69 - Village of Sherburne

Notice

Village of Sherburne Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

Prepared for:

New York State Energy Research and Development Agency (NYSERDA)
17 Columbia Circle
Albany, NY 12203-6399
Project Manager: Michael Razanousky

Prepared by:

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

Date Submitted: March 30, 2016

Contract Number: 61966, Task 5

Points of Contact Authorized for the Village of Sherburne Microgrid Study:

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

Travis Dubois
15 West State Street
P.O. Box 704
Sherburne, NY 13460
Phone: 607-674-2202
Email: travis.dubois@sherburne.org

Notice

Abstract

Together with the Village of Sherburne (hereafter Sherburne or the Village), Booz Allen Hamilton has completed the feasibility study for a proposed microgrid. This study summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is feasible, though not without challenges. The commercial and financial viability of the project have been analyzed and detailed in this document. The Sherburne microgrid project faces the challenge of high capital costs, but it benefits from an advantageous mix of generation and loads as well as the presence of a municipally-owned utility. Running natural gas infrastructure to the Village will be a project prerequisite to support a new 2 megawatt (MW) combined heat and power (CHP) unit. Alongside a 2 MW solar photovoltaic (PV) array, the CHP unit will provide reliable electricity and steam to customers while demonstrating a proof of concept for a community microgrid owned by a municipal utility. The Sherburne microgrid also offers an ideal opportunity to explore the expansion of advanced metering infrastructure (AMI) functionality. 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, Sherburne

Contents

Notice i

Abstract ii

Figures vi

Tables vi

Acronyms and Abbreviations viii

Executive Summary x

1. Introduction 1

2. Microgrid Capabilities and Technical Design and Configuration 1

2.1 Project Purpose and Need 2

2.2 Microgrid Required and Preferred Capabilities (Sub Tasks 1.1 and 1.2) 3

2.2.1 Serving Multiple, Physically Separated Critical Facilities 4
2.2.2 Limited Use of Diesel Fueled Generators 5
2.2.3 Local Power in both Grid-Connected and Islanded Mode 5
2.2.4 Intentional Islanding 5
2.2.5 Seamless and Automatic Grid Separation Restoration 5
2.2.6 Standardized Interconnection 6
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 8
2.2.12 Resiliency to Weather Conditions 8
2.2.13 Black Start Capability 8
2.2.14 Energy Efficiency (EE) Upgrades 8
2.2.15 Cyber Security 9
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 10
2.2.21 Active Network Control System 10
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 11
2.2.27 Protection Coordination 11
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
2.2.32 Demonstrate Tangible Community Benefit 12

2.3 Distributed Energy Resources Characterization (Sub Task 2.3) 12

2.3.1 Existing Generation Assets 12
2.3.2 Proposed Generation Assets 14
2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics 14
2.4 Load Characterization (Sub Task 2.2) 15
2.4.1 Electrical Load 15
2.4.2 Thermal Consumption 19
2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1) 19
2.5.1 Grid Connected Parallel Mode 20
2.5.2 Intentional Islanded Mode 20
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 24
2.6.3 Basic Protection Mechanism within the Microgrid Boundary 26
2.6.4 Thermal Infrastructure 26
2.7 Microgrid and Building Control Characterization (Sub Task 2.5) 26
2.7.1 Microgrid Supporting Computer Hardware, Software and Control Components 27
2.7.2 Grid Parallel Mode Control 28
2.7.3 Islanded Mode Control 28
2.7.4 Black Start 29
2.7.5 Resynchronization to NYSEG Power 30
2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6) 31
2.8.1 Existing IT & Telecommunications Infrastructure 31
2.8.2 IT Infrastructure and Microgrid Integration 31
2.8.3 Network Resiliency 31
2.9 Microgrid Capability and Technical Design and Characterization Conclusions ... 32
3. Assessment of Microgrid's Commercial and Financial Feasibility (Task 3) . 33
3.1 Commercial Viability – Customers (Sub Task 3.1) 34
3.1.1 Other Stakeholders 35
3.1.2 Purchasing Relationship 36
3.1.3 Solicitation and Registration 37
3.2 Commercial Viability – Value Proposition (Sub Task 3.2) 37
3.2.1 Business Model 37
3.2.2 Replicability and Scalability 39
3.2.3 Benefits, Costs and Value 40
3.2.4 Demonstration of State Policy 47
3.3 Commercial Viability – Project Team (Sub Task 3.3) 47
3.3.1 Stakeholder Engagement 47
3.3.2 Project Team 47
3.3.3 Financial Strength 50
3.4 Commercial Viability – Creating and Delivering Value (Sub Task 3.4) 50
3.4.1 Barriers to Completion 51
3.4.2 Permitting 52
3.5 Financial Viability (Sub Task 3.5) 52
3.5.1 Revenue, Cost, and Profitability 52

3.5.2 Financing Structure 54
3.6 Legal Viability (Sub Task 3.6) 55
3.6.1 Ownership and Access 55
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) 62
4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3) 65
4.3.1 Peak load support 65
4.3.2 Demand Response 66
4.3.3 Deferral of Transmission/Distribution Requirements 66
4.3.4 Ancillary Service 67
4.3.5 Development of a Combined Heat and Power System 67
4.3.6 Environmental Regulation for Emission 68
4.4 Project Costs (Sub Task 4.4) 69
4.4.1 Project Capital Cost 69
4.4.2 Initial Planning and Design Cost 73
4.4.3 Operations and Maintenance Cost 74
4.4.4 Distributed Energy Resource Replenishing Fuel Time 75
4.5 Costs to Maintain Service during a Power Outage (Sub Task 4.5) 76
4.5.1 Backup Generation Cost during a Power Outage 76
4.5.2 Cost to Maintain Service during a Power Outage 79
4.6 Services Supported by the Microgrid (Sub Task 4.6) 79
4.7 Industrial Economics Benefit-Cost Analysis Report 80
4.7.1 Overview 81
4.7.2 Methodology and Assumptions 81
4.7.3 Results 83
5. Summary and Conclusions 94
5.1 Sherburne Lessons Learned 94
5.1.1 Statewide Lessons Learned 95
5.1.2 Stakeholder Lessons Learned 98
5.2 Benefits Analysis 99
5.2.1 Environmental Benefits 99
5.2.2 Benefits to Local Government 100
5.2.3 Benefits to Residents of Sherburne 100
5.2.4 Benefits to Industrial Stakeholders 100
5.2.5 Benefits to Commercial Customers 100
5.2.6 Benefits to New York State 101
5.3 Conclusion and Recommendations 101
Appendix 103
Typical 24-Hour Load Profile - Municipal Building ..... **Error! Bookmark not defined.**

Typical 24-Hour Load Profile - Sherburne Electric and DPW . **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Sherburne-Earlville Central Public Schools **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Waste Water Treatment Plant **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Railroad Crossing Gate .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Wastewater Pump Station ...... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - U.S. Postal Service .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Chenango Memorial Hospital Health Clinic .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Basset Healthcare .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Service Pharmacy .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Southern Tier Pet Nutrition .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Egg Low Farms Inc. .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Mirabito’s Gas Station .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Big M Supermarket .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - NBT Bank of Sherburne......... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Frontier Communications....... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - NYCM Insurance .... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Grace Manor.......................... **Error! Bookmark not defined.**
Typical 24-Hour Load Profile - Senior Housing...................... **Error! Bookmark not defined.**
Sherburne Microgrid Operation One-Line: Black Start / System Isolated .... **Error! Bookmark not defined.**
Sherburne Microgrid Operation One-Line: Island Mode.......... **Error! Bookmark not defined.**
Sherburne Microgrid Operation One-Line: Parallel Mode (from Islanded Mode) .... **Error! Bookmark not defined.**
Sherburne Microgrid Operation One-Line: Grid Connected Mode .... **Error! Bookmark not defined.**

Figures

Figure ES- 1. Map of Sherburne Microgrid Coverage Area.. xii
Figure 1. Sherburne Equipment Layout.. 17
Figure 2. Typical 24-Hour Cumulative (74 points) Load Profile, Aug. 2015 Metering Data 18
Figure 3. Monthly Steam Thermal Loads, Southern Tier Pet Nutrition and Egg Low Farms...... 19
Figure 4. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate).. 84
Figure 5. Present Value Results, Scenario 2 (Major Power Outages Averaging 3.6 Days/Year; 7 Percent Discount Rate) 92

Tables

Table ES- 1. Prospective Microgrid Facilities ... x
Table ES- 2. Microgrid Generation Assets ... xi
Table 1. Outage Summary by Category ... 2
Table 2. Microgrid Capabilities Matrix ... 3
Table 3. New York State Interconnection Standards ... 6
Table 4. Potential EE Upgrades to Microgrid Facilities ... 9
Table 5. Existing Distributed Energy Resources ... 14
Table 6. Proposed Generation Assets ... 14
Table 7. Sherburne List of Prospective Microgrid Facilities ... 16
Table 8. Sherburne's 2014 Microgrid Load Points ... 18
Table 9. Sherburne Distributed Switches Description ... 21
Table 10. Sherburne Network Switch Description ... 22
Table 11. Sherburne Server Description ... 22
Table 12. List of Additional Components ... 25
Table 13. Microgrid Customers ... 34
Table 16. Sherburne Microgrid SWOT ... 38
Table 15. Microgrid Benefits, Costs, and Value Proposition for Sherburne Electric ... 41
Table 16. Microgrid Benefits, Costs, and Value Proposition for Sherburne ... 42
Table 17. Microgrid Benefits, Costs, and Value Proposition for Residents ... 43
Table 18. Microgrid Benefits, Costs, and Value Proposition for Industry ... 44
Table 19. Microgrid Benefits, Costs, and Value Proposition for Commerical Customers ... 45
Table 20. Microgrid Benefits, Costs, and Value Proposition for the Community ... 46
Table 21. Microgrid Benefits, Costs, and Value Proposition for New York State ... 46
Table 22. Project Team ... 48
Table 23. Project Team Roles and Responsibilities ... 48
Table 24. Savings and Revenue Streams ... 53
Table 25. Capital and Operating Costs ... 53
Table 26. Available Incentive Programs ... 54
Table 27. Facility and Customer Detail Benefit ... 59
Table 28. Distributed Energy Resources ... 64
Table 29. Distributed Energy Resource Peak Load Support ... 66
Table 30. Emission Rates ... 69
Table 31. Capital Cost of North and South Substations ... 70
Table 32. Capital Cost of Distributed Equipment ... 72
Table 33. Capital Cost of Proposed Generation Units ... 72
Table 34. Initial Planning and Design Cost ... 74
Table 35. Fixed Operating and Maintenance Cost ... 75
Table 36. Maximum Fuel Operating Time for Distributed Energy Resource ... 76
Table 37. Cost of Generation During a Power Outage ... 78
Table 38. Critical Services Supported ... 80
Table 39. BCA Results (Assuming 7 Percent Discount Rate) ... 83
Table 40. Detailed BCA Results, Scenario 1 ... 85
Table 41. Backup Power Costs and Level of Service, Scenario 2 ... 89
Table 42. Detailed BCA Results, Scenario 2 ... 93

Acronyms and Abbreviations

AC	Alternating Current
AMI	Advanced Metering Infrastructure
ATS	Automatic Transfer Switch
BCA	Benefit Cost Analysis
BEMS	Building Energy Management Systems
BTU	British Thermal Unit
CAIDI	Customer Average Interruption Duration Index
CCA	Community Choice Aggregation
CHP	Combined Heat and Power
DADRP	Day Ahead Demand Response Program
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
GOAB	Group-operated Air-break
Hz	Hertz
ICCP	Inter-Control Center Communications Protocol
IEc	Industrial Economics
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor Owned Utility
ISM	Industrial Scientific and Medical
IT	Information Technology
ITC	Investment Tax Credit
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hour
LAN	Local Area Network
LED	Light-Emitting Diode
Mcf	One Thousand Cubic Feet of Natural Gas
MCS	Microgrid Control System
MHz	Megahertz
MMBTU	One Million British Thermal Units
$MMTCO_2e$	Million Metric Tons CO_2 Equivalent
$MTCO_2e$	Metric Tons CO_2 Equivalent
MVA	Mega Volt Amperes
MW	Megawatt
MWh	Megawatt-hour

NFPA	National Fire Protection Association
NPV	Net Present Value
NYISO	New York Independent System Operator
NYMPA	New York Municipal Power Agency
NYPA	New York Power Authority
NYPSC	New York Public Service Commission
NYS DEC	New York State Department of Environmental Conservation
NYSEG	New York State Electric and Gas Corporation
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
OPC	Open Platform Communication or OLE (Object Link Embedded) Process Control
OPF	Optimal Power Flow
PCC	Point of Common Coupling
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PV	Photovoltaic
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 Village of Sherburne, New York. This deliverable presents the findings and recommendations, discusses the results and lessons learned from the project, and lays out the environmental and economic benefits for the project. Our design demonstrates the Village 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) by constructing 4 MW of clean energy generation capability. The study concludes that the technical design is feasible.

The Sherburne microgrid project will connect seven critical facilities (per NYSERDA's definition), five facilities important to the community as a whole, and seven other facilities into a community microgrid. Table ES-1 lists the facilities under consideration for the microgrid.

Table ES- 1. Prospective Microgrid Facilities

Table lists the facilities in the Village of Sherburne's proposed microgrid, including their classifications as public, commercial, or residential. The table denotes critical/important facilities and provides their labels for Figure ES-1.

