subject to a variety of federal permits and emission standards depending on the type of engine, the fuels combusted, the heat or electrical output of the system, how much electricity is delivered to the grid versus used onsite, and the date of construction. The specific details of the CHP project in Kingston will determine the applicability of the regulations below. CAA regulations applicable to Reciprocating Internal Combustion Engine systems, including CHP, will apply. These regulations include:

- National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines (RICE): 40 CFR part 63 subpart ZZZZ
- New Source Performance Standards (NSPS) for Stationary Compression Ignition (CI) Internal Combustion Engines (ICE): 40 CFR part 60 subpart IIII
- NSPS for Stationary Spark Ignition (SI) ICE: 40 CFR part 60 subpart JJJJ

Per EPA guidance, these regulations apply to all engine sizes, regardless of the end use of the power generated. However, further review and analysis must be conducted when details of the type and size of the CHP 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 6NYCR:

- 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 CHP system.

3.7 Project Commercial and Financial Viability Conclusions

The Kingston microgrid concept is financially feasible as currently proposed and will include a mix of healthcare and municipal facilities. The microgrid will be owned by a hybrid structure with separate Special Purpose Vehicles for the microgrid controls and systems and the CHP.

[16] City of Kingston Code §405.32: http://ecode360.com/6728481#6728481.

Ownership of the microgrid controls SPV will be led by CHG&E and include outside investors as necessary. Ownership of the CHP SPV will be led by outside investors. Overall revenue streams from the project are estimated at $1,600,000 per year, and will be captured primarily through the sale of electricity from the generation units to CHG&E and the sale of thermal resources to Benedictine Hospital. Smaller revenues will come from demand response programs and the microgrid tariff levied on customers of the project. Annual operations and maintenance costs, including generator fuel and scheduled maintenance, are estimated at approximately $1,100,000 per year. Cash benefits will accrue to all asset owners in the microgrid project, and Benedictine Hospital will realize the added benefit of a reduction in in-house steam production and the associated costs. More broadly, the community will realize benefits from the availability of a wide range of critical and important facilities in the event of an outage.

The issue of permitting and regulatory challenges should be reasonably straightforward, though siting permits and zoning variances will be required for the installation of the CHP. The localized distribution of thermal resources should occur outside of PSC regulation, and the primary regulatory consideration will be the Clean Air Act permitting of the new CHP unit.

These estimates and value propositions are predicated on several assumptions, with an acknowledgement of the risks present in the development of this project. Benedictine Hospital will host the CHP unit. As the sole thermal off-taker and majority owner, this is the most efficient placement of the unit; installation elsewhere will negatively impact the conveyance of steam to Benedictine and overall project economics. Further, the document assumes net metering will govern the sale of electricity from the solar array. Net metering is supported by both state and utility policy and should therefore be implemented. Lastly, the Team assumes the AMI infrastructure will have remote disconnect capability, a required feature in this microgrid concept.

4. Cost Benefit Analysis

To achieve the next step of the feasibility study, the Project Team has carefully assembled a cost-benefit analysis of the microgrid project. Much of the data used for this analysis comes from concrete cost, load, and other relevant data; the Project Team addressed any data gaps by using estimates from similar projects or industry standards.

This section is made up of seven sections in addition to the introduction:

- ***Section 1*** analyzes the *facilities connected to the microgrid* and their energy needs.
- ***Section 2*** discusses the *attributes of existing and proposed distributed energy resources*, including factors such as nameplate capacity and expected annual energy production.
- ***Section 3***, analyzes *potential ancillary services sales and the value of deferring transmission capacity investments*.
- ***Section 4*** reviews the *overall costs* associated with construction and installation of the microgrid as well as the fuel, operation, and maintenance costs required over the lifetime of the microgrid.

- ***Sections 5 and 6*** discuss the *community benefits* of maintaining power during a grid-wide outage and outline the costs associated with operating the microgrid in island mode.
- ***Section 7*** presents the Industrial Economics (IEc) *benefit-cost analysis report and associated Project Team commentary.*

4.1 Facility and Customer Description (Sub Task 4.1)

The Kingston microgrid will include six facilities from various rate classes and economic sectors (See Table 25). NYSERDA designates three primary rate classes based on type of facility and average electricity consumption: residential, small commercial (less than 50 MWh/year), and large commercial (greater than 50 MWh/year). All six proposed microgrid facilities belong to the large commercial rate class. The large commercial buildings account for all of the microgrid's annual electricity demand, requiring approximately 15,500 MWh of electricity per year. The average electricity usage per facility is 2,570 MWh/year, with half of the facilities requiring less than 100 MWh/year. See Table 25 for basic statistics on each facility's energy usage.

The generation assets included in the microgrid design will be capable of meeting 100% of the average aggregate facility energy usage during a major power outage, but they will approach their generation limits if several large facilities simultaneously reach peak energy use. In these situations, the natural gas generator may need to come online to supply additional electricity. Some of the facilities do not operate 24 hours a day, such as City Hall and the Kingston School District that will only operate 8-12 hours per day during both grid-connected. 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 school complex normally requires electricity for lighting, electrical appliances, and heating/cooling during the daytime hours. However, in an emergency, it will serve as a community shelter, extending 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 25.

Table 25. Facility and Customer Detail Benefit[17]

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 CHG&E

[17] Load data was provided to Booz Allen by CHG&E.

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates existing and new distributed energy resources, including one existing natural gas generator, a natural gas-fired CHP generator, and a solar PV array. The proposed CHP unit and solar PV array will produce an average of 1.735 MW of electricity throughout the year,[18] and the existing natural gas generator at City Hall will provide a maximum of 100 kW of backup power in emergency situations.

The CHP unit will provide approximately 65% of Benedictine Hospital's thermal energy requirements. It will capture waste heat from the electricity turbine and use this heat to produce approximately 21,120 MMBTU of steam per year,[19] which will be used by Benedictine Hospital. The generator has a nameplate capacity of 2 MW and will operate nearly continuously. Assuming a capacity factor of 85%, the CHP unit will produce approximately 14,900 megawatt hours (MWh) of electricity over the course of the year. If a major power outage occurs, the CHP unit can produce a maximum of 48 MWh (the CHP system's full 2 MW nameplate capacity) of electricity per day, which would provide for over 100% of the microgrid's average daily demand. Assuming a heat rate of 9.5 MMBTU/MWh,[20] the CHP unit will incur a fuel cost of approximately $53/MWh.[21]

Limited by weather conditions and natural day-night cycles, the 0.25 MW solar PV array is expected to produce around 306 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, the solar array will produce an average of around 0.84 MWh of electricity per day, which represents approximately 2% of average daily electricity demand from microgrid-connected facilities. Maintenance costs for the solar array will be around $5,000 per year,[22] which means the total cost of producing solar electricity will be about $34/MWh.

The existing natural gas generator at City Hall will be used only in emergency situations when the microgrid requires a black start or when the proposed CHP and solar array are not producing sufficient electricity to meet aggregate demand. The natural gas generator at City Hall has a nameplate capacity of 0.1 MW. This generation capacity could be vital in emergency situations, or when the solar array or CHP unit go offline for maintenance. The Booz Allen team predicts the existing back-up natural gas generator will operate approximately 20% of the time during the 2.3 hours of larger grid outage per year,[23] for a total of around 0.046 MWh of power per year.[24]

---

[18] **CHP 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).