Key on Map	Property	Address	Classification
F1	**Village Municipal Building** (Village office, Fire Department, Police Department, and Ambulance)	15 W. State St	Public
F2	**Sherburne Electric and DPW**	13-27 Classic St	Public
F3	**Sherburne-Earlville Central Public Schools**	13 School St	Public
F4	**Wastewater Treatment Plant**	50 West State St	Public
F5	**Railroad Crossing gates/signal**	State Rte. 80	Public
F6	**Village of Sherburne Wastewater Pump Station**	Canal St	Public
F7	**US Postal Service**	4 W. State St	Public
F8	**Chenango Memorial Hospital Health Clinic**	38 Classic St	Health
F9	**Basset Healthcare**	20 Chapel St	Health
F10	**Service Pharmacy**	6 N. Main St	Health
F11	**Southern Tier Pet Nutrition**	8 W. State St	Industry
F12	**Egg Low Farms Inc.**	35 W. State St	Industry
F13	**Mirabito's Gas Station**	86 N. Main St	Commercial
F14	**Big M Supermarket**	4 South Main St	Commercial
F15	**NBT Bank of Sherburne**	30 N Main St	Commercial
F16	**Frontier Communications**	14 Classic St	Commercial
F17	**NYCM Insurance**	16 Chapel St	Commercial
F18	**Grace Manor (low-income housing)**	2-8 Knapp St	Residential
F19	**Senior Housing**	18 Chapel St	Residential

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.

- Two existing backup diesel generators at Frontier Communications (1 MW) and NYCM Insurance (500 kilowatts (kW))
- Two existing 10 kW solar PV arrays at Sherburne-Earlville Central High School and the Sherburne Electric and Department of Public Works (DPW)
- A proposed 2 MW natural gas-fired continuous duty reciprocating CHP generator located behind Sherburne's Firehouse (15 West State Street) that will provide the thermal energy (steam) requirements for Southern Tier Pet Nutrition and Egg Low Farms
- A proposed 2 MW PV array system behind Sherburne's DPW facility

The existing and proposed generation assets will supply 100% of the electricity requirements of the facilities in Table ES-1 during emergency outage conditions, providing relief to residents in and around Sherburne. The backup power generated by the microgrid will ensure food, fuel, banking, and healthcare all remain accessible in the event of a long-term grid outage. In addition, the CHP unit will sell steam to the industrial customers Egg Low Farms and Southern Tier Pet Nutrition during both grid-connected and island mode, lowering the energy costs and greenhouse gas (GHG) emissions of these facilities, and it will push electricity into the Sherburne grid during normal and islanded operation. The PV array will also operate in islanded and grid-connected mode to lower the Village's overall electricity costs. With the addition of these generation assets, the Village could experience stabilized and reduced energy prices and potentially profit from exporting excess energy back to New York State Electric and Gas (NYSEG). Table ES-2 provides details about the generation assets, and Figure ES-1 shows the locations of both the assets and the prospective facilities.

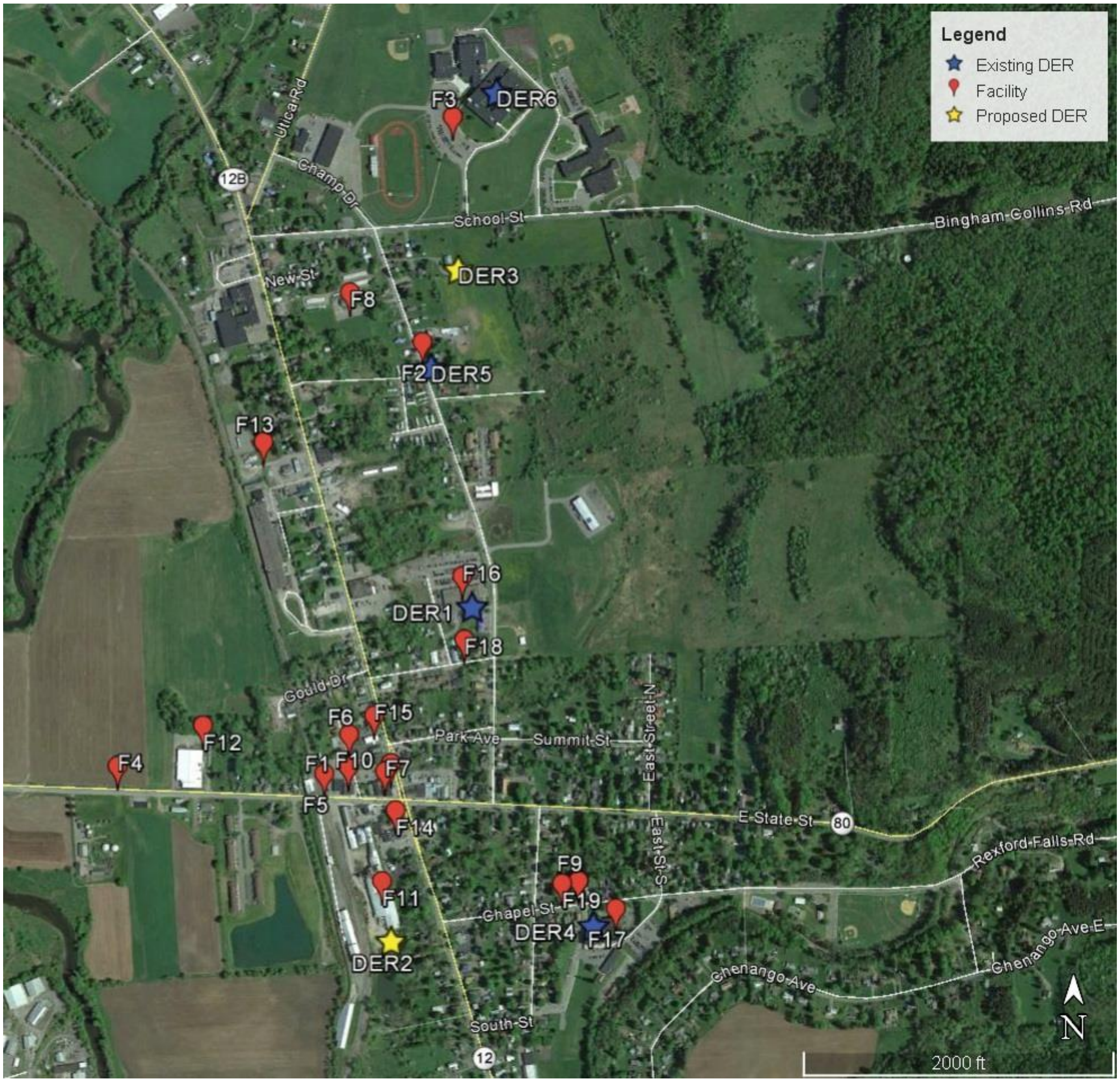
Table ES- 2. Microgrid Generation Assets

Table lists the existing and proposed distributed energy resources (DERs) in the Village of Sherburne's proposed microgrid and provides their labels for Figure ES-1.

Name	Description	Fuel Source	Capacity (kW)	Address
DER1	Frontier Communications Backup	Diesel	1,000	14 Classic St
DER2	Proposed Natural Gas CHP unit	Natural Gas	2,000	15 West State St
DER3	Proposed Solar PV array	N/A	2,000	Behind 27 Classic St
DER4	NYCM Insurance Backup	Diesel	500	16 Chapel St
DER5	Existing PV	N/A	10	13-27 Classic St
DER6	Existing PV	N/A	10	13 School St

Figure ES- 1. Map of Sherburne Microgrid Coverage Area

Detailed map of the coverage area illustrating where the microgrid facilities and DERs are located relative to each other and the main streets within Sherburne.



Sherburne and the municipally-owned utility (MOU) Sherburne Electric will own the microgrid, and all equipment will be installed on city or utility-owned land. Because Sherburne Electric is wholly owned by the municipality, it is well positioned to adopt a vertically integrated, utility-owned microgrid. This ownership model offers many benefits, including increased flexibility for the utility and Village customer base and a simplified permitting process. The vertically integrated ownership model also affords Sherburne a seamless integration of generation, microgrid controllers, and distribution infrastructure and allows the utility to capture the full suite of revenue streams, estimated at $1.4 million per year. The model will maintain the current billing and rate capture mechanisms because Sherburne Electric is already the energy provider to all proposed microgrid customers.

The microgrid will incur initial capital costs of $9.8 million as well as operation, maintenance, and fuel costs totaling $1.1 million per year. Sherburne Electric cannot support a cash outlay, so instead it will initiate a bond offering on the municipal bond market for its share of the capital cost. If Sherburne receives NY Prize Phase III, this bond offering will total $4.9 million. NY Prize Phase III funding is critical to this proposal's viability because the revenues generated by the electric and steam sales will not fully recover capital expenditures. The Project Team did not include additional incentive payments from the NY Sun Program, CHP Performance Program, or Federal Investment Tax Credit (ITC) as part of the commercial feasibility analysis because Sherburne Electric, the owner and operator of the microgrid, will not qualify for these programs. However, Sherburne Electric may be able to slightly improve the project's commercial feasibility by selling the tax equity from the ITC to an eligible private entity.

In order to successfully establish a microgrid in Sherburne, natural gas infrastructure must be extended to the Village and the existing AMI needs to be upgraded to allow for remote disconnect to control loads. Sherburne is already planning to bring natural gas to the Village, so this is not viewed as a cost to the microgrid project. The AMI remote disconnect, a cutting edge technology, is not fully supported by the existing AMI meters in Sherburne. Technical issues are still being worked out, including how the AMI meters will tie into the Supervisory Control and Data Acquisition (SCADA) control system and how quickly remote reconnect can be achieved from control systems signals. However, the Booz Allen Hamilton team expects this functionality to be operational by the time of construction based on conversations with the community and the AMI provider.

The Sherburne microgrid concept, with new clean and renewable generation and the integration of existing energy resources, provides the Village with an energy resilience solution that is technically sound and, with NY Prize Phase III funding, financially viable. The ability to island 19 critical and important facilities, including groceries, fuel, banking, healthcare, and emergency services, will significantly bolster the resilience of the Village during emergencies and extended grid outages.

1. Introduction

Working with the Sherburne, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary microgrid concept to connect 19 critical and important facilities across the Village to two new generation assets, a 2 MW CHP and a 2 MW solar PV array. Using the existing AMI network in the Village, the microgrid will serve physically disparate facilities, providing a diverse array of services to the residents of Sherburne and surrounding areas.

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

Because the local generation assets can operate in parallel with the main grid, the microgrid will stabilize energy costs in addition to supporting the Village during major power outages. In order to achieve islanding capabilities, Sherburne should utilize a combination of smart switches and AMI meters with remote disconnect capabilities to isolate critical loads. Two significant items remain in order for the microgrid design to become a reality: the natural gas line needs to be extended to Sherburne and the AMI meters need to be able to remotely disconnect loads with SCADA control.

The construction of the microgrid will require significant capital at the outset as well as ongoing costs for fuel, operation, and maintenance. In order to improve the financial viability of the project, Sherburne should incorporate the large industrial presence clustered in the Village center as a continuous baseload for electric and thermal generation. Permitting and regulatory challenges should not present any difficulties because new construction will occur on land owned by the Village or utility.

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

Sherburne and its residents seek to improve resiliency of energy service, stabilize costs, and lower their environmental footprint. The Sherburne microgrid will improve the resiliency of the local electricity grid, accommodate distributed energy resources, stabilize energy prices during peak events through decreased New York Municipal Power Authority (NYMPA) purchases, and reduce greenhouse gas emissions. More specifically, the Village faces several challenges that could be resolved with a community microgrid:

- There are critical services in Sherburne—specifically village offices, police department, and fire department—without emergency back-up generation. In the event of interruption to grid supplied power, these services will be greatly impaired. A microgrid could mitigate this threat by tying critical services to existing generation assets and building a stronger case for distributed energy resources.
- Typical to the state, Sherburne Electric's coverage area has experienced interruption of service due to storm-related events and other causes. This includes loss of over 8,000 customer minutes because of Hurricane Irene and Hurricane Sandy. Other factors have also cause significant interruption to service, including transformer failure, fallen trees, and lightning as demonstrated in Table 1 below.

Table 1. Outage Summary by Category

An overview of customer minutes lost and number of customer outages per major cause including hurricanes, lightning, fallen trees and transformer failures. Also included is the outage duration in minutes.

Cause	# of Customer (minutes)	Customers Impacted	Outage Duration per Customer (minutes)
Hurricanes Sandy and Irene	8,445	108	78
Lightning	26,225	496	53
Tree in Right-of-Way	73,860	1155	64
Tree out of Right-of-Way	68,115	747	91
Transformer Failure	24,675	110	224

Distributed energy resources also provides for more price stability in electricity production and the ability to avoid relatively expensive purchases outside of Sherburne's primary Power Purchase Agreement (PPA) with the New York Power Authority (NYPA). Sherburne pays between $.011 and $.014/kWh for NYPA power, while NYMPA costs are approximately $.1/kWh, a nearly ten-fold increase for the 15-20% of Sherburne electricity that comes from NYMPA. The microgrid, by virtue of the 2 MW solar PV and the replacement of No. 2 fuel oil steam production with natural gas CHP steam production, will reduce Sherburne's GHG footprint. While a portion of the offset electricity purchases are from hydropower, the overall effect of replacing the fuel oil, adding the solar, and reducing non-hydro peak purchases yield a net decrease in emissions.

Sherburne has a strong interest in distributed energy resources. Many industrial entities have large thermal and electric appetite, which make them good candidates for cogeneration. There is also ample flat and unproductive land that could be used to produce solar energy. A microgrid could aid in this by combining multiple loads in order to improve the financial case for a project.

Implementing a community microgrid may address these and other goals such as acting as a catalyst for bringing natural gas supply to the Village and fully utilizing the AMI remote disconnect meters tied into the proposed SCADA and energy management system (EMS) control system.

The proposed solution consists of two distinct parts, distributed energy resources (DER) and the communication infrastructure with accompanying monitoring and control of the DER. The DER component includes local power generation—including 1.52 MW of existing assets as well as new clean energy sources to be developed—and controllable loads. If the local generation is producing the power in parallel with the main grid, the supporting communication and control infrastructure will ensure that the local generation assets follow the main grid frequency, voltage, and phase by operating in a fully synchronized manner with the New York Independent System Operator (NYISO) grid provisions. During the islanding operation, the supporting infrastructure will provide orderly microgrid connection and disconnection from the main grid, local load following, acceptable frequency and voltage, load shedding, and black start capability.

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

The NYSERDA statement of work (SOW) 61966 outlines 15 required capabilities and 18 preferred capabilities each NY Prize microgrid feasibility study must address. Table 2 summarizes required and preferred capabilities met by the proposed microgrid design in greater detail.

Table 2. Microgrid Capabilities Matrix

Listing of NYSERDA required and preferred capabilities and annotations of whether or not the Sherburne microgrid will be able to meet these criteria.

Capability	Required/ Preferred	Microgrid will meet (Y/N)
Serves more than one, physically separated critical facilities	Required	Y
Primary generation source not totally diesel fueled	Required	Y
Provides on-site power in both grid-connected and islanded mode	Required	Y
Intentional islanding	Required	Y
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

Capability	Required/ Preferred	Microgrid will meet (Y/N)
Diverse customer mix (residential, commercial, industrial)	Required	Y
Resiliency to wind, rain, and snow storms	Required	Y
Provide black-start capability	Required	Y
Energy efficiency 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 sections that follow address how the microgrid will meet these capabilities in more detail.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

Sherburne and the Booz Allen team have identified seven facilities that are considered critical facilities by NYSERDA's definition to be tied into the microgrid, including schools (which could be used for shelter during a natural disaster), a wastewater treatment plant, and health clinics.[1] The microgrid will also serve power to facilities not designated as critical by NYSERDA standards, but that the team views as important to be operational during an outage or emergency (e.g. railroad crossings, gas stations, supermarkets, banks, and assisted living homes). See Table ES-1 for a full list of prospective critical and important facilities to be tied into the microgrid.

In total, the current number of proposed facilities to be included in the microgrid is 19, which amounts to 74 total load points. All loads are within a 1 mile radius, interconnected via medium voltage (8.3 kilovolt (kV)) distribution which is owned by Sherburne. Sherburne has a suitable existing IT network that is capable of adding the microgrid to its operations, however, it will still

[1] RFP 3044 NY Prize Community Grid Competition, NYSERDA, 2015, Page 3

rely on the microgrid's devices which use industry standard protocols such as Distributed Network Protocol (DNP3), Modbus, IEC 61850, and others as required, to utilize the existing IT network by enabling remote monitoring and control of the physically separated critical facilities. The microgrid design is also flexible and scalable to accommodate the addition of, or expansion of, critical facilities.

2.2.2 Limited Use of Diesel Fueled Generators

The proposed design includes a new natural gas fired CHP unit to serve as the primary energy source for the microgrid. Southern Tier Pet Nutrition and Egg Low Farms, two local industrial partners, have expressed interest in being the main off-takers of the steam generated by the CHP facility. Southern Tier Pet Nutrition requires dry (superheated) steam at a pressure close to 125 psi which the proposed 2 MW CHP is capable of generating. The 2 MW solar PV array will supplement the natural gas fired base-load generation.

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 stability and reliability of the microgrid. While in grid connected mode, or paralleling with the grid, the microgrid will optimize the use of available assets to reduce energy cost when possible and export to the connected grid if and when economic and technical conditions are in alignment. For example, a solar PV system could operate in parallel to the grid under normal operation, reducing Sherburne's dependence on grid power. In island mode, the solar PV system would function alongside the other generators to meet critical load needs as well.

2.2.4 Intentional Islanding

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

More data on the microgrid's operation in island mode can be found in Section 2.5.2. It bears repeating to note here that not all of the Village will be electrified during islanded mode, only the facilities registered as part of the microgrid footprint will.

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.

2.2.6 Standardized Interconnection

This microgrid feasibility study will be governed by the New York Public Service Commission (NYPSC) interconnection standards. Table 4 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 Sherburne, 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 resources components as outlined in Table 3.

Table 3. 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 Herz (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

Standard Category	Description
	• 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. For 24/7 operation capability to be met, the Village will have to install a gas distribution pipeline that taps into the existing gas line connection points. One interconnection point is located 2.5 miles away, and the other is 5 miles away; the latter offers more capacity and pressure. Another option for achieving 24/7 capability is to utilize a storage tank large enough to hold a 7 day supply of natural gas.

2.2.8 Two Way Communication with Local Utility

Sherburne Electric's current automation system allows the operator to receive data but does not allow him to send controls to the existing substation. The new automation solution proposed in this deliverable will serve as a protocol converter to send and receive all data available over Sherburne's network using industry standard protocols such as DNP3 as well as Open Platform Communication (OPC), Modbus, IEC 61850, ICCP (IEC 60870-6).

2.2.9 Voltage and Frequency Synchronism When Connected to the Grid

Power generated either by the rotating sources or inverter based energy sources (e.g. PV) will be frequency and phase synchronized with the main grid. Synchronization is accomplished by comparing the two generation assets' output voltage, frequency, and phase using a phase-locked-loop circuit. This is one of the most fundamental principles allowing 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 maintain control of 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

Power quality and stability of the supply can be negatively affected by too much industrial and/or electronics based loads. To avoid power quality challenges the Sherburne Microgrid will have a more balanced load across customer classes. The Microgrid Power Management System will allow for an acceptable mix of residential, commercial, or industrial customers. The Sherburne microgrid will have the following customer mix:

- Residential – 4% of load
- Industrial – 23% of load
- Commercial – 33% of load
- Government - 40% of load

2.2.12 Resiliency to Weather Conditions

Most typical forces of nature affecting Sherburne 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 deployment of other sensors to ensure the network is as resilient as possible to storms and other unforeseen forces of nature. Positioning proposed equipment in higher areas of the town that are not prone to flooding is also important. Ideally the natural gas pipeline will be buried 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. The proposed CHP will, at a minimum, have a container to harden it from adverse weather conditions. More research is being done by the team to best protect this generator and all the others in the microgrid.

2.2.13 Black Start Capability

When the grid power goes out for Sherburne, islanded mode is initiated by distributed energy resources' black start capability. This mode of operation will require generators being used for black start to have black start capability by having at a minimum a direct current (DC) auxiliary support system which must have 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 diesel generators be equipped with black start capabilities.

2.2.14 Energy Efficiency (EE) Upgrades

Reducing the size of facilities loads is essential to minimize the generation capacity required to power the microgrid. The project implementation team worked with Sherburne electric to benchmark and estimate the electricity demand reduction potential and the EE upgrades to help achieve this. Booz Allen estimates the reduction potential for the 19 facilities to be approximately 200 kW.

Table 4 provides a list of potential EE upgrades that will help achieve this targeted reduction. The project will utilize Sherburne Electric's successful EE program to implement the projects and identify further reduction at the microgrid facilities. The project implementation team will also seek to qualify microgrid facilities for NYSERDA funded EE programs, including the enrolling the industrial facilities —the largest loads in the microgrid—in the Commercial Existing Facilities Program.

Table 4. Potential EE Upgrades to Microgrid Facilities

Provides an overview of the potential energy efficiency upgrades at the following facilities: Egg Low Farms, Southern Tier Pet Nutrition, Sherburne-Earlville Central Public Schools, Village Offices, Fire Department, and Senior Housing and Grace Manor. Also denotes existing efficiency programs.

Facility	Potential EE Upgrades	Existing Utility EE Program (✓)
Egg Low Farms	- Upgrade/replace refrigeration	
	- Building envelop	✓
	- Process improvements	✓
Southern Tier Pet Nutrition	- Replace high-bay lighting with light-emitting diode (LED)	✓
	- Process improvements	✓
NYCM Insurance	- T8 fluorescent lighting	
	- Building envelop	✓
Sherburne-Earlville Central Public Schools	- Replace gymnasium lighting with LED	✓
	- Building envelop (including sealing air leaks in windows and doors)	
Village Officers	- Replace lighting with LED	✓
	- Electric heating system upgrades	
	- Building envelop	
Fire Department	- Building envelop (including replacing doors)	
Senior Housing & Grace Manor	- Electric heating system upgrades	

2.2.15 Cyber Security

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

Considering the logical controllers (IEDs) will be located at or near loads, this means the distributed equipment will take the IT system to the “edge” of the Village network, therefore, potentially more vulnerable to hackers. A practical tool to prevent unauthorized access into the

Sherburne network is a program called sticky media access control (MAC). Every network attached device has a media access control MAC interface that is unique to it and will never change. The sticky MAC program is configured to monitor the unique address of the device and its designated network port so that if it is ever disconnected, it will disable that 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 IEDs serving as microgrid logic controllers are described in more detail in Section 2.7.1. The role of the IED 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

Sherburne has Elster Energy Axis AMI meters installed throughout its coverage area. These meters and other smart technologies will be able to connect via the industry standard protocols as required. The meters will be programmed to automatically disconnect themselves from the grid during a grid power outage. The critical and important loads within the microgrid will reconnect and enable those loads to be electrified by the microgrid's generation assets. The meters not included in the proposed microgrid footprint, approximately 873, will remain disconnected until they receive a reconnect signal from the microgrid controller.

2.2.19 Distribution Automation

The automation solution outlined in this study for Sherburne's microgrid includes automatic switch isolation, automatic circuit breaker open, and automatic AMI disconnection.

2.2.20 Energy Storage

At this time, battery storage technologies have not been identified as an optimal energy solution for Sherburne 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 IEDs to connect to Sherburne's

IT network. The IT network will operate over the Village's existing 48-strand Fiber Optics backbone.

2.2.22 Demand Response

Sherburne already deploys a successful demand response (DR) program utilizing 750 kW of water heat controllers for purposes of managing its coincident peak demand. The microgrid EMS has the capability to utilize DR programs by maximizing renewable on-site generation and energy storage systems and combining it with consumer demand by automating load shedding capabilities and monitoring trends and predicting consumption patterns to change the price of electricity over time.

2.2.23 Clean Power Sources Integration

It is envisioned that Sherburne's microgrid will include a natural gas fired CHP unit and also utilize three solar PV arrays, two of which are already in operation, as distributed energy resources.

2.2.24 Economic Dispatch

Sherburne's microgrid is expected to be mid-scale, with 6 generation resources. An economic dispatch will comprise of the pre-determined priority list which will take into account generation availability, balancing run-times, and fuel costs. The 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

If energy storage is incorporated in the future system design or through expansion, it will include intelligent controls necessary to work in unison with the microgrid controls. The microgrid EMS will fully utilize and optimize the storage resources and optimize storage to reduce peak demand and smooth ramping including the charge/discharge management of energy storage.

2.2.26 PV Monitoring, Control, and Forecasting

PV inverters will be tied into the MCS and can be controlled to reduce output, either to match load or to better align with simultaneous generation from 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 amount and distribution. The currently implemented protection scheme is very likely based on the assumption that the power flow is unidirectional and of certain magnitude. While the bidirectional flow can happen in the grid connected mode, islanding mode of operation might introduce some additional difficulties. The microgrid designer and implementer will perform protection studies accounting for possible bidirectional power flows and very low currents which can occur when the network is in islanding mode of operation.

2.2.28 Selling Energy and Ancillary Services

It is unclear whether the microgrid will be permitted to back-feed through Sherburne's main substation into the broader NYSEG transmission system. If allowed, the microgrid will sell excess solar energy back to NYSEG. It is also envisioned the proposed CHP could technically be configured to sell ancillary services like provide frequency response and spinning/operation reserve to NYSEG grid.

2.2.29 Data Logging Features

The microgrid EMS and SCADA system include a 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 in discussions with potential investors, however the investment needs to be balanced against Sherburne's ability to provide bond financing up to their existing debt limits. More detail is provided in Section 3.3.3.

2.2.31 Accounting for Needs and Constraints of Stakeholders

Developing the best possible value proposition for the community, utility, local industry, and other community stakeholders is 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 3.2.3.

2.2.32 Demonstrate Tangible Community Benefit

The proposed microgrid will provide availability of emergency services and overall community resiliency benefits. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As described above, the proposed microgrid will utilize several DERs in Sherburne. 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

Sherburne currently has two types of generation resources: diesel back-up generators and solar PV arrays. Several factors must be considered when deciding whether or not an existing diesel back-up generator should be included in the microgrid. These include generator capacity, load following capability, reactive power generation control, functionality (whether it serves emergency power), and location with respect to the loads it is intended to serve. Finally, the use of diesel generators may not be ideal if a clean generation asset is available. Construction of the 2 MW natural gas fired CHP unit and 2 MW solar PV array will greatly reduce the Village's need for diesel generation.

Sherburne has several diesel backup generators that cannot be included in the microgrid. Generators at the Waste Water Treatment Plant (150 kW), Basset Healthcare (45 kW), and Sewer Pump station (45 kW) were not considered for inclusion because of their limited generation capacity. Most of these generators are also only connected via an Automatic Transfer Switch (ATS) with no grid paralleling capability. Other emergency backup generators were not considered for inclusion in the microgrid because they are mandated by National Fire Protection Association (NFPA) safety codes and regulations, and connection to the microgrid could interfere with crucial emergency functions. The school's existing diesel backup generator (1,125 kW) is not included in the projected microgrid for this reason. As most of the town's diesel generators were installed for emergency situations only, there could be some emissions implications if they were used more in the proposed microgrid. Finally, these units were not designed for continuous duty and do not have the fuel storage needed for extended operation.