[19] 2 MW CHP thermal output will be 1670 MMBTU per month (Siemens estimate).

[20] 2013 EIA average for natural gas fired Gas Turbine (http://www.eia.gov/electricity/annual/html/epa_08_02.html).

[21] **Price of natural gas**: $5.74 per Mcf (average CHG&E supply price from 2013-2015).

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

[23] Grid outage data from DPS 2013 Electric Reliability Performance Report (CHG&E average CAIDI).

[24] The Booz Allen team forecasts a 20% level of operation from the backup generator based on historical loads and expected generator output. In 2014, the average load in Kingston was 1.759 MW. The CHP can provide a maximum of 2 MW of

The 0.1 MW generator requires around 0.93 Mcf of natural gas per hour of operation.[25] In the event of a major power outage, this generator could produce a maximum of 2.4 MWh/day—however, assuming that the CHP and solar will require backup power during only 20% of emergency outage hours, this figure drops to a more realistic 0.48 MWh/day. See Table 26 for a detailed list of all proposed and existing distributed energy resources in Kingston.

generation. Load is expected to exceed the CHP's maximum output for approximately 20% of time spent in island mode. Solar output is unreliable, but it should provide significant support on the most irradiated days of the year when peak demand is highest.

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

Table 26. Distributed Energy Resources

Table lists DERs incorporated in the microgrid, including their energy/fuel source, nameplate capacity, estimated average annual production under normal operating conditions, average daily production in the event of a major power outage, and fuel consumption per MWh generated (for fuel-based DERs). "Normal operating conditions" assumes approximately 0.46 effective hours of operation per year for natural gas backup generators.

Distributed Energy Resource Name	Location	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Average Daily Production During Major Power Outage (MWh)	Potential Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
							System fuel	Units of MMBTUs
DER1 – CHP	CHP at Benedictine Hospital	Natural Gas	2.0	14,892	40.8	48	9.26 Mcf	9.5 MMBTUs
DER2 – Solar PV	New Solar Panel at City Hall	Sun Light	0.25	306.6	0.84	2.0[26]	N/A	N/A
DER3 – Backup Generation	City Hall (backup generation)	Natural Gas	0.1	0.046	0.48	2.4	9.3 Mcf	9.6 MMBTUs

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

4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3)

4.3.1 Peak Load support

The microgrid's proposed generation assets will operate nearly continuously throughout the year, providing a constant level of load support. Although continuous operation will limit the CHP's ramp-up capability during peak demand events, it will maximize revenue for the owners and decrease electricity purchases from CHG&E's grid-supplied power. The existing natural gas backup generator will also be available to reduce peak load in cases of extreme demand. See Table 27 for the maximum generation capacities of the proposed and existing DERs.

The proposed solar array will be at its most productive on days with peak solar irradiance when peak demand events are common, thus providing peak load support when it is most needed. The solar array will provide around 0.035 MW of load support on average over the course of a year. However, its generation depends on weather conditions and time of day, therefore the solar array is not a reliable source of peak load support.

Table 27. Distributed Energy Resource Peak Load Support

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

Distributed Energy Resource Name	Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER1 – CHP	CHP at Benedictine Hospital	Maximum of 2	No
DER2 – Solar PV	New Solar Panel at City Hall	Maximum of 0.25	No

4.3.2 Demand Response

Demand response programs require facilities to curtail load or expand generation using generators or battery storage in response to forecasted or real-time peak demand events on the larger grid. Entering island mode is the primary method for a microgrid to reduce load on the larger grid and thus participate in DR programs. The microgrid-connected assets and loads will be able to disconnect from the larger grid as a single point. Because the microgrid will only enter island mode during emergency outages, its ability to participate in DR programs is limited to reducing energy usage or expanding energy generation on the level of individual generators or loads. The Project Team is currently assuming a high baseline level of operation for the CHP and therefore negligible participation in DR programs. Additionally, the solar array's variable production prevents reliable participation in DR programs.

4.3.3 Deferral of Transmission/Distribution Requirements

The 1.7625 MW of average local generation produced by the DERs will reduce the amount of electricity imported from the CHG&E power lines, which will defer the need to invest in new or upgraded power lines. Although these power lines will last up to one hundred years if well maintained,[27] they can only transmit a limited amount of power. As demand for electricity in Kingston increases, the lines may need to be supplemented to handle additional load.

The same is true for distribution capacity investments on a local, feeder-by-feeder basis. While the City of Kingston has ample capacity within the town, and construction of DERs will not require a significant distribution capacity investment, it likely will not defer upgrade costs for CHG&E.

4.3.4 Ancillary Services

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

Although the CHP unit will not participate in paid NYISO ancillary service programs, it will provide many of the same ancillary services to the local Kingston grid. For example, the CHP will provide frequency regulation as a by-product of its operation. The Kingston 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 goods are being bought or sold. Instead, provision of ancillary services will represent a direct value to microgrid connected facilities.

4.3.5 Development of a Combined Heat and Power System

Benedictine Hospital will be a steady and reliable customer for all of the steam generated by the CHP facility. At normal levels of operation, the CHP unit will produce approximately 1,760 MMBTUs of steam per month. This will meet approximately 41% of the Hospital's average monthly thermal energy demand, which is around 4250 MMBTUs.[28] By purchasing steam from the CHP unit, Benedictine Hospital will replace around 21,120 MMBTUs of natural gas with co-generated steam every year.

4.3.6 Environmental Regulation for Emission

Although the CHP system will lead to a GHG emissions reduction for Benedictine Hospital, the microgrid's generation assets will drive an 874 $MTCO_2e$ net increase of emissions in Kingston as compared to the New York State energy asset mix. The CHP unit and natural gas generator will emit approximately 8,173 $MTCO_2e$ (metric tons CO_2 equivalent) per year,[29] while the solar array will emit none. The current New York State energy asset mix would emit approximately 5,516

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

[28] Data supplied by the Health Alliance, Kingston.

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

$MTCO_2e$ to produce the same amount of electricity[30], and natural gas-fired boilers would emit around 1,120 $MTCO_2e$ to produce the same amount of thermal energy.[31] The microgrid's generation assets will therefore generate 8,173 $MTCO_2e$, whereas the standard New York State energy asset mix would produce 6,637 $MTCO_2e$, resulting in a net increase of about 1536 $MTCO_2e$.

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. The New York State overall emissions limit was 64.3 $MMTCO_2e$ in 2014, but it 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 it does not require assets under 25 MW to purchase allowances. The CHP unit is defined as a "small boiler" by NYS Department of Environmental Conservation (NYS DEC) limits (fuel input of 10-25 MMBTU/hour). The NYS DEC is currently developing output-based emissions limits for distributed energy resource assets, and 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 CHP will require an operating permit in addition to other construction permits. The costs of obtaining this permit will be in line with the cost of a construction permit and not comparable to the price of emissions allowances. The existing natural gas generator is already permitted and therefore will not incur any significant emissions costs.

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

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

[31] **Average emissions rate for natural gas boilers**: 0.053 $MTCO_2e$/MMBTU. Info from EIA (117 lb CO_2 per MMBTU; http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).