The two existing diesel generators that will be included in the microgrid are located at Frontier Communications (1 MW) and NYCM Insurance (500 kW). These were selected for their ample generation capacity and ability to supplement the grid if the PV array is not able to produce enough power at a given time in islanded mode. Grid paralleling switchgear will be required for these two units. Frontier and NYCM have 1,000 and 1,400 gallon storage tanks, respectively. Assuming the generators are running at full load, Frontier would consume approximately 71 gallons per hour, and NYCM would consume about 36 gallons per hour. Frontier's generator can therefore run continuously for 14 hours and NYCM's can run for 39 hours (1.625 days). Both generators are currently on a maintenance program; NYCM was confirmed to be serviced by a local Caterpillar dealer. Though they will be included in the microgrid, the diesel generators were not intended for 24/7 continuous duty. Therefore, they will only be activated in islanded mode to support peak load demand.

Sherburne possesses two other existing generation assets: two 10 kW solar PV arrays. One array is located at the Sherburne-Earlville Central High School and the other is located at the DPW/Sherburne Electric. Both PV arrays are equipped with inverters which enable them to operate in parallel with the utility power supply. As these arrays are relatively small compared to the overall microgrid load, they will not require any additional controls in order to be incorporated in the microgrid. The existing DERs that will be included in the microgrid are summarized in Table 5.

Table 5. Existing Distributed Energy Resources

Name of all four DERs, technology, rating in kW, fuel and address. Includes two PV arrays and two diesel backup generators

Name	Technology	Rating (kW)	Fuel	Address
Frontier Communications	Recip. generator	1,000 kW	Diesel	14 Classic St
Sher Earl Central High School	Solar PV array	10 kW	N/A	13 School St
NYCM Insurance	Recip. generator	500 kW	Diesel	16 Chapel St
Sherburne Electric and DPW	Solar PV array	10 kW	N/A	13-27 Classic St

2.3.2 Proposed Generation Assets

The two proposed generation assets include a 2 MW natural gas-fired, continuous duty reciprocating generator and a 2 MW PV array system, shown in Table 6. The natural gas CHP generator will be located behind the Village-owned firehouse (15 West State Street) where there is 500 square feet of land for the unit. This location also allows Sherburne to avoid any ownership conflicts being located on their land, but still close to the steam off takers. The CHP unit will provide most of the year-round thermal energy (steam) requirements for Southern Tier and Egg Low Farms. Steam is not easily transported, so the proximity of these two industrial facilities to the CHP unit makes them suitable year-round steam recipients.

The 2 MW PV array system under consideration is located on the Village-owned land behind their DPW facility (27 Classic Street). The PV array could easily be incorporated into the microgrid system with inverters that are able to synchronize in both normal grid and islanded mode.

Table 6. Proposed Generation Assets

CHP reciprocating generator rating, fuel and address, and solar PV rating and address

Name	Technology	Rating (kW)	Fuel	Address
Natural Gas CHP Recip.	Recip. generator	2,000 kW	Natural Gas	Land behind Sherburne's Firehouse (15 West State St)
PV Array	Solar	2,000 kW	N/A	Land behind Sherburne's DPW facility (27 Classic St)

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides Sherburne with several additional energy resources. In grid-connected mode two existing PV arrays, one proposed PV array, and the proposed natural gas CHP unit will operate in parallel with the main grid, exporting excess power and importing supplementary power to meet peak demand when necessary. In islanded mode, the PV arrays and CHP will supply the base load with supplementary power from two existing diesel generators available to meet peak loads. The CHP unit and diesel generators are capable of covering the microgrid's demand during island mode, providing power in situations where the solar PV arrays may be offline due to weather or time of day. The proposed 2 MW natural gas CHP runs continuously while also generating approximately 1,760 MMBTU per month of steam for Southern Tier Pet Nutrition and Egg Low Farms.

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 generators will have auxiliary power (batteries) required to start and establish island mode grid frequency.
- Generator controllers for diesel generators and natural gas CHP are able to adjust generation output power according to frequency deviation signal to achieve load following.
- Conformance with New York State Interconnection Standards[2], described in above.

2.4 Load Characterization (Sub Task 2.2)

Electricity and steam demand data from Sherburne's load points is essential to correctly size new power generation and thermal DERs. The load characterizations below fully describe both the electrical and thermal loads served by the microgrid when operating in islanded and parallel modes based on metering data from Sherburne Electric and thermal loads from the facilities. Written descriptions of the sizing of the loads to be served by the microgrid along with redundancy opportunities to account for downtime are included.

2.4.1 Electrical Load

Electrical load characterization consisted of analyzing 19 housing, government, commercial, and industrial facilities (74 loads) located within the boundaries of the Sherburne microgrid. These facilities and their loads are summarized below in Table 7. Refer to the Appendix for typical 24-hour load profiles for each of the 74 microgrid facilities during the month of August 2015.

[2] 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.

Table 7. Sherburne List of Prospective Microgrid Facilities

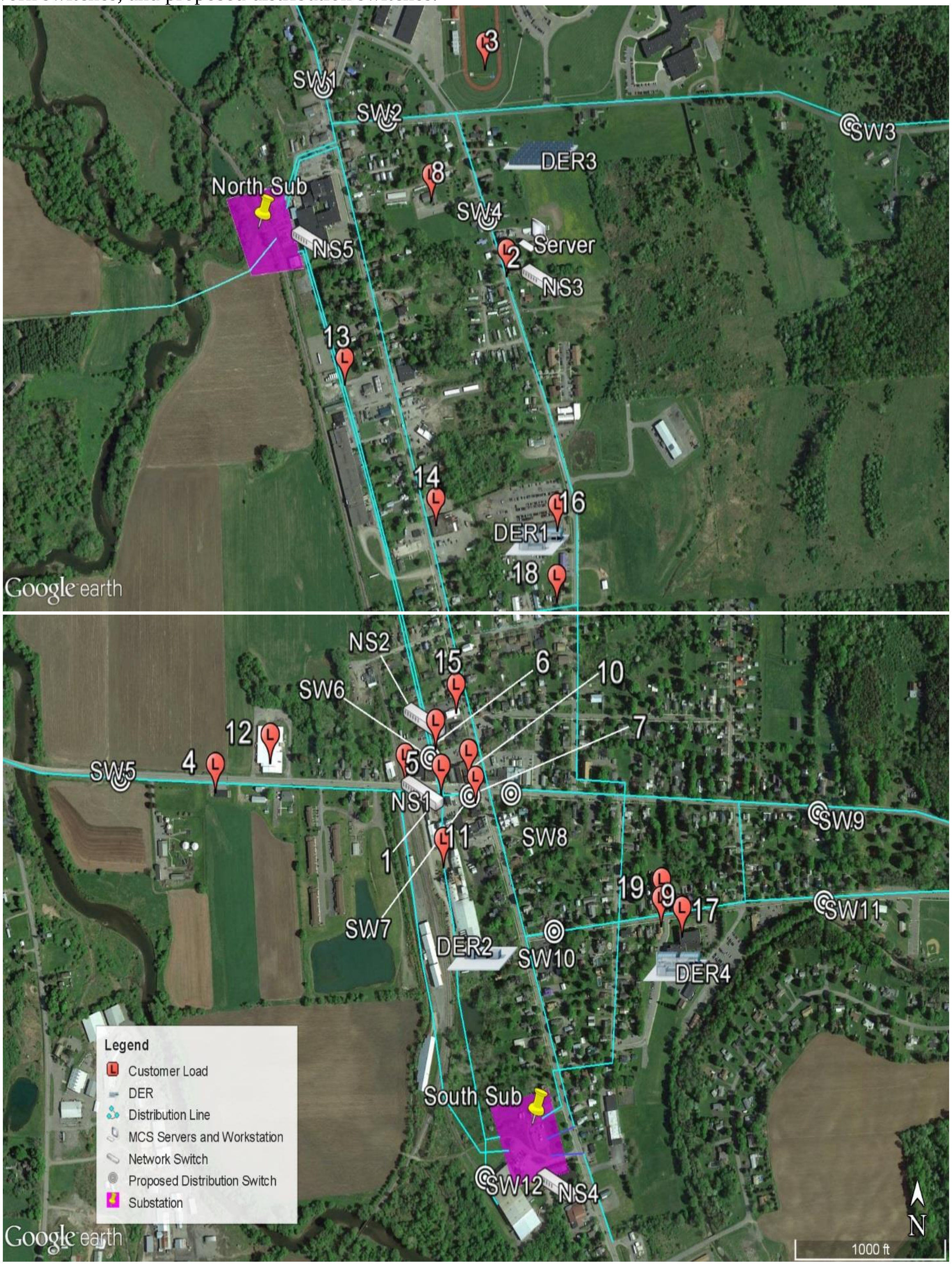
List of potential microgrid facilities, addresses classification of the facility as public, health, industry, commercial, or residential and points of load interconnection

	Property	Address	Classification	Load Points
1	**Village Municipal Building** (Village office, Fire Department, Police Department, and Ambulance)	15 W. State St	Public	4
2	**Sherburne Electric and DPW**	13-27 Classic St		1
3	**Sherburne-Earlville Central Public Schools** (Elementary, Junior High, and Senior High Schools)	13 School St	Public	2
4	**Wastewater Treatment Plant**	50 West State St	Public	1
5	**Railroad Crossing gates/signal**	State Rte. 80 in Village	Public	1
6	**Village of Sherburne Wastewater Pump Station**	Canal St	Public	1
7	**US Postal Service**	4 W. State St	Public	1
8	**Chenango Memorial Hospital Health Clinic**	38 Classic St	Health	1
9	**Basset Healthcare**	20 Chapel St	Health	1
10	**Service Pharmacy**	6 N. Main St	Health	1
11	**Southern Tier Pet Nutrition**	8 W. State St	Industry	2
12	**Egg Low Farms Inc.**	35 W. State St	Industry	1
13	**Mirabito's Gas Station**	86 N. Main St	Commercial	1
14	**Big M Supermarket**	4 South Main St	Commercial	1
15	**NBT Bank of Sherburne**	30 N Main St	Commercial	1
16	**Frontier Communications**	14 Classic St	Commercial	1
17	**NYCM Insurance**	16 Chapel St	Commercial	4
18	**Grace Manor (low-income housing)**	2-8 Knapp St	Residential	20
19	**Senior Housing**	18 Chapel St	Residential	29

Figure 1 provides an illustration of the proposed microgrid design and layout.

Figure 1. Sherburne Equipment Layout

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



The 12 months of metering data for 2014 was provided by Sherburne Electric and is summarized below in Table 8. The total peak load in Sherburne in 2014 was 4.11 MW, and the monthly average was 1.5 MW. For a cumulative hourly load profile of the 74 loads see Figure 2.

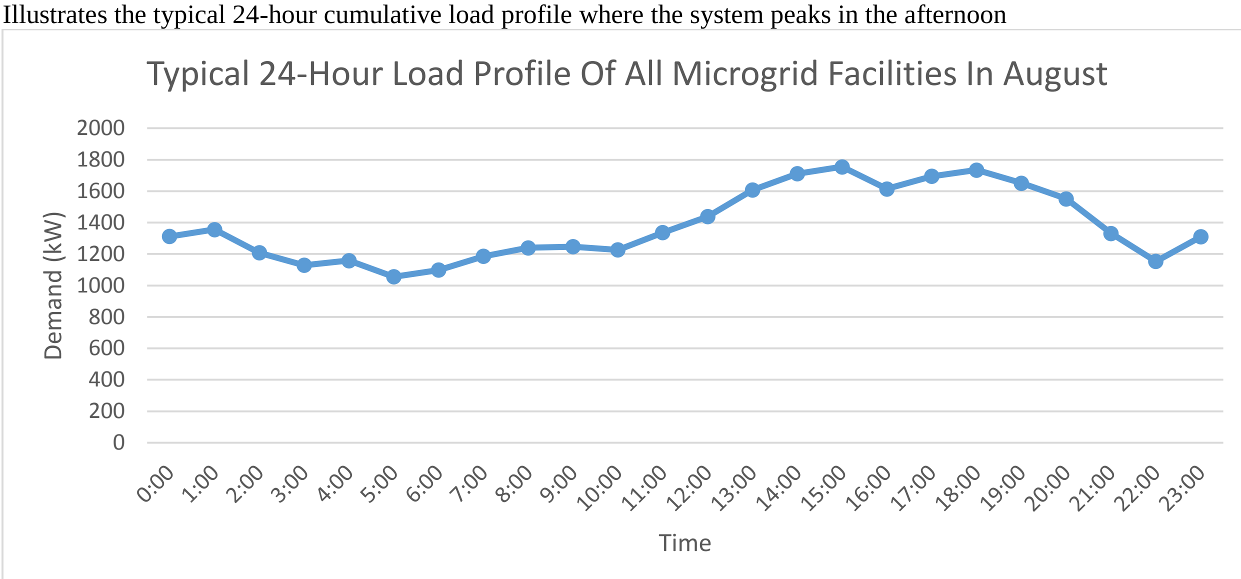
Table 8. Sherburne's 2014 Microgrid Load Points

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	4,110	1,509	12,851,062	1,062,439	247,079	23,053	1921	447

Figure 2. Typical 24-Hour Cumulative (74 points) Load Profile, Aug. 2015 Metering Data

Illustrates the typical 24-hour cumulative load profile where the system peaks in the afternoon



The proposed natural gas-fired CHP plant and solar PV arrays will operate continuously in both parallel and islanded mode. Because the PV arrays will not always operate at their full capacity of 2.02 MW, the existing diesel generators (totaling 1.5 MW of generation capacity) will be available during islanded operation.

The combined 4.02 MW (2 MW CHP + 2.02 MW PV) of generation in Sherburne (not including diesel generators) should be adequate to provide power to the microgrid in both grid-connected and islanded modes—in 2014 the yearly average load for all 19 facilities was 1509 kW and total load never exceeded 4.11 MW. The equipment layout (Figure 1) illustrates the microgrid components and are referenced throughout the rest of the document.

2.4.2 Thermal Consumption

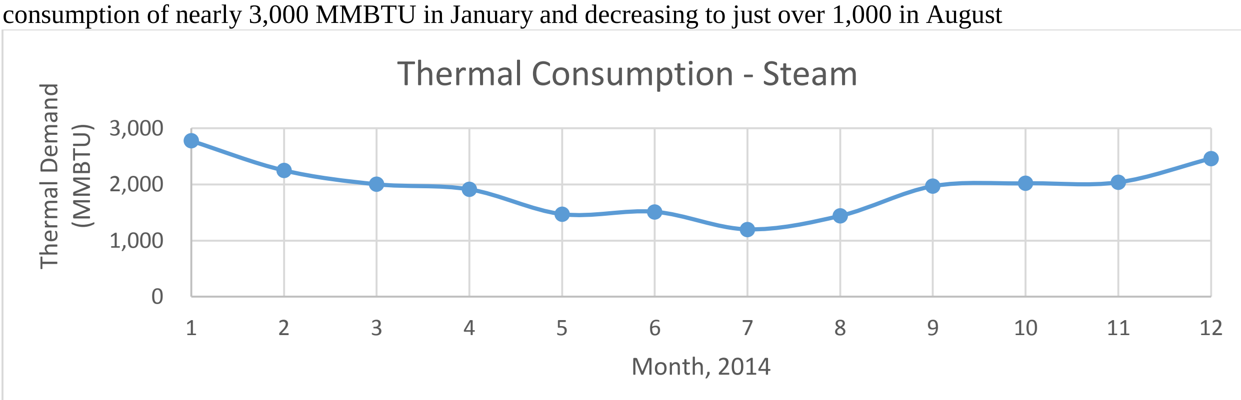
Although not all thermal consumption is essential for the microgrid technical design, all thermal information is discussed. Thermal consumption for this feasibility study can be separated into three main categories. The first is facility steam usage, which will be served by the microgrid's CHP unit. The second thermal consumption type is No. 2 oil used for facility heating. The third is propane used for drying products. Heating and drying will not be served by the microgrid.

Several of Sherburne's buildings use No. 2 oil for heating purposes. In 2014, the school used more oil for heating than any other building in Sherburne (16,618 million British Thermal Unit (MMBTUs)), followed by the Waste Water Treatment Plant (1,096 MMBTUs) and the Fire Department (634 MMBTUs). Southern Tier Pet Nutrition uses propane to dry their product, in 2014 this facility used 20,881 MMBTUs of propane.

The intent of this study with respect to thermal consumption is to identify oil-based thermal loads that can be replaced with steam from the proposed CHP generator. The industrial facilities at Southern Tier Pet Nutrition and Egg Low Farms currently use Number Two (No. 2) oil boilers to generate steam for their products, in 2014, Southern Tier Pet Nutrition used 17,173 MMBTUs and Egg Low Farms used 5,880 MMBTUs. Their cumulative values are shown in Table 10. Combined monthly thermal load demand from these facilities will likely range from approximately 1,000 MMBTUs to approximately 3,000 MMBTUs (see Figure 3 for monthly combined thermal loads in 2014). The two facilities, with an average monthly load demand of 1,921 MMBTUs, will receive approximately 85% of their steam demand from the CHP, which produces an average of 1,760 MMBTUs/month, throughout the year.

Figure 3. Monthly Steam Thermal Loads, Southern Tier Pet Nutrition and Egg Low Farms

Illustration of thermal consumption by Southern Tier Pet Nutrition and Egg Low Farms with a high steam consumption of nearly 3,000 MMBTU in January and decreasing to just over 1,000 in August



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 normal, grid parallel operation, the microgrid will have the capability to operate the proposed 2 MW gas fired CHP unit, proposed 2 MW PV array and two existing 10 kW PV arrays in parallel with the grid. During grid parallel operation the existing and proposed distributed energy resources assets will supply energy to the entire Sherburne distribution system, supplemented by power from the main grid. The existing diesel generators will not operate in grid parallel mode, as they are not built for continuous duty operation.

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 NYSEG.

2.5.2 Intentional Islanded Mode

In islanded mode, the system will manage the microgrid’s distributed energy resources assets to meet the power needs of the critical facilities within the microgrid. The existing diesel generators will only be used when necessary (for example, black start, and also when the solar PV array is producing far below its capacity).

2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)

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

2.6.1 Electrical Infrastructure

Electricity enters Sherburne’s system from the NYSEG-owned 44 kV lines at the North Substation, where it first splits to serve an underground feed line to the South Substation, and then connects to a high voltage utility breaker, UB1. The single underground 44 kV line enters the South Substation high voltage utility breaker, UB2. After UB2, the line connects to a bus splitter which serves both TX2 and TX3 in the South Substation. The transformer TX1 at the North Substation and the transformers TX2 and TX3 at the South Substation then both step the voltage down to 8.3 kV. Each substation has a capacity of 15 Mega Volt Amperes (MVA) and, under normal operation, they share the system load equally. Each substation has the ability to energize all of the feeders, providing redundancy at the medium voltage level power supply. If a feeder loses connection from one substation, service is restored by connecting to the other substation.

However, there is still an inherent risk of losing power when both substations are down. Although equipment like transformers and switches are resilient to most weather issues (such as rain, snow, wind, or tornados), these forces of nature cause fallen trees and downed power lines. Over the last few years, almost 50% of customer outage hours were due to tree damage to the overhead distribution power lines. Lightning is another frequent source of disruption and has recently caused 11% of outages despite existing lightning arrestors in the distribution system. To protect the microgrid from these forces of nature and damaged lines, the proposed control system will be able to detect breaks in lines on the microgrid, isolate (open switches for) that section, and re-route power. The latter will utilize existing power lines in the microgrid and will be managed by automated control switches.

Sherburne's microgrid will have automated group-operated air-break (GOAB), knife, and cutout switching equipment throughout the distribution grid, enabling different routings of power flows and isolation/bypass of certain areas as needed, the switches and servers are outlined in Tables 9-11. Sherburne's One-Line is shown below in Figure 4.

Table 9. Sherburne Distributed Switches Description

Outlines all twelve distributed switches with description, status as proposed and which line the switch is on

Name	Description	New/Upgrade	Attached Line
SW1	Knife Switch (existing, needs upgrade)	Proposed	L2000
SW2	Gang Operated Air Breaker (existing, needs upgrade)	Proposed	L2100
SW3	Automated Switch (new)	Proposed	L2100
SW4	Automated Switch (new)	Proposed	L2000
SW5	Gang Operated Air Breaker (existing, needs upgrade)	Proposed	L6000
SW6	Automated Switch (new)	Proposed	L8000
SW7	Automated Switch (new)	Proposed	L1000
SW8	Automated Switch (new)	Proposed	L1000

Name	Description	New/Upgrade	Attached Line
SW9	Gang Operated Air Breaker (existing, needs upgrade)	Proposed	L1000
SW10	Cutout Switch (existing, needs upgrade)	Proposed	L5000
SW11	Automated Switch (new)	Proposed	L5000
SW12	Automated Switch (new)	Proposed	L3000

Table 10. Sherburne Network Switch Description

Outlines all five network switches with description, status as existing or proposed, and the address of the switch

Name	Description	Status	Address
NS1	Municipal Building Network Switch	Existing	15 W. State Street
NS2	Sewer Pump Station Network Switch	Existing	Canal Street
NS3	Sherburne Electric Control Center Network Switch	Existing	13 classic Street
NS4	Connected South Substation Network Switch	Proposed	At South Substation
NS5	Connected North Substation Network Switch	Proposed	At North Substation

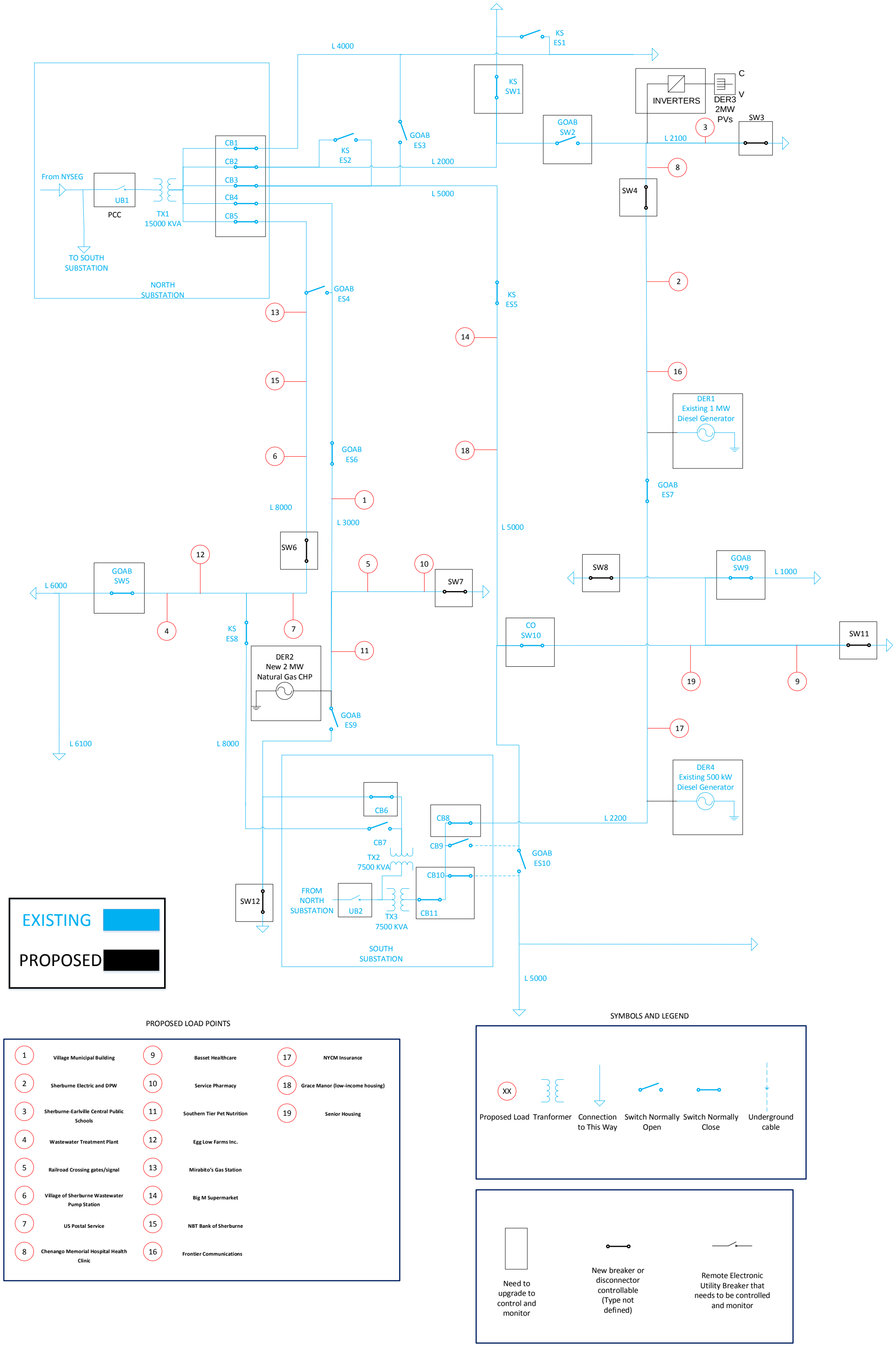
Table 11. Sherburne Server Description

Description of four servers and one workstation, status as proposed and the address on 13 Classic Street

Name	Description	Status	Address
Sever1	SCADA Primary	Proposed	13 classic St
Sever2	SCADA Secondary	Proposed	13 classic St
Sever3	Energy Management System (EMS) Primary	Proposed	13 classic St
Sever4	EMS Secondary	Proposed	13 classic St
Workstation	Operator/Engineer workstation	Proposed	13 classic St

Figure 4 Sherburne One-Line Diagram

One-line diagram for Sherburne illustrating interconnections and lay-out



2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The proposed interconnection points and investments in Sherburne's distribution infrastructure for microgrid operation are listed in Table 12. The proposed Point of Common Coupling (PCC) between the main grid and the microgrid is located at the North Substation. In order to serve multiple, non-contiguous loads using generators spread across the existing distribution grid, the microgrid will rely on two key components to segment loads:

1. *Sherburne's existing 900 AMI meters*. Remote disconnect smart meters will need to be programmed to automatically disconnect themselves from the grid during a grid power outage, while the critical and important (74 loads) will remain connected. The non-critical meters (approximately 873) will remain disconnected until they receive a reconnect signal from the microgrid controller.
2. *Automated isolation switches across the feeders*. Automated switches will replace the existing manual knife/cut-out/GOAB switches, 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.