Table 28. Emission Rates

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

Distributed Energy Resource Name	Location	Emissions Type	Emissions Per MWh (Metric Tons/MWh)
DER1 – CHP	CHP at Benedictine Hospital	CO_2	0.553
		SO_2	0.0000067[32]
		NO_x	0.00055[33]
DER3 – Backup Generation	City Hall (backup generation)	CO_2	0.508
		SO_2	9.09358E-07[34]
		NO_x	0.006309834
		PM	1.19237E-07

4.4 Project Costs (Sub Task 4.4)

4.4.1 Project Capital Cost

The microgrid design requires the following new pieces of equipment at the Jansen 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 both substations as well as the smaller 13.8 kV and 14.4 kV distribution feeders.
- Automated distribution switches installed throughout the City to allow the microgrid to isolate problematic areas and maintain power to the rest of the grid when falling trees or other environmental hazards damage key lines.
- Grid-paralleling switchgear to synchronize each generator's output to the system's frequency.

The total installed capital cost of the equipment is estimated to be $510,750 at the Jansen Substation and $20,000 for communication cabling throughout the grid. The 0.25 MW solar PV array and 2 MW CHP unit will carry installed costs of $600,000 and $4.4 million, respectively.[35] This brings the total installed capital cost to approximately $5.53 million, not including interconnection fees and site surveys. See Tables 29 and 30 below for estimated installed costs for each microgrid component.

[32] CHP calculator, EPA.
[33] EPA, http://www3.epa.gov/chp/documents/faq.pdf.
[34] "Natural Gas-fired Reciprocating Engines" – EPA, http://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s02.pdf.
[35] **CHP Capital Cost**: $2,200/kW, Siemens estimate.
Solar PV Capital Cost: $2,400/kw, pro-rated from Siemens 2 MW Solar PV estimate.

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

Table 29 details capital cost to the Jansen Substation. The substation upgrades include equipment such as the microgrid control system, IED, and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid.

Table 29. Capital Cost of Jansen Substation

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

Jansen Substation				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Microgrid Control System (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	$50,000	7 - 8	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
Microgrid Control Center (Siemens MGMS or equivalent)	1	$300,000	20	Provides data trending, forecasting, and advanced control of generation, loads and AMI/SCADA interface, interface to NYISO for potential economic dispatch.
Automated Transfer Switch (Siemens 7SC80)	2 new 2 upgrade	$50,000 $10,000	20	Single pole, two throw switch which is remotely controlled to switch microgrid loads/generation onto the proper distribution bus as well as isolate additional utility feeders. (Jensen Ave and Mary's Ave)
Transformer High Side CB (7SJ85 or 7UT85)	1	$5,000	20	Disconnects utility Jansen feed from Jansen sub to initiate Microgrid Mode.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay)	3	$15,000	20	Upgraded breakers/switches at 2 distribution load feeders. Isolate downstream loads from the Microgrid. (High School and Fire Station)
Automated PME (Siemens 7SJ85 multi breaker control relay)	2	$20,000	20	Pad mount enclosure to be updated to be automated with remote control relay capable of isolating downstream loads from the microgrid and separating microgrid loads onto different Jansen feeders. (City Hall and Broadway)

Jansen Substation				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Jansen Substation Multi Feeder Breaker Control (Siemens 7SC80 with 3 modules for additional breaker control.	1	$10,000	20	Four feeders at Jansen sub controlled by one microprocessor relay. Includes necessary modules to control and protect all four feeders.
Generation Controls (OEM CAT, Cummins, etc.) (Load Sharing Woodward)	2	$8,000	20	Serves as the primary resource for coordinating the paralleling, load matching, and load sharing of spinning generation.
PV Inverter Controller (OEM Fronius, etc.)	1	$5,000	20	Controls PV output and sends data to MGMS for forecasting.
Ethernet Switches	1	$750	20	Network interface between devices and controllers. Ring topology will provide 1 level of redundancy.
Installation Costs	-	$37,000	-	Installation of capital components in the microgrid.

Table 30. Capital Cost of Proposed Generation Units

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

Proposed Generation Units				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
0.25 MW PV System	1	$600,000	30	Generation of electricity
2.0 MW CHP System	1	4,400,000	20	Generation of electricity

The microgrid IT infrastructure will also require Cat-5e Ethernet and 1000 Base-F two strand fiber optic cables for communication between distribution switches, generation switchgear, PV inverters, and network switches. The design uses Cat-5e cabling, including RJ-45 connectors at $0.60 per cable,[36] for distances under 100 meters. For greater distances the design calls for fiber optic cables using LC connectors at a cost of $7.60 per cable.[37] The total installation cost of cabling is approximately $5.65 per foot for Cat-5e cables and approximately $4.65 per foot for

[36] Commercially available RJ-45 connectors, $0.30 per connector.
[37] Commercially available LC connectors, $3.80 per connector.

fiber optic cables.[38] The microgrid will also need a new network switch at Benedictine Hospital which will cost approximately $750.[39] The Project Team will use the existing cabling infrastructure to install the communications cables, thereby avoiding the high costs of trenching the proposed lines. Once the IT infrastructure is installed, the Project Team estimates that the Network Switch/VLAN configuration will take approximately eight hours at $150 per hour.[40] The estimated total cost for the microgrid IT infrastructure is around $20,000.[41]

4.4.2 Initial Planning and Design Cost

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

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

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

Table 31. Initial Planning and Design Cost

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

Initial Planning and Design Costs ($)[42]	Cost Components
$750,000	Design considerations and simulation analysis
$100,000	Project valuation and investment planning
$75,000	Assessment of regulatory, legal, and financial viability
$75,000	Development of contractual relationships
$1,000,000	**Total Planning and Design Costs**

[38] **Installation costs for Cat5e**: $5.45/ft. **Installation costs for fiber optic**: $4.40/ft (Siemens).
Component cost for Cat5e: $0.14/ft (commercially available). **Component cost for fiber optic**: $0.24/ft (commercially available).

[39] Commercial cost for Cisco 3750G Series 24 Port Gigabit Switch, WS-C3750G-24TS-S.

[40] Project Team Engineers' estimate.

[41] The Project Team estimated ~1500 feet of Cat5e and ~1700 feet of fiber optic will be necessary.

[42] 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 costs, including fixed annual service contracts.

Annual service for the CHP unit will cost around $208,500.[43] The microgrid will also incur $6,500/year in total costs for annual fixed system service agreements for the solar PV array and backup natural gas generator.[44]

The DERs will also incur variable O&M costs that fluctuate based on output. These include fuel and maintenance costs outside of scheduled annual servicing. For example, the CHP will require capital for fuel, consumable chemicals, and other operating expenses. The natural gas usage of the backup natural gas generators is difficult to predict because they will be used only during some emergency outage situations.

The solar PV array will not require fuel to operate, and it should not require service outside of the normally scheduled maintenance. Normally scheduled maintenance should cost approximately $20/kW per year.[45]

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[46] Table 32 outlines all fixed operations and maintenance (O&M) costs associated with annual operation of the microgrid.