Table 12. List of Additional Components

List of all substation components at both north and south substations as well as distribution devices

North Substation Device	Quantity	Purpose/Functionality
Microgrid Control System Protocol Converter (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	Protocol Converter responsible for operating the microgrid's field devices via protocol IEC-61850
Intelligent Electronic Device (IED) – Utility voltage (Siemens 7SJ85 Siprotec 5 or equivalent)	1	Combined IED Automation and Protection device for interfacing with 44 kV utility breaker
Automated Circuit Breaker	5	Upgraded breakers on all 5 distribution feeders to enable interface with microgrid IED
IED – Distribution Feeders (Siemens 7SJ85 Siprotec 5 or equivalent)	1 Primary IED 5 Modules	Combined IED Automation and Protection device with 5 sub-modules interfacing with each 8.3 kV distribution feeder circuit breaker
Centralized Generation Controls (Woodward EasyGen or equivalent)	1	Serves as the primary resource for coordinating the paralleling of all remotely located generators
South Substation Device	**Quantity**	**Purpose/Functionality**
IED – Utility voltage (Siemens 7SJ85 Siprotec 5 or equivalent)	1	Combined IED Automation and Protection device for interfacing with 44 kV utility breaker
Automated Circuit Breaker	4	Upgraded breakers on 4 normally closed distribution feeders to enable interface with microgrid IED
IED – Distribution Feeders (Siemens 7SJ85 Siprotec 5 or equivalent)	1 Primary IED 3 Modules	Combined IED Automation and Protection device with 3 sub-modules interfacing with each normally closed 8.3 kV distribution feeder circuit breaker behind TX3
Distribution Devices	**Quantity**	**Purpose/Functionality**
PV interface switches	3	Microgrid controls switches that will work with the PV system inverters.
IED – Distribution Switches (Siemens 7SC80 or equivalent)	12	Combined PLC Automation and Protection device interfacing with Automated Distribution Switches
Generation Switchgear	3	Each generator will have the required grid-paralleling switchgear, enabling each unit to synchronize to the system's frequency.
Generation Controllers (Woodward EasyGen or equivalent)	3	Engine-generator control and protection with peer-to-peer paralleling functionality

All microgrid devices will require a reliable source of DC power. At each device (or grouping of devices in a similar location), there will be a primary and back-up power supply source. During normal operation, 120 volt alternating current (VAC) power source (provided by Sherburne Electric) will be sent through an alternating current (AC)/DC converter to power the microgrid devices and maintain the charge of the DC battery bank. When normal AC voltage is unavailable, likely due to an issue outside or elsewhere in Sherburne'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 will have to perform protection studies accounting for possible bidirectional power flows and very low currents, which can occur when the network operates in island mode.

Since it is unclear whether the microgrid will be permitted to back-feed through Sherburne's main substation into the broader NYSEG transmission system, the current proposed design includes controls that have the necessary hardware and protection scheme to prevent back-feeding power into the NYSEG system. However, if selling power as an ancillary service is allowed, the microgrid is capable of selling excess energy back to NYSEG.

2.6.4 Thermal Infrastructure

There is currently no natural gas infrastructure in Sherburne, though there have been active discussions about bringing gas to the area. The pipeline must traverse either 2.5 or 5 miles, depending on the capacity level of gas required by Sherburne. Regardless of microgrid success, the Village has ample natural gas consumption potential and sees the pipeline's extension as an inevitable next step in its economic development.

With the addition of a 2 MW CHP located behind Sherburne's Firehouse (15 West State St), steam supply lines will also be required to transport steam to Southern Tier Pet Nutrition and Egg Low. For Southern Tier Pet Nutrition, the steam supply lines are expected to be approximately 400 feet in length. Egg Low Farms will require a longer steam line to serve that facility approximately 1,100 feet in length away from the source, following the State Street corridor.

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 has the potential to sell excess electricity to NYSEG according to NYSEG's guidelines. Because switching to island mode entails disconnecting hundreds of Sherburne's electricity meters from power, the microgrid will only switch to island mode in emergency outage situations. The microgrid will also automatically re-synchronize to the NYSEG 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 scope; however, several of the components that comprise 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). This allows for the future addition of building energy control systems (ventilation, lighting, fire and security) as 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 will use a Service Oriented Architecture (SOA) software platform that functions as the messaging and integration platform for monitoring and control of the proposed power devices regardless of which vendor is ultimately chosen. The SOA software platform 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 the proposed microgrid design are as follows:

- SOA software platform – software that functions as the messaging and integration platform for monitoring and control of virtually any power device or control system from any major vendor
- Microgrid Control System (MCS) – capable of monitoring and controlling the system
- Redundant Array of Independent Disks (RAID) 5 servers (including 1 primary, 1 backup) for EMS and SCADA – EMS works with the SCADA system to optimize microgrid elements such as critical loads to be supplied, use of PV, including high resolution solar forecasting, and energy storage charging and discharging. 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. 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
- Historian database server – Historian database collects data from various devices on the network and log information to its database.
- Applications server (one or more) – Application servers are very broad in use and depending on the software and hardware vendors' preference, application servers may be used for numerous purposes. Some common uses for an application server include, but are not limited to: backup and recovery, antivirus, security updates, databases, a web server, or some other software depending on how the SCADA and EMS vendors configure their platform.
- Operator workstations for SCADA and EMS – Workstation computers, sometimes called thin-clients, allow operators either at the SCADA control room, or remotely, to view the real-time data and control the microgrid if the user has the proper access rights and permissions to do so.
- Intelligent Electronic Devices (IEDs) – The microprocessor based logic controllers in the field at or near loads, also referred to as IEDs, 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 IEDs connected to control elements such as the 44 kV utility breaker, automated distribution switches, and other objects either by discrete (open/close), or analog signals, depending on the process.

- Layer 3 Gigabit Ethernet Switches – to connect the host servers with the logic controllers and other network attached equipment over Sherburne's LAN.

2.7.2 Grid Parallel Mode Control

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.

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 (e.g. 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 assure 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.

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

2.7.3 Islanded Mode Control

The microgrid will switch to intentional islanding when there is a larger grid outage that would leave the whole of Sherburne without power. During the intentional islanding operation, the microgrid will receive the operator's command to prepare to enter island mode of operation. 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 Village 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 control scheme sequence of operation in the Appendix.

Energy Management in Islanded Mode

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 Sherburne microgrid function by managing load and generation resources and prioritizing critical loads according to operational requirements.

2.7.4 Black Start

It is envisioned that the CHP unit and two existing diesel generators will be equipped with black start capabilities. When the grid power goes out for Sherburne, the microgrid controller initiates island mode by orchestrating the predefined black start sequence. The microgrid then enters un-intentional islanding mode. This mode of operation will require the generators to have a DC auxiliary support system which must have enough power to start the generator multiple times in case it fails to start the first time.

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

1. PCC breaker opens (anti-islanding protection)
2. The microgrid controller waits a pre-set amount of time, approximately 30 seconds (in case NYSEG power comes back)
3. The microgrid controller EMS calculates expected load

4. The microgrid control system then automatically starts to synchronize generation by operating the breakers at the generation 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 Sherburne grid does not properly isolate from NYSEG utility power. Lower priority loads will be energized only if sufficient capacity can be guaranteed. Contingency algorithms will handle the case where one or more generators do not start as expected during a utility outage. If possible, the microgrid will still be formed but with only critical loads satisfied.

The EMS will allow operators to designate certain generators as unavailable for participation in the microgrid (e.g., if they require maintenance) so 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, where 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 **Error! Reference source not found.** in the Appendix for control scheme sequence of operations.

2.7.5 Resynchronization to NYSEG Power

When NYSEG 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 NYSEG power supply.

While in emergency island mode, the system will constantly monitor the status of the utility feed at the North 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 breaker at the North Substation. The 2 MW PV system will be disconnected. Before the microgrid system starts paralleling with the utility, it will balance the generation and load as not to exceed both minimum or maximum export limits and time durations set forth in the utility interconnection agreement. Once the North Substation is restored, generation breakers for diesel generators will trip automatically. The South Substation will be connected in re-synchronized mode. Consequently, the PV will be synchronized back to the grid automatically by inverters.

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

2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6)

The existing information technology (IT) and telecommunication infrastructure at Sherburne has the bandwidth capacity for a microgrid. The presence of this network is conducive to the addition of an automated microgrid. The microgrid hardware will seamlessly integrate with the IT system using a minimal amount additional hardware necessary to operate (i.e. the network switches, servers, and computers required to manage a microgrid).

2.8.1 Existing IT & Telecommunications Infrastructure

Sherburne already takes advantage of its existing 48 strand single mode fiber optic backbone ring and existing Ethernet switches for reliable internet and Local Area Network (LAN) activities, making convergence quite feasible. The existing smart meters, which have the capability to enable whole load disconnect remotely, also utilize Sherburne's LAN via a TCP/IP connection on the existing network. Remote disconnect and reconnection of these smart meters could be enabled by utilizing a gatekeeper. The gatekeeper, which works on open architecture protocols, uses a TCP/IP Ethernet-enabled component that controls each of the uniquely addressed meters wirelessly via a standard, non-licensed radio frequency mesh 900 Megahertz (MHz) industrial scientific and medical (ISM) band signal network.

2.8.2 IT Infrastructure and Microgrid Integration

While the IT infrastructure is reliable and available for the expansion of the proposed automated microgrid system, additional microgrid hardware and software is needed. There are seven main components required for the any microgrid system to successfully integrate with an IT/telecommunication infrastructure: host servers, application servers, operator workstations, network switches, network-attached logic controllers, data transmission systems (either fiber or Ethernet cables), and the SOA software that functions as the messaging and integration platform for monitoring and control of virtually any power device or control system from any major vendor. All of these critical parts work together and serve a specific role.

2.8.3 Network Resiliency

The data transmitted throughout the proposed Sherburne 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 65,535 TCP ports that are not being used to make the microgrid system work. Depending on final configuration, only a few TCP ports will need to be active. This especially depends on whether or not the available Enterprise-level or remote monitoring outside the Village's private domain will be utilized—if this is the case, more TCP ports will need to be active.

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

Physical security measures, such as electronic badge access or cipher combination hardware locksets, should also be considered. 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 Village network, where it is potentially more vulnerable to hackers. Sticky MAC is inexpensive and practical program that can help prevent unauthorized access and protect the Sherburne 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.

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

2.9 Microgrid Capability and Technical Design and Characterization Conclusions

This preliminary technical design portion of the overarching feasibility study has provided a solution based on a thorough examination of the existing utility infrastructure and energy demand requirements in order to conceptualize a real time operation that is reliable and efficiently managed. The proposed design has incorporated 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.

The project is technically feasible, however, two significant items remain in order for Sherburne's microgrid to become a reality. The natural gas line needs to be extended to Sherburne, and the AMI meters need to be able to remotely disconnect loads with SCADA control.

The natural gas line is currently under preliminary design. All indications show the site will have adequate capacity and pressure for the CHP unit. While the proposed microgrid's CHP unit depends on the natural gas line for electrical and thermal generation, the arrangements to bring gas service to Sherburne have already been established regardless of the microgrid success. Village officials have expressed interest in bringing natural gas to the village in order to supplant the use of fuel oil for industrial and heating purposes. The Village, with support from the county

Chamber of Commerce, has opened discussions with local developers to explore extending existing pipelines to the village. The village sees the pipeline's extension as an inevitable next step in its energy evolution. Costs associated with building the natural gas pipeline are currently close to $325,000 per mile. The estimated time to complete the installation of the natural gas line at Sherburne is 1.5 years from contractual commitment. That time will include a 9 month licensing stage and 3 months of construction after procurement and engineering is finalized.

Although the AMI smart meters installed have remote disconnect capabilities, the manufacturer is still finalizing technical development of remote disconnect capability from a control system signal as proposed in this study. The company states they are close to having the technology ready to meet this requirement. Current New York state law restricts remote disconnection of service for nonpayment issues, but does not cover remote disconnect capability in the context of a microgrid. A report prepared by NYSERDA suggests that AMI with remote disconnection capability can be a useful component of a microgrid, which implies a lack of significant legal barriers to implementing this technology. Technical development of the remote disconnect capability presents a significant challenge, but does not make the proposed concept infeasible.

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

The current financial viability assessment is based on the assumptions previously discussed regarding natural gas availability and AMI technical upgrades. Additionally, the Project Team has assumed that the Village and Utility have bonding authority and are interested in leveraging it for microgrid construction, and that Sherburne is the sole and full owner of Sherburne Electric Co. and, though they have separate bonding authorities, the liabilities of the utility ultimately return to the Village.

Attendant to these assumptions are certain risks that must be acknowledged. Specifically:

- If the natural gas line is not extended into Sherburne, the proposed CHP unit will not be possible and the microgrid will not be developed as proposed. Any increase in the capacity of the new natural gas line that is required to support the CHP would become attributable to the microgrid, however, internalizing the entire cost of the natural gas pipeline to the microgrid would create a difficult financial case for the project.
- Steam conveyance infrastructure must also be constructed to facilitate the offtake of the CHP steam resources; without it, a major revenue stream would be unavailable and the project would not be financially sound.
- Similarly, if either of the steam off-takers terminates their purchases, and no new off-taker is identified, project revenues may be insufficient to cover operational and debt costs.
- The viability of bonding the project is based on the expectation of interest rates low enough to be a prudent choice by Sherburne Electric. A dramatic rise in interest rates could

materially alter the project economics and yield an unviable project, or one requiring more costly direct outside investment.

- Further, the viability of the project as conceived relies on winning Phase III funding from the NYSERDA NY Prize competition.

3.1 Commercial Viability – Customers (Sub Task 3.1)

As detailed above, customers of the Sherburne microgrid can be categorized as critical or important. The critical and important facilities would maintain electric service during intentional islanding of the microgrid. The 19 critical and important facilities represent 74 individual load points on the microgrid. The remaining 873 meters in Sherburne would remain connected during normal operations and disconnected from the grid in island mode. Thus, the latter group would benefit from overall lower prices due to reduction in energy purchased from NYMPA, and the availability of critical services in the event of an emergency, but they would not receive power in the event of an outage or island event. Each of the public, health, and retail commercial facilities serving the broader community and identified as critical or important will remain online and available during an islanded event. A comprehensive accounting of the entire population of microgrid beneficiaries includes individuals beyond the direct employees or residents of the critical and important facilities. The broader population of beneficiaries is addressed in Section 3.1.1: Other Stakeholders.