Table 32. Fixed Operating and Maintaining Cost

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

Fixed O&M Costs ($/year)	Cost Components
~ $208,500 including both fixed and variable costs	CHP System Service Agreement and Employee Costs – Annual costs of maintenance and servicing of unit and Labor cost of running CHP
$5,000	Solar PV System Service Agreement – Annual costs of maintenance and servicing of unit
$1,500	Natural Gas Generator (City Hall) 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

43 **CHP O&M**: $0.014/kWh (Siemens).
44 $5,000 for solar PV array ($20/kW per year) and $1,500 for natural gas generator (Pete Torres, Prime Power; yearly service for seldom-used small scale natural gas generator).
45 NREL (projects $0/kWh variable maintenance costs): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
46 O&M for non-DER microgrid components: $70,000/year (Siemens).

4.4.4 Distributed Energy Resource Replenishing Fuel Time

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

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

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

4.5.1 Backup Generation Cost during a Power Outage

The proposed generator will serve as a backup generator in the event of an extended power outage, but the CHP will be the most reliable and productive. It has a nameplate capacity of 2 MW operating at 85% efficiency and will supply an average of 1.7 MW to the microgrid throughout the year. Because the CHP will use natural gas from the pipeline as fuel, disruptions to its fuel source are unlikely. Operating at full capacity in an emergency situation, the CHP will generate approximately 48 MWh per day, using around 444 Mcf (456 MMBTU) of natural gas. The CHP will not require startup or connection costs in order to run during island mode and should not incur any daily variable costs other than fuel.

The solar array will be available for backup generation during a power outage, but its production is too inconsistent for it to qualify as a true backup generator. Extreme weather is responsible for many emergency outages in New York State, and such weather will greatly reduce the output of the solar panels. However, when outages occur due to high electricity demand during the most irradiated days of the year, the solar panels will be at their most productive and could provide up to 0.25 MW of load support to the Kingston microgrid. Table 33 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

The backup natural gas generator will only come online when the CHP unit and solar array do not provide sufficient power to the islanded microgrid. Because the CHP can produce 2 MW of power at full capacity and the microgrid's loads had an average power demand of 1.76 during 2014, the CHP and solar array should be capable of satisfying the microgrid's power demand in most situations. The natural gas generator will only be necessary for about 20% of total outage time, which translates to an average production of 0.48 MWh per day. The generators will require around 4.5 Mcf per day at this level of production. One-time startup costs or daily non-fuel maintenance costs for either of the natural gas generators is not anticipated.

Table 33. Cost of Generation during a Power Outage

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

Location	Distributed Energy Resource	Energy Source	Nameplate Capacity (MW)	Power Outage Operating Capacity (%)	Avg. Daily Production During Power Outage (MWh/ Day)	Fuel Consumption per Day		One-Time Operating Costs ($)	Ongoing Operating Costs per day – (Fuel and O&M)
						Quantity	Unit		
CHP at Benedictine Hospital	DER1 – CHP	Natural Gas	2.0	100%	48	444	Mcf	N/A	$3,100[47]
New Solar Panel at City Hall	DER2 – Solar PV	N/A	0.25	14%	0.84[48]	N/A	N/A	N/A	$15
City Hall (backup generation)	DER3 – Backup Generation	Natural Gas	0.1	100%	2.4	23	Mcf	N/A	$130

[47] = Daily fuel cost during an outage (Mcf/day) + (Yearly O&M/365).
[48] This output assumes that the PV arrays are still operational after an emergency event.

4.5.2 Cost to Maintain Service during a Power Outage

There are no costs associated with switching the microgrid to island mode during a power outage other than the operational costs already accounted for in Table 333. Please refer to Table 333 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.

4.6 Services Supported by the Microgrid (Sub Task 4.6)

Many of the facilities to be connected to the microgrid are municipal government buildings (such as the City Hall, Fire Department, and Department of Public Works) that serve the entirety of the population in Kingston. Others, like the health facilities, serve a smaller population for most of the year but may provide critical services to more of the population during emergency situations. For estimates of the population served by each critical facility, see Table 34.

Backup power supplied by the microgrid should provide 100% of each facility's electricity demand during outage situations. However, if backup power from the microgrid is not available, the critical services provided by these facilities will be severely hampered. Some critical services do not require electricity (e.g., driving a police car to the scene of a crime), while others are completely dependent on a stable power supply (e.g., municipal buildings or local water sanitizing operations). Based on the portfolio of services that each facility provides and the electricity dependency of each service, Table 34 34 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 34. Critical Services Supported

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

Facility Name	Population Served by This Facility	Percentage Loss in Service During a Power Outage[49]	
		When Backup Power is Available	When Backup Power is Not Available
City of Kingston (City Hall)	~ 23,500	0%	50-75%
Kingston Fire Department	~ 23,500	0%	> 50%
Department of Public Works	~ 23,500	0%	> 90%
Broadway Campus Hospital (Health Alliance)	~ 23,500	0%	> 90%
Benedictine Hospital (Health Alliance)	~ 23,500	0%	> 90%

[49] 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).

4.7 Industrial Economics Benefit-Cost Analysis Report

As follows is a direct cost-benefit analysis from Industrial Economics. IEc was hired by NYSERDA to conduct a benefit-cost analysis of each feasibility study. The benefit-cost analysis of the Kingston microgrid was delivered to the Project Team on February 25, 2016.

4.7.1 Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the City of Kingston ("Kingston") has proposed development of a microgrid that would serve six local facilities:

- Kingston City Hall.
- The Kingston Department of Public Works, which oversees services such as sewer maintenance, sanitation, wastewater treatment, and park maintenance.
- The Kingston Fire Department Headquarters, which provides fire suppression, rescue, and emergency medical services to the community.
- Kingston High School, a public secondary school with a total enrollment of approximately 1,900 students.[50]
- Kingston Hospital (i.e., Broadway Campus), which is part of HealthAlliance's multi-campus health care system. This facility is a 150-bed hospital with an emergency care center.
- The Benedictine Hospital (i.e., Mary's Avenue Campus), which is also part of HealthAlliance's multi-campus health care system. This facility is a 150-bed hospital with a cancer treatment center.

The microgrid would be powered by two new distributed energy resources – a 2.0 MW natural gas unit and a 250 kW photovoltaic array. The natural gas unit would incorporate CHP systems that would produce thermal energy as well as electricity. In addition, the microgrid would also incorporate a 100 kW natural gas backup unit currently installed at the City of Kingston City Hall building. The town anticipates that the new natural gas unit and photovoltaic system would produce electricity for the grid during periods of normal operation. In contrast, the existing backup natural gas unit would produce power only during an outage, when the microgrid would operate in islanded mode. The system as designed would have sufficient generating capacity to meet average demand for electricity from the six facilities during a major outage. Project consultants also indicate that the system would have the capability of providing black start support to the grid.

To assist with completion of the project's NY Prize Phase I feasibility study, IEc conducted a screening-level analysis of the project's potential costs and benefits. This report describes the results of that analysis, which is based on the methodology outlined below.

[50] New York State Education Department. 2015. Kingston High School Enrollment (2014-15). Accessed December 20, 2015 at http://data.nysed.gov/enrollment.php?year=2015&instid=800000036302.

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.[51] 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 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

[51] 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 $PM_{2.5}$, and therefore also applies a three percent discount rate to the calculation of damages associated with each of those pollutants. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.]

stakeholders (e.g., customers, utilities). When facing a choice among investments in multiple projects, the "societal cost test" guides the decision toward the investment that produces the greatest net benefit.