Table 13 below identifies each of the direct microgrid customers and the scenarios during which they would purchase services from the microgrid.

Table 13. Microgrid Customers

Table 1 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	Existing Backup Generation	Normal vs Island Mode
Village Municipal Building (Village Office, Fire Department, Police Department, and Ambulance)	15 W. State St.	Public	Yes	No	Both
Sherburne Electric and DPW	13-27 Classic St.	Public	Yes	Yes (Solar)	Both
Sherburne-Earlville Central Public Schools	13 School St.	Public	Yes	Yes (Diesel)	Both
Wastewater Treatment Plant	50 W. State St.	Public	Yes	Yes (Diesel)	Both
Railroad crossing gates/signal	State Rte. 80 in Village	Public	Yes	No	Both
Village of Sherburne Wastewater Pump Station	Canal St.	Public	Yes	Yes (Diesel)	Both
US Postal Service	4 W. State St.	Public	No	No	Both

Property	Address	Classification	Critical Service	Existing Backup Generation	Normal vs Island Mode
Chenango Memorial Hospital Health Clinic	38 Classic St.	Health	Yes	No	Both
Basset Healthcare	20 Chapel St.	Health	Yes	Yes (Diesel)	Both
Service Pharmacy	6 N. Main St.	Health	No	No	Both
Southern Tier Pet Nutrition	8 W. State St.	Industry	No	No	Both
Egg Low Farms Inc.	35 W. State St.	Industry	No	No	Both
Mirabito's Gas Station	86 N. Main St.	Commercial	Yes	No	Both
Big M Supermarket	4 South Main St.	Commercial	Yes	No	Both
NBT Bank of Sherburne	30 N. Main St.	Commercial	Yes	No	Both
Frontier Communications	14 Classic St.	Commercial	No	Yes (Diesel/ Solar)	Both
NYCM Insurance	16 Chapel St.	Commercial	No	Yes (Diesel)	Both
Grace Manor (low-income housing)	2-8 Knapp St.	Residential	No	No	Both
Senior Housing	18 Chapel St.	Residential	Yes	No	Both

3.1.1 Other Stakeholders

The range of stakeholders in the Sherburne microgrid extends beyond the direct purchasers of services or the utility. Additional stakeholders include customers of Sherburne Electric (not captured by the 19 critical and important facilities), existing generation asset owners, and residents of the areas outlying Sherburne and beyond the Sherburne Electric service area.

Benefits will accrue to Sherburne, the surrounding community, and existing backup generation asset owners. Vendors, suppliers, and local labor and construction will also benefit during the construction and operations phases. When in islanded mode, the listed important and critical services—many of which are equally accessible and available to residents outside of the Village of Sherburne—will remain available. These services include food, fuel, banking, and healthcare, all of which will remain accessible in the event of a long-term grid outage as the CHP and solar PV will be able to run indefinitely and the diesel backup will have a 7-day fuel supply. In addition, the availability of steady and inexpensive steam from the CHP, coupled with microgrid access, may encourage industrial producers to relocate to the town or prompt the existing manufacturing facilities to expand production. Either scenario brings added revenues and jobs to the Village and surrounding community. Lastly, Frontier Communications and NYCM Insurance stand to gain from the integration of their diesel backup into the microgrid and the nominal standby fees, and microgrid access. Frontier owns 1000 kW of diesel generation, and NYCM Insurance owns 500kW of diesel generation

Stakeholders will face relatively few negative effects and challenges. Regulatory issues may need to be addressed before extending the pipeline, but nearby towns completing similar work do not appear to have faced prohibitive concerns. Extending the steam conveyance infrastructure from the Village-owned firehouse to the off-takers will also be necessary, with 400 feet required to reach Southern Tier Pet Nutrition and 1,100 feet required to reach Egg Low Farms. This extension is not expected to be onerous, but it must be constructed to facilitate the sale of steam.

Islanded operation in a given year is estimated at approximately six hours. In such an event, which would occur in response to an outage on the macrogrid, non-microgrid connected Sherburne Electric customers would already be without electricity, so there is no net change in their status during an island event induced by a macrogrid outage. As power is restored to the grid, they will be reconnected via remote AMI controls in an orderly fashion that maintains the integrity of the Sherburne grid and the local generation assets.

3.1.2 Purchasing Relationship

The microgrid will be owned by Sherburne Electric, and the direct customers will be the critical and important facilities listed in Section 2.2.1. The utility-purchaser relationship will remain largely the same, since electricity will flow through the same system and rates will be captured though the same billing mechanism. The relationship between the utility and existing diesel generation asset owners (Frontier Communications and NYCM Insurance) will change from a one-way electricity provision relationship, in which the customers simply purchase electricity from the Sherburne grid, to a two-way relationship in which Sherburne Electric may purchase power back from the diesel assets in certain islanded situations. This will require agreements with the diesel owners and agreements pertaining to rates and payment for use of the assets.

Sherburne Electric will also initiate the supply of new thermal resources from the proposed CHP facility to off-takers, creating additional tie-ins with existing customers. This dynamic will be further described in Section 2.4.2. NYSEG and NYISO may also become part-time customers of the Sherburne microgrid, depending on the final configuration and on potential agreements with NYSEG and NYISO regarding electricity and ancillary services sales to the macrogrid. This would be a shift in the relationship between Sherburne Electric and NYSEG/NYISO, since neither of the latter are presently customers of Sherburne Electric. See Section 3.2.1 for a detailed description of the business model.

Microgrid operation will generate direct and indirect services for Sherburne Electric and indirect services for NYISO and NYSEG. Direct services include those that are directly related to the sale of energy resources to customers, such as electricity and steam tariffs, as well as savings directly attributable to operational changes, such as decreasing NYMPA purchases. Indirect services include deferred transmission and distribution investments and ancillary service opportunities.

Services to Sherburne Electric:

- Revenue from thermal resource sales
- Islanded operation tariffs
- Decreased costs to Sherburne Electric as peak purchases are offset and congestion charges decrease

Services to NYISO/NYSEG:

- Possible new source of ancillary services on the macrogrid (e.g., frequency regulation)
- Decreased congestion on transmission lines up to the total potential generation of 4+ MW of the new assets in Sherburne

3.1.3 Solicitation and Registration

The Village and utility will work with identified customers to encourage participation in the project, and we have already solicited input from many of these facilities. This outreach will continue with informal discussions and, ultimately, signed agreements of participation in the microgrid, subject to NYPSC approval. 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. If additional generation becomes available in the future, new customers will be solicited and registered based on the priorities of the utility and Village leadership and the desire of new participants to participate in the microgrid.

Electricity purchases from the microgrid during normal operations will follow existing contractual and purchase relationships between the utility and the customers. Steam purchases will be governed by a long-term (i.e., 10 year) Purchase Agreement between the utility and the industrial off-takers Egg Low Farms and Southern Tier Pet Nutrition. This arrangement will provide a fixed revenue stream for the microgrid while providing cost and quantity assurance for the off-taker, and it should be negotiated and agreed to during development before approaching the municipal bond market for financing. 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. All the aforementioned contracts are proposed, and none are currently in force.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to direct participants, non-customer stakeholders, Sherburne Electric, and the larger State of New York. The 2 MW solar array and a 2 MW natural gas-fired CHP turbine will reduce the town's GHG emissions and provide stable energy resources to critical facilities in emergency situations. The small-scale solar in the town will continue to contribute but will not be microgrid controlled due to the very small 10 kW size and its location behind the meter. Electricity customers will benefit from a more stable power supply, while steam customers will pay less per MMBTU for heat energy as described in Section 3.4. Sherburne Electric will receive stable cash flows from the proposed energy generation resource for many years to come. The benefits, costs, and total value of the microgrid project are discussed in detail below.

3.2.1 Business Model

Sherburne Electric is wholly owned by the municipality and is well positioned to adopt a vertically integrated, utility-owned microgrid. The Project Team believes that vertical integration provides the greatest benefits and flexibility to both the utility and the Village customer base. It also avoids unnecessary regulatory and contract issues that are attendant to privately owned microgrids. While REV seeks a decoupling of generation from the ownership and operation of the utility system, the small scale of the Village and the presence of a locally-owned, municipal utility creates an economic case that supports vertical integration. In the future, there are no structural or technical reasons preventing a private interest from developing generation to tie into the Sherburne grid. Table 16 below provides an overview of Sherburne microgrid project, including an analysis of project strengths, weaknesses, opportunities, and threats (SWOT).

Table 14. Sherburne Microgrid SWOT

Table discusses the strengths, weaknesses, opportunities, and threats of the Sherburne microgrid project.

Strengths	Weaknesses
• Vertical integration will allow one entity to collect the various incentive payments and revenues associated with the microgrid, reducing coordination requirements around distribution of financial benefits. • Provides existing mechanism for collecting fees and tariffs related to microgrid or new products (such as thermal). • Creates a single organization point of interaction with the macrogrid and wholly controlled physical points of interaction with the macrogrid • Single ownership and control of new generation assets allows for seamless integration with microgrid control apparatus. • Muni ownership (requisite for most vertically integrated projects) expedites local approval and permitting processes. • Lack of PSC rate setting rules on steam products allows for incrementally higher revenues compared to electricity sales.	• Immediate size and investment potential is limited by the available cash or bond limits. • Less ability than an IOU hybrid project to absorb cost increases and construction overruns; overall less financial cushion. • Default on the project could imperil the finances of the owning municipality in addition to those of the utility itself. • There is no assurance that the microgrid will be able to back-feed into the NYSEG system, impacting a potential revenue stream. However, the Sherburne Electric load averages more than 6 MW, compared to less than 4 MW of generation from the new assets, and consequently sales to NYSEG would be rare or nonexistent.
Opportunities	**Threats**
• Vertical integration facilitates future expansion of microgrid coverage (adding more facilities to the microgrid) as well as future construction of microgrid-integrated generation assets. • As natural gas, microgrid, and steam infrastructure in Sherburne expand, a vertically integrated microgrid will be uniquely positioned to capitalize on emerging demand for lower cost local electricity and thermal energy resources.	• Changes in regulatory structures, such as prices, generation asset ownership rules, environmental permitting, and changes in net metering, could negatively impact steam revenues, sales of power and services to the grid, or the ability of municipal utilities to own distributed energy resources. • If federal and state incentives sunset before generation assets are completed and connected, the value of investing in the microgrid will drop significantly.

While the strengths and opportunities of the vertically integrated model are strong, there are also weaknesses and threats to the Sherburne microgrid that must be addressed. The following represent mitigation strategies and context for the weaknesses and threats:

- Financial – The use of risk-based capital, consistent with the goals of REV, implies a financing structure that could theoretically fail. However, based on the identified revenues and costs, there is a very low likelihood of financial challenges for this project, based on the Village and utility's relatively strong investment rating, reserves, and operating income.
- Regulatory – Consistent communication with the PSC and other municipal utilities can create a dialogue that represents the interests and motivations of all actors. Moreover, this dialogue with the PSC means that upcoming regulatory changes are well known before they take effect.
- Incentives – The proposed microgrid is highly dependent on securing Phase II and Phase III funding from the NY Prize competition. The Project Team anticipates responding to the Phase II RFP when it is released.

3.2.2 Replicability and Scalability

The Sherburne microgrid is a largely replicable and scalable model. It 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. Most muni-served and IOU-served communities across New York are not currently outfitted with AMI technology at a community-wide level. 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 NYSEG grid are industry standard.

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. A natural gas connection is required for the natural gas CHP option. Without a connection, a non-CHP generation asset would be required and the project would no longer be a replica of Sherburne.

Organizational Replicability. The organizational structure is highly replicable among other municipally owned utilities that have a strong credit rating and bonding authority. Municipal ownership of the utility provides a unique set of circumstances that allow for full vertical integration. It could be problematic when applied to investor-owned utilities due to rules governing the ownership of distributed energy resources assets and other system components.

The viability of replication depends heavily on local weather conditions, electricity prices, the geography of load points, and incentive programs.[3] The Sherburne project is dependent on

[3] (from Sub Task 3.4, Point 11)

certain conditions to achieve profitability, and unless a potential replication site has drastically different electricity prices or outage patterns, these will be largely similar. As discussed above, the correct size and placement of CHP steam off-takers is critical for the commercial success of this microgrid design. In addition to the capital investment required in Sherburne, the cost of the AMI infrastructure will have to be additionally included in any future pro forma, and that could potentially impact the commercial viability of the project.

Scalability. The microgrid is scalable to the limits of the AMI radio controllers and the ability to physically partition the microgrid from the macrogrid. The microgrid could be feasibly scaled to include the entirety of Sherburne's territory. Scalability is limited by the need to identify a sufficiently large steam customer with consistent demand. There are no other components that should restrain this microgrid concept from serving a larger population. To be sure, expanding the proposed generation assets would provide islanded electricity to more facilities than those identified, but the exact type and size of expanded generation is contingent upon the availability of steam off-takers and sufficient natural gas supplies. Without new steam off-takers there is no business case for expanded CHP and without sufficient gas supplies there can be no expansion of natural gas fired engines beyond the current proposal. While it is unnecessary at this time in Sherburne, there is sufficient electricity load to support further electric generation.