The BCA considers costs and benefits for two scenarios:

- Scenario 1: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).
- Scenario 2: The average annual duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under Scenario 1.[52]

4.7.3 Results

Table 35 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 4.5 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

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

	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
ECONOMIC MEASURE	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 4.5 DAYS/YEAR
Net Benefits - Present Value	-$6,680,000	$117,000
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	-8.5%	7.3%

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

Scenario 1:

Figure 5 and Table 36 present the detailed results of the Scenario 1 analysis.

Figure 5. Present Value Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

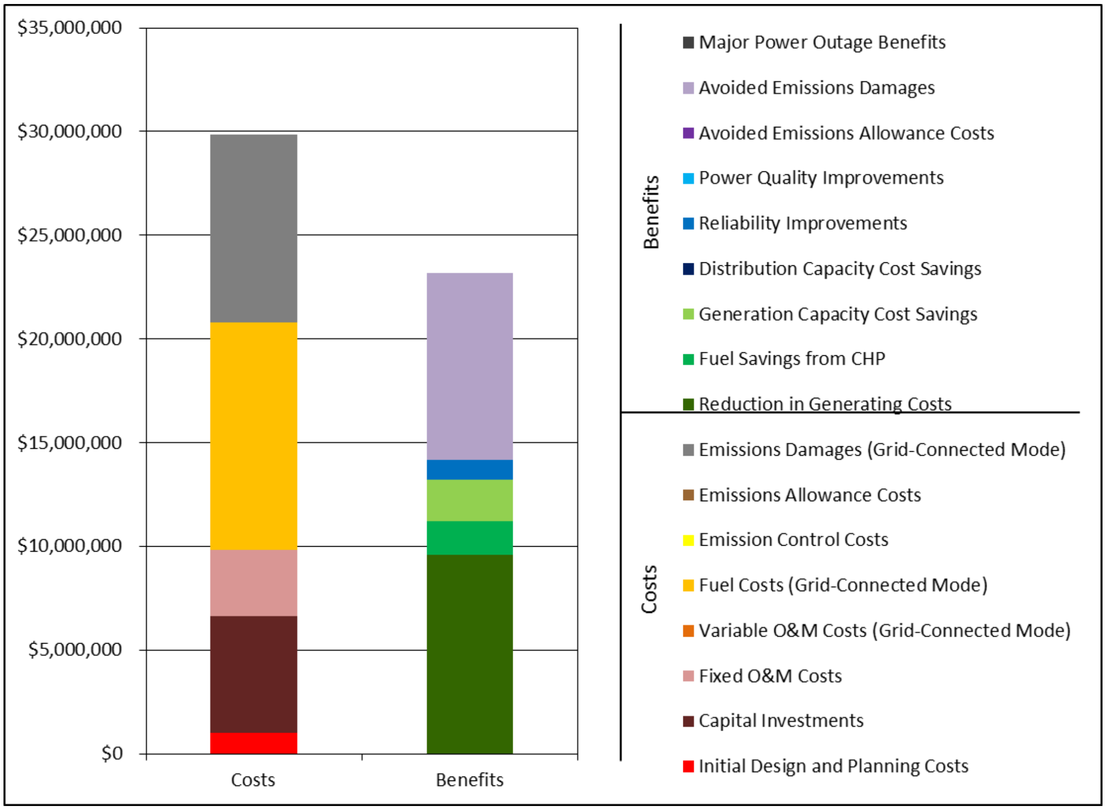


Table 36. Detailed BCA Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$1,000,000	$88,200
Capital Investments	$5,610,000	$487,000
Fixed O&M	$3,230,000	$285,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$11,000,000	$967,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$9,070,000	$592,000
Total Costs	**$29,900,000**	
Benefits		
Reduction in Generating Costs	$9,600,000	$847,000
Fuel Savings from CHP	$1,640,000	$144,000
Generation Capacity Cost Savings	$1,980,000	$175,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$934,000	$82,500
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$5,160	$455
Avoided Emissions Damages	$9,030,000	$589,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$23,200,000**	
Net Benefits	**-$6,680,000**	
Benefit/Cost Ratio	**0.8**	
Internal Rate of Return	**-8.5%**	

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 $5.6 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 2.0 MW natural gas unit with CHP capabilities; and the new 250 kW photovoltaic array. Operation and maintenance of the entire system would be provided under fixed price service contracts, at an estimated annual cost of approximately $285,000. The present value of these O&M costs over a 20-year operating period is approximately $3.2 million.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's primary generator. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the Project Team and projections of fuel costs from New York's State Energy Plan (SEP), adjusted to reflect recent market prices.[53] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $11.0 million.

The analysis of variable costs also considers the environmental damages associated with pollutant emissions from the distributed energy resources that serve the microgrid, based on the operating scenario and emissions rates provided by the Project Team and the understanding that none of the system's generators would be subject to emissions allowance requirements. In this case, the damages attributable to emissions from the new natural gas generator are estimated at approximately $592,000 annually. The majority of these damages are attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $9.1 million.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. In the case of the City of Kingston'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 $9.6 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. The reduction in demand for electricity from bulk energy suppliers would also reduce emissions of CO_2 and particulate matter from these sources, and produce a shift in demand for SO_2 and NO_x emissions allowances. The present value of these benefits is approximately $9.0 million.[54]

The microgrid's CHP system could deliver additional cost savings over the microgrid's 20-year operating period. The fuel savings provided by the CHP system would lead to avoided fuel costs with a present value of approximately $1.6 million.

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

[54] 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.

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.[55] Based on standard capacity factors for solar and natural gas generators, the Project Team estimates the project's impact on demand for generating capacity to be approximately 1.735 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 $2.0 million over a 20-year operating period.

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

Reliability Benefits

An additional benefit of the proposed microgrid would be to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $82,500 per year, with a present value of $934,000 over a 20-year operating period. This estimate is calculated using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[56]

- System Average Interruption Frequency Index – 1.24 events per year
- Customer Average Interruption Duration Index – 136.2 minutes[57]

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

[55] 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.

[56] www.icecalculator.com.

[57] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for Central Hudson Gas & Electric.

rate for backup generators.[58] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

It is important to note that the analysis of reliability benefits assumes that development of a microgrid would insulate the facilities the project would serve from outages of the type captured in SAIFI and CAIDI values. The distribution network within the microgrid is unlikely to be wholly invulnerable to such interruptions in service. All else equal, this assumption will lead the BCA to overstate the reliability benefits the project would provide.

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.8; i.e., the estimate of project benefits is approximately 80 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.[59,60]

As noted above, the City of Kingston's microgrid project would serve six facilities: the City Hall; the Department of Public Works; the Fire Department Headquarters; Kingston High School; Kingston Hospital (i.e., Broadway Campus); and the Benedictine Hospital (i.e., Mary's Avenue Campus). The project's consultants indicate that at present, only the City Hall building is equipped with a backup generator; this unit can support the full level of ordinary services at City Hall. Operation of this unit costs approximately $750 per day. Should this unit fail, City Hall could maintain operations by bringing in a portable diesel generator with sufficient power to

[58] http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1.

[59] 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.

[60] 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.

maintain all services. The operation of this unit would cost approximately $1,100 per day. Similarly, the other facilities served by the microgrid could maintain service by bringing in portable generators. The portable generators would cost approximately: $530 per day for the Fire Department Headquarters; $690 per day for the Department of Public Works; $4,600 per day for Kingston High School; $11,800 per day for Kingston Hospital; and $11,800 per day for the Benedictine Hospital. In the absence of backup power – i.e., if the backup generator failed and no replacement was available – the Fire Department Headquarters would experience at least a 50 percent loss in service capabilities; City Hall and Kingston High School would experience a 75 percent loss in service capabilities; and the Department of Public Works and the hospital facilities would experience at least a 90 percent loss in service capabilities.

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

- City Hall would rely on its existing backup generator, experiencing no loss in service capabilities while the generator operates. If the backup generator fails, the facility would experience a 75 percent loss of service.
- The Fire Department Headquarters would rely on a portable generator, experiencing no loss in service capabilities while this unit is in operation. If the portable generator fails, the fire department would experience at least a 50 percent loss in service effectiveness.
- The Department of Public Works would rely on a portable generator, experiencing no loss in service capabilities while this unit is in operation. If the portable generator fails, the department would experience at least a 90 percent loss in service effectiveness.
- Kingston High School would rely on a portable generator, experiencing no loss in service capabilities while this unit is in operation. If the portable generator fails, the high school would experience a 75 percent loss in service effectiveness.
- Kingston Hospital (i.e., Broadway Campus) would rely on a portable generator, experiencing no loss in service capabilities while this unit is in operation. If the portable generator fails, the hospital would experience at least a 90 percent loss in service effectiveness.
- The Benedictine Hospital (i.e., Mary's Avenue Campus) would rely on a portable generator, experiencing no loss in service capabilities while this unit is in operation. If the portable generator fails, the hospital would experience at least a 90 percent loss in service effectiveness.
- In all six cases, the supply of fuel necessary to operate the backup generator would be maintained indefinitely.
- At each facility, there is a 15 percent chance that the backup generator would fail.

The economic consequences of a major power outage also depend on the value of the services the facilities of interest provide. The analysis calculates the impact of a loss in the city's fire, hospital, and emergency medical services using standard FEMA values for response time to structure fires, the ratio of total property losses to direct property losses due to fires, and the ratio of total value of mortality and injuries to total property loss due to fires; for emergency department visits, death rates from acute myocardial infarction and from various injuries, and the relationship between deaths and travel distance to the emergency department; for cardiac arrest incidence rates per capita, cardiac arrest response times for different environments, and the value of a statistical life. The impact of a loss in service at other facilities is based on the following value of service estimates:

- For City Hall, a value of approximately $34,000 per day. This figure was developed using the U.S. Department of Energy's ICE Calculator.
- For the Department of Public Works, a value of approximately $28,000 per day. This figure was also developed using the ICE Calculator.
- For the Kingston High School, a value of approximately $124,000 per day. This figure is based on the school district's budget for the current school year, scaled to an average daily value and prorated by the percentage of the district's student body who attend the high school. [61,62,63]
- For the Benedictine Hospital, a value of approximately $200,000 per day. This figure was developed using the ICE Calculator (Benedictine Hospital does not have an emergency department and therefore cannot be evaluated using the FEMA methodology for hospital services).

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the six facilities is approximately $134,000 per day.

[61] FY2014-2015 Proposed School District Budget for Kingston City School District (http://www.kingstoncityschools.org/files/1290061/2014-2015budget.pdf).

[62] FY2014-2015 Kingston City School District Total Enrollment (http://data.nysed.gov/enrollment.php?year=2015&instid=800000036308).

[63] FY2014-2015 Kingston High School Enrollment (http://data.nysed.gov/enrollment.php?year=2015&instid=800000036302).

Summary

Figure 6 and Table 37 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 4.5 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

Figure 6. Present Value Results, Scenario 2

(Major Power Outages Averaging 4.5 Days/Year; 7 Percent Discount Rate)

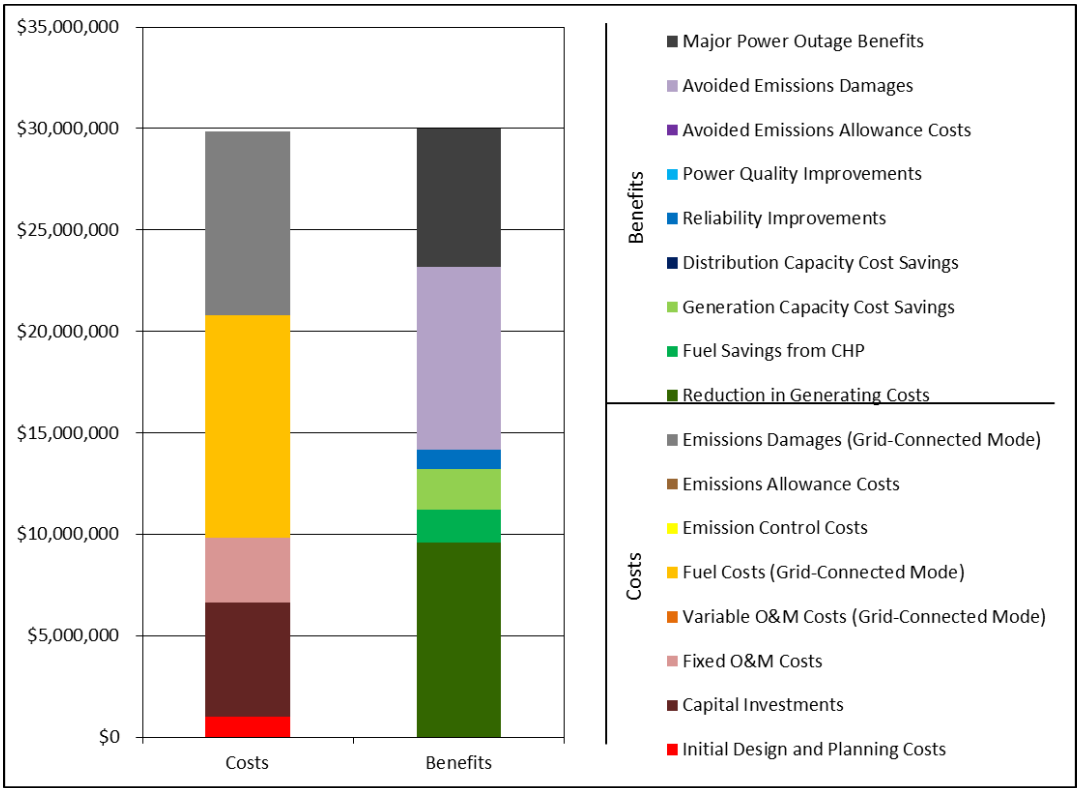


Table 37. Detailed BCA Results, Scenario 2

(Major Power Outages Averaging 4.5 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$1,000,000	$88,200
Capital Investments	$5,610,000	$487,000
Fixed O&M	$3,230,000	$285,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$11,000,000	$967,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$9,070,000	$592,000
Total Costs	**$29,900,000**	
Benefits		
Reduction in Generating Costs	$9,600,000	$847,000
Fuel Savings from CHP	$1,640,000	$144,000
Generation Capacity Cost Savings	$1,980,000	$175,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$934,000	$82,500
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$5,160	$455
Avoided Emissions Damages	$9,030,000	$589,000
Major Power Outage Benefits	$6,800,000	$603,000
Total Benefits	**$30,000,000**	
Net Benefits	**$117,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**7.3%**	

The Project Team assumed an electricity sales price of $0.078 per kWh in Kingston. This is the supply cost for CHG&E, the average amount spent by CHG&E 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 CHG&E grid. In Kingston, the Hudson Valley LBMP is $37.00 per MWh[64], or $0.037 per kWh, a more than 52%

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

reduction in price from the supply cost. The benefits allowed for capacity cost reductions do not bring the electricity prices to parity. This has a predictable influence on the economics of the projects and is the driving force behind the divergent cost benefit analyses developed by the Project Team and by IEc. The Project Team is unaware of any community microgrid business model or generation set that is financially self-sufficient at the LBMP.

5. Summary and Conclusions

5.1 Kingston Lessons Learned and Areas for Improvement

The lessons learned from the Kingston community microgrid feasibility study are divided into two parts. The first part in Section 5 highlights Kingston-specific issues to be addressed moving forward. The second part in Sections 5.1.2 and 5.1.3 addresses statewide issues, replicability, and the perspectives of many stakeholder groups. These lessons learned may be generalized and applied across the State and NY Prize communities.

5.1.1 Kingston Lessons Learned

Through the Kingston community microgrid feasibility study, the Project Team learned site-specific lessons applicable to other communities in its portfolio and around the state. Kingston is the first project in the Team's portfolio to be in an investor-owned utility (IOU) footprint, which brought both advantages and disadvantages to the process.

The Kingston electrical system is triple redundant, meaning the reliability of the system is exceptionally high and outages and other system disruptions are nearly non-existent. This situation undercuts one of the primary arguments in favor of community microgrids: enhanced system resilience. In New York, large storms in recent years have spurred the drive for greater redundancy across the system; however with many of the IOUs this justification does not resonate strongly with the utility. Even though the project is financially justifiable and provides additional steam resources to the community, the utility is not inclined to construct community microgrids in such highly redundant systems. In fact, The feedback from several utilities has been that very few of the NY Prize community microgrids in their service territories address infrastructure cost deferrals or congestion issues. There has also been some apparent discrepancies in the congestion issue zones identified by the NYSERDA website map and the actual issue zones proposed by the IOUs. If it is the case there are only few areas where community microgrids bring immediate resiliency, the utility needs an incentive beyond system resiliency; profitable operation will not incentivize the utility, as IOUs are unlikely to be allowed to own vertically integrated systems and the profits will accrue elsewhere. Therefore, the State and developers must approach IOUs in the context of developing multiple community microgrids and present them with the prospect of serving in a revenue generation distributed system platform (DSP) capacity.

As a utility with a moderately large footprint, customer base, and transmission and distribution (T&D) network, CHG&E has many issues to manage that require its attention, among which community microgrids and NY Prize were just one. For this reason it can be challenging to acquire data and clarifications, although CHG&E responded to requests for load data and infrastructure information. Given their positive engagement, we expect CHG&E to be a strong partner for community microgrids in more reliability-challenged pockets of their footprint or where revenue streams can be found.

A NY Prize Phase II award would require more extensive conversations with CHG&E about their role in a future community microgrid on the proposed footprint and how a community microgrid might utilize existing infrastructure absent direct involvement of the utility.

5.1.2 Statewide Replicability and Lessons Learned

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

Technical. The existing electrical and natural gas infrastructure in a community is the chief determinant of what is possible. The CHG&E feeder structure determined which facilities were included in the community microgrid design, and the Project Team had to work within the existing electrical constraints and CHG&E's operational preferences. CHG&E was not supportive of tying together multiple feeders downstream from the substation. For reasons related to power flow, redundancy, and general system operations, utilities in general have not supported laying new lines to connect different feeders, particularly if the feeders are of different voltages. This limits the number and diversity of facilities that can be connected in the community microgrid because the feeders do not always follow expected alignments. In Kingston, the design relies on an existing redundant feeder to connect the CHP directly to the Jansen Avenue Substation; this line allows the community microgrid to bypass the intermediate facilities and enables blue-sky islanding capability. Further, and with good reason, utilities generally require proposed community microgrids to be placed on the ends of feeders. By doing so, the utility avoids the liability of power supply problems for the non-connected facilities. While this is a practical and reasonable measure, it also limits the placement of the community microgrid and the facilities that can be included.

Lastly, the availability of natural gas infrastructure is a major contributor to positive project feasibility. In communities without natural gas, generation is typically limited to solar PV and the tie in of existing diesel backup generation, given the high costs of storage and biomass and the larger footprints required for wind. Given the intermittency of solar, and the low capacity factor in New York State (approximately 15%), solar installations of a few hundred kW do not provide reliable generation for an islanded community microgrid. In contrast, natural gas-fired generation provides a high reliability baseload, is relatively clean and efficient, and allows for cogenerated steam sales if there is a proximate off-taker. Kingston is fortunate to have the requisite natural gas infrastructure as well as a conveniently located steam off-taker at the hospital. Moreover, solar requires several orders of magnitude more space than containerized natural gas units, rendering large solar generation infeasible in suburban or urban settings such as Kingston.

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

Project financial structures are also important to consider. Revenue from these projects is driven almost exclusively by the sale of electricity and, if available, steam; however, the community 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 community microgrid controls owner(s) would have little opportunity to recoup their investment. This is especially true for privately owned community 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 community microgrid can be developed "behind the meter." While it remains to be seen if utilities will allow this to transpire, a fully behind-the-meter solution in an area with moderate to high electricity prices would likely be a more advantageous financial proposition for connected facilities, as well as for generation and controls owners. Moreover, ancillary services have the potential to provide positive revenue for community microgrids; however, they are hard to qualify for because they require high levels of reserve capacity for most programs, and the payments are somewhat small relative to the electricity that could be generated and sold with an at-capacity generator.

Policy. State policy does not currently address community 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 community microgrids could take payments for islanding in times of high demand on the macrogrid. This scenario, while advantageous from a load shedding perspective, would also remove the community 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. Due to this lack of clarity, DR revenue has generally been excluded from the Project Team's revenue analysis.

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[65] for primarily natural-gas fired projects. Qualifying Facilities must meet certain tests regarding generation type and size, distance, and number of users. A behind-the-meter community microgrid would provide significantly stronger returns to investors, propel New York State in the direction of a "grid of grids," and provide more opportunities for load support and DR across the state. This solution would allow generation assets to load follow the facilities within the community microgrid, selling power closer to retail rates to the associated facilities, which would result in greater revenues. Excess power may be sold to the utility when the locational-based marginal price (LBMP) is greater than the variable cost of production, and additional revenue may be generated through DR programs participation. While many microgrids may already be eligible for QF designation, uncertainty about any given project's regulatory disposition drives up costs. The Project Team believes energy costs in New York State, and the current condition of the electricity infrastructure in the State, are ripe for an economically efficient expansion of a system of community microgrids. However, this remains an elusive proposition without clarifications in policy.

Lastly, local community involvement is an important contributor to community 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 Kingston, support from the utility for this effort has been reasonable, but, though the community has been engaged, communication will need to increase for a successful Phase II execution. In other communities, the Project Team has been in close and frequent contact with administrators, elected officials, and non-governmental community representatives; this type of engagement is necessary to not only build support among prospective facilities but also to engage on ownership models, generation options, and other considerations that will directly affect the feasibility of the proposal. In communities like Kingston, with less engagement, it is somewhat difficult to make firm recommendations, and the Project Team runs the risk of suggesting solutions that are, for whatever reason, unpalatable to the community or utility.

Scalability. Scalability is governed by three factors. The structure of the electrical infrastructure, defined in the technical lessons learned section above, is a key factor to expansion of the community microgrid. At some point of expansion, it becomes necessary to link multiple feeders, and having proximate feeders of the same voltage and connected to desirable facilities is an important criteria. Second, widespread AMI infrastructure makes expansion far less complicated and allows for the selective disconnect of facilities that are not community microgrid participants, and thus the ability to direct power to participating facilities in the event of a grid outage. Kingston's community microgrid is not an AMI remote disconnect based design; however, the utility of AMI is evident in other projects in the Project Teams' portfolio. Lastly, the larger the community microgrid grows, the more switches and controls are need to be

[65] 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.

installed, connected, and maintained for smooth islanding and grid-reconnect processes. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are also likely to push back if the community microgrid grows to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the local utilities to find acceptable footprints that meet the goals of NYSERDA and respect the operational concerns of the utilities.

5.1.3 Stakeholder Lessons Learned

Developers. While Kingston is an exception, 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 community 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; these conditions drive project profitability. Moreover, many of the municipalities are interested in part or full ownership of the projects, but either do not have available funds or lose the project economics without the available tax credits and incentives. In these situations, there may be opportunities for developers to leverage the tax benefits through design-build-own-operate arrangements.

Utilities. The Project Team often experienced problems with information flow. The Project Team would request information about feeders, switches, and other infrastructure from the utilities to inform the best possible community 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.

IOUs in the Project Team's portfolio, including CHG&E in Kingston, were uniformly against allowing a third party operational control of utility-owned infrastructure. This view is understandable, however it engenders a particularly difficult situation if the utility does not support the of community microgrid development. In such situations, the community microgrid will generally be forced to construct duplicate infrastructure, with is both prohibitively expensive and against the spirit of the NY Prize. In the case of Kingston, the Project Team proposes to use already installed duplicate infrastructure; however the consent of CHG&E to move forward has not been forthcoming. In general, utilities which support the integration of their infrastructure to the extent technically possible allow for more expansive community microgrid possibilities.

Academics. Academic considerations in community microgrid development may center around three areas. First, research into a relatively small grid systems with multiple generators (some spinning, some inverter-based), temporally and spatially variable loads, and multidirectional power flows may inform better designs and more efficient placement of generation and controls relative to loads. The second is optimizing financial structures for collections of distributed energy resources and control infrastructure. To date, most microgrids in the United Stated have been campus-style developments in which the grid serves a single institution and can be easily segregated from the macrogrid. Community microgrids consisting of multi-party owned facilities and generation are a new concept, and literature on how best to own and operate such developments is not yet robust. Lastly, and related to financial structures, is the idea of how a "grid of grids" would be managed and structured to provide optimal operational support and the right mix of incentives to encourage customer and utility buy-in.

Communities. Engaged communities are important, but so too are realistic expectations of what a community microgrid might include. Many communities expected dozens of facilities, or entire towns, to be included in the community 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 community microgrid development. Setting expectations ahead of future community microgrid initiatives will help communities begin with more concise and actionable goals for their community microgrids.

NYSERDA. NYSERDA awarded 83 Phase I feasibility studies, providing a wide canvas for jumpstarting community 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 that, while the NY Prize will create a body of knowledge around the development of community microgrids that did not previously exist, it is unlikely to spur unbridled growth of community microgrids in the State without policy changes. This is especially true in regions with relatively low electricity costs. Additionally, 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 community microgrid will provide more resilient energy service, lower peaking emissions, ensure critical and important facilities remain operational during grid outages, and support the goals of New York's REV.

5.2.1 Environmental Benefits

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

5.2.2 Benefits to the City of Kingston

Critical and important facilities in the City of Kingston will receive resilient backup power from the proposed generation assets, ensuring they are available in outage situations and reducing the need for further investments in backup generation. The electricity generated with the solar PV array and the natural gas-fired CHP unit will also offset higher-emission peaking assets during peak demand events. In addition, the PV array will help Kingston achieve its goal of generating at least 20% of the city's energy from renewable sources by 2020. The additional electricity supply will also obviate the need for the hospital to run its diesel generators whenever there is a grid interruption, reducing local emissions. The Project Team met with the community in person on February 12th, 2016 to provide a summary of project analyses and provide a recommended approach for a path forward.

5.2.3 Benefits to Residents in and around Kingston

Residents of Kingston and the surrounding community stand to gain from access to a broad range of critical services anytime the community microgrid is forced into islanded operation by an outage on the grid. Even if they are not formally connected to the community microgrid, all residents of Kingston and nearby surrounding communities will have access to healthcare and municipal services in the event of an outage. In the future, the community microgrid could be expanded to connect more facilities.

5.2.4 Benefits to Healthcare Customers

The Benedictine and Broadway Campus Hospitals will benefit from the reliability and resilience of the community microgrid. The community microgrid will allow the hospitals to operate at near full capacity during a grid outage and will reduce their reliance on relatively more expensive diesel backup generation. Moreover, the Benedictine Hospital will be able to reduce operational wear and tear on its existing steam boilers as it switches to CHP generated steam for much of its load.

5.2.5 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 Kingston community microgrid will provide a proof of concept for the ownership and operation of a hybrid community microgrid with local utility support. In addition, the lessons learned described in Section 5.1 are widely applicable to the further development of REV and future NY Prize efforts. Tasks 2 and 3 also illustrate the support provided by this community microgrid proposal, and its lessons learned, to the REV proceedings.

5.3 Conclusion and Recommendations

The Project Team has concluded the proposed Kingston community microgrid is feasible. This document has detailed the capabilities of the community microgrid, its primary technical design, the commercial, financial, and legal viability of the project, and the costs and benefits of the community microgrid. The community microgrid meets all of the NYSERDA required capabilities and most of its preferred capabilities.

Major challenges include gaining CHG&E's support of using existing infrastructure and working with the hospital to both site the CHP and off-take the steam. A failure to address any one of these conditions would make it difficult to develop and operate the community microgrid as it is current proposed. With positive adjudication, the community microgrid stands to be a case study in collaborative operation and the drivers of community microgrid profitability.

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

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

Finally, the project will demonstrate the widely distributed benefits of community microgrids paired with DER assets. The utility will see increased revenues and grid performance, customers will see stabilized electricity and steam prices provided by a more reliable grid system, the community will reap the positive benefits of living in and around the community microgrid, and industrial customers will benefit from reduced energy costs and the value of avoided outages. For these reasons, the Project Team strongly recommends this project be selected for continued participation in the NYSERDA New York Prize Community Microgrid Competition.

Appendix

With fully executed non-disclosure agreements (NDAs), the team was able to compile load data leveraging CHG&E's on-line portal. A simulator was used to more accurately profile typical 24-hour load curves for each facility. They are included in this feasibility study to show which facilities have the highest and lowest load demands at different times of the day. Analyzing these load demand curves has allowed the team to develop a better overall understanding of the generation capacity needed to sustain the microgrid. Further, by knowing precisely when load demands are at their peak, the team was able to formulate a peak-shaving program to efficiently manage the system.

REDACTED PER NDA WITH CHG&E