3.2.3 Benefits, Costs and Value

The microgrid will provide widely distributed benefits, both direct and indirect, to the multitude of stakeholders identified in Section 3.2.3. The utility will see increased revenues and grid performance, customers will see stabilized electricity and steam prices provided by a more reliable grid system, and the community will reap the positive benefits, as outlined in Tables 17 through 23, of living in and around the microgrid. Except for marginally increased electricity costs during island mode and potential microgrid participation fees of a minimal amount, no costs of the project will be borne by the customers of Sherburne Electric or the community. Moreover, peak electricity rates are likely to decrease slightly, providing an offset of any increases. Projected project economics indicate that rates will not need to increase to finance the cost of construction and operation, and new revenues will be sufficient to cover associated costs. These revenues include electricity sales and steam sales, and costs avoided include forgone NYMPA purchases beyond the existing PPA with NYSEG Therefore, this proposal provides an excellent value proposition to all involved, from the local, non-customer resident of the Village to the State of New York.

Table 15 below provides an overview of benefits and costs Sherburne will realize by the construction and operation of this project. The benefits, costs, and value propositions for Sherburne Electric are disaggregated to better capture how Sherburne Electric is benefitting financially versus how they are benefiting as a provider of utility services.

Table 15. Microgrid Benefits, Costs, and Value Proposition for Sherburne Electric

Table separates Sherburne community into expected stakeholder groups and defines the costs, benefits, and total value to each group.

	Description of Benefits	Description of Costs	Value Proposition
Sherburne Electric, as Owner	- Revenues from generation assets and microgrid fees cover investment costs and provide stable future cash flows. This is due to a decrease in NYMPA purchases and the retention of electricity sale revenue within Sherburne Electric - State incentive programs, if all captured, provide a total of ~$2 MM over the project's first three years and are detailed in Section 3.5.1	- High up-front investment cost for generation assets and microgrid equipment totaling ~$9.8 MM (interconnection with the larger grid, smart meters, etc.); however, state incentives provide relief as detailed in Section 3.5.1 - Costs for fuel, operation, and maintenance to keep generation assets running (~$1.1MM /year) - Sherburne Electric will bear all capital and O&M costs as outlined in Section 3.2.3	- Revenue streams will continue beyond the initial investment repayment, providing future cash flows for the utility to reinvest in services and reliability
	Description of Benefits	**Description of Costs**	**Value Proposition**
Sherburne Electric, as Utility	- Improved resiliency and redundancy to large load pocket - Peak load reductions will reduce reliance on the macrogrid, partially avoiding grid-wide outages - Reduced risk associated with power losses	- Encouraging construction of distributed energy resources assets in the community may reduce future electricity sales—however, a move towards decoupling[4] sales volumes from revenues would ensure that the utility will be paid based on customer engagement rather than sales volume - Construction of the CHP is contingent upon expanding the natural gas pipeline	- Specific design decisions will allow a future scale-up of the project, and the extension of the natural gas line into the town will provide new generation opportunities - Construction of the microgrid will develop a more informed and engaged customer base—as utilities shift away from a "revenue per kWh sold" and towards a "revenue per customer serviced" business model, this will be key - The fully automated grid will make Sherburne a leader in microgrid operation in NYS

The Village government will benefit from the expansion of local, distributed energy resources that will help create a more resilient grid in the area and, in the long term, could catalyze the development of business in the Village that puts a high premium on the reliability of its electricity supply. While the Village may also be responsible for extending the natural gas pipeline, this will happen with or without the construction of the microgrid. Table 16 describes the benefits to the Village government.

Table 16. Microgrid Benefits, Costs, and Value Proposition for Sherburne

Table describes the costs, benefits, and total value to the municipal government of Sherburne.

	Description of Benefits	Description of Costs	Value Proposition
Municipal Government	- Facilities will receive backup power from proposed distributed energy resources assets and will 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 - In the future, the municipal government facilities could transition to steam instead of fuel oil for heating - Reduced GHG emissions - Further integration as a smart community	- Ultimate guarantor of the project as the owner of Sherburne Electric - Cost and time to extend the natural gas pipeline and, depending on exact arrangements, steam infrastructure - Regulatory challenges in extending natural gas pipeline - When the microgrid enters island mode for power availability reasons, customers will pay a slightly higher price for electricity than they would for electricity from the larger grid. This cost is offset by the greater reliability and higher power quality the microgrid brings	- Critical and important services will keep the lights on during outages, allowing the Sherburne to be an oasis of relief for the Village, Town, and surrounding areas - Government facilities will realize value from reduced electricity prices during peak demand hours - The microgrid project will serve as a catalyst for customers becoming more engaged in energy service opportunities and will inspire residential investment in DER assets, such as solar PV and battery storage, as citizens see benefits associated with avoiding peak demand hours, producing enough electricity to be independent from the larger grid, and selling electricity in a local market - Generating electricity and heat with solar PV arrays and a natural gas fired CHP plant will reduce net GHG emissions in the town by approximately 500 metric tons of CO_2 equivalent per year

[4] The dissociation of utility profits from volumetric sales of energy resources are instead based on meeting metrics and customer engagement.

Residents of Sherburne stand to gain from access to a broad range of critical and important services anytime the microgrid is forced into islanded operation, and on a regular basis will benefit from the ability of the local utility to reinvest savings in expanding the resiliency of the local grid. Residential microgrid customers may pay a slight tariff to support their inclusion, but this is a small additional amount. See Table 17 for a description of these costs and benefits.

Table 17. Microgrid Benefits, Costs, and Value Proposition for Residents

Table describes the costs, benefits, and total value to the residents of Sherburne.

	Description of Benefits	Description of Costs	Value Proposition
Residents	- Reliable and resilient energy supply to homes - Lower peak electricity costs due to avoided NYMPA purchases offset with cheaper CHP and PV generation - Potential for increased green job opportunities in Sherburne and elsewhere as local knowledge builds - Opportunities to achieve more energy savings by building interconnected DER assets such as solar PV arrays and utilizing battery storage - Ability to connect new or existing storage to the microgrid and realize positive cash flow through net metering	- Residential customers of the microgrid may experience slightly higher prices via the participation tariff of ~1%	- Residential customers in the microgrid coverage area will have access to a reliable, resilient energy source (even during emergencies); civilians outside the coverage area will still realize tangible benefits from critical facilities in power outage situations - Combined with facilitating interconnection of DER assets and creating a local market for excess generation, involving and educating the greater Sherburne public will help the town achieve NY REV goals as a community - Greater engagement and understanding of the city's energy issues

Local industry stands to gain significantly from the cheaper and abundant steam that will be created by the CHP unit, offsetting both costs and emissions. Each will have the opportunity to lock in steam purchases through long-term purchase agreements, thereby avoiding the volatility of No. 2 fuel oil prices. See Table 18 for a description of these benefits.

Table 18. Microgrid Benefits, Costs, and Value Proposition for Industry

Table describes the costs, benefits, and total value to the industrial stakeholders in Sherburne.

	Description of Benefits	Description of Costs	Value Proposition
Industry (Southern Tier Pet Nutrition and Egg Low Farms)	- Stabilized electricity costs due to new generation assets producing at lower cost than peak NYMPA prices - Resilient and redundant energy supply to operations—the EPA estimates that a power outage costs industrial customers ~$50.00/kWh - Two primary industrial facilities (Egg Low Farms and Southern Tier Pet Nutrition) will save ~$180,000 per year by using CHP-produced steam instead of fuel oil	- Egg Low Farms and Southern Tier Pet Nutrition may have specific pressure and quality requirements for steam; depending on location of proposed CHP generator, there may be significant steam lost in transmission - Industrial customers of the microgrid will experience slightly higher electricity prices via the ~1% tariff	- Construction of the CHP will provide a constant flow of low cost thermal energy to industrial off-takers - Decreased costs of production 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

Commercial customers of the microgrid will benefit from the reliability and resilience of the microgrid and ability to stay in business during any macrogrid outages. Any future steam users would have potential access to steam produced at far cheaper costs than internal boilers. See Table 19 for a description of these benefits.

Table 19. Microgrid Benefits, Costs, and Value Proposition for Commerical Customers

Table describes the costs, benefits, and total value to the commercial customers in Sherburne.

	Description of Benefits	Description of Costs	Value Proposition
Commercial	- Steam supplied by CHP generator could be made available to commercial entities (proposed or future microgrid customers) for heating or process requirements if Egg Low Farms or Southern Tier reduces their demand - Resilient and redundant energy supply to critical services (EPA estimates that a power outage costs commercial entities at least $40.00/kWh) - Lower cost of electricity during peak demand hours - Creation of a local market for excess energy production	- Commercial customers of the microgrid will experience slightly higher prices via the 1% tariff	- Commercial entities will benefit from lower electricity costs and constant, reliable power supply (allowing them to maintain operations and sales during power outages and periods of poor power quality) - Commercial entities with significant steam heating bills and in reasonable proximity to the CHP could save ~$8.50/MMBTU[5] by switching from heating fuel oil to steam produced by the CHP generator - Extending natural gas pipelines to Sherburne will guarantee a constant flow of cheap and clean heat to customers - 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

The community, both within the Sherburne Electric service territory and beyond, will have continuous access to critical services including banking, groceries, and emergency services during any outage. Moreover, Sherburne customers could be reconnected in an island situation if there is an abundance of power available; however, this is not considered likely. Table 20 provides a description of these benefits.

[5] Based on the current cost of steam production using No. 2 fuel oil versus the projected selling cost of CHP produced steam to industrial off-takers.

Table 20. Microgrid Benefits, Costs, and Value Proposition for the Community

Table describes the costs, benefits, and total value to the Sherburne community at large.

	Description of Benefits	Description of Costs	Value Proposition
Community at Large	- Access to a wide range of critical services during grid outages, including banking, healthcare, fire and safety, and food items - Potential for rate decreases in the future as Sherburne Electric realizes continued revenues beyond the 30 year period of bond payment	- Because the Village is the guarantor of the debt, Village residents are collectively responsible. However, there is a small chance of default or negative impact on town finances	- Extension of natural gas infrastructure could encourage expanded use of natural gas heating and stoves, significantly cheaper than electric or fuel oil heating - Potential for reconnect in outage situations if generation assets are out-producing the demand of critical and important loads - As local generation expands, so can the facilities included in the islanded microgrid, through the use of unique IDs on each AMI meter

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 moves forward the goals of REV and provides a more resilient overall grid. New York will likely be responsible for rebate and incentive payments to support the financing of the Sherburne grid. See Table 21 for a description of these benefits.

Table 21. Microgrid Benefits, Costs, and Value Proposition for New York State

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

	Description of Benefits	Description of Costs	Value Proposition
New York State	- DER assets will reduce overall GHG emissions - Cash flows will provide tangible evidence of microgrid project's commercial viability - Indirect benefits (such as outages averted) will demonstrate the benefits of microgrids paired with DER assets - 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 DERs - 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 vertically integrated microgrid will demonstrate the tangible value of microgrid projects as investments

3.2.4 Demonstration of State Policy

Sherburne will coordinate plans to develop a community microgrid to provide a platform for the delivery of innovative services to the end-use customers. Sherburne Electric already subscribes interested customers to a DR program using water heat controllers to manage the utility's coincident peak demand. The great success of the program could mean that there is an opportunity to introduce new and more aggressive demand management programs. The Sherburne 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 Village, the microgrid can be reprogrammed to support these assets and various direct and ancillary services they provide.

Additionally, Sherburne has expressed interest in Community Choice Aggregation (CCA). It views the partnership established and excitement generated by this community microgrid project as a catalyst for customers becoming more engaged in energy service and other opportunities like CCA. The interest in both the microgrid and CCA throughout Sherburne will pave the way to an "animated" market, as consumers and producers (both large and small) are engaged in both understanding and managing their energy use. This engagement, coupled with the right price signals, will produce a more efficient use of existing infrastructure and thus further progress towards REV goals.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

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

3.3.1 Stakeholder Engagement

The Project Team has been engaged and in constant communication with local stakeholders from the outset. The team has had several in-person visits with Sherburne Electric and Village officials, including the project kickoff meeting in Sherburne on May 21, 2015, as well as frequent communication on numerous aspects of the microgrid planning and development process. The Village and the utility are both engaged players in the feasibility study and are committed to a successful project outcome. Booz Allen and its Village partners have also communicated with each of the critical and important facilities that will comprise the customer base of the microgrid to gauge electric and steam demand and discuss other aspects of the project development.

3.3.2 Project Team

The Sherburne microgrid project is a collaboration between the public sector, led by Sherburne Electric and the Village, 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 the Village and Sherburne Electric have a long history of providing reliable utility service and a forward-looking approach to improving their operations and resiliency. Tables 22 and 23 provide background on these entities and outline their roles and responsibilities.

Table 22. Project Team

Table provides background on Booz Allen Hamilton, Siemens AG, Power Analytics, and Sherburne Electric.

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.			
Sherburne Electric	Headquarters: Sherburne, NY	Annual Revenue: $3.8 M	Employees: 7
History and Product Portfolio: Sherburne Electric is a local electric company for this city. This Electric Company is important to the development of the microgrid due to their commitment to renewable energy, advanced metering, and providing enhanced energy resiliency to their customer base. Approximately 80% of the power Sherburne provides to its customers is renewable. Almost all power is hydro power received from the Niagara Power Project. This is more than four times the average amount of renewable energy purchased by investor owned utilities in New York State.			

Table 23. 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.

	Roles and Responsibilities		
Team Member	**Project Development**	**Construction**	**Operation**
Sherburne Electric	Sherburne Electric, as the owner and operator of the microgrid, has a foundational role in development. They are the source for all utility data and information	Sherburne Electric will have a construction oversight role and will be responsible for financing the	Sherburne Electric will operate the microgrid either wholly in-house or in conjunction with outside assistance. They

	Roles and Responsibilities		
Team Member	**Project Development**	**Construction**	**Operation**
	on relationships with the macrogrid; they have a strong voice in proposed features of the microgrid and work closely with the Village and BAH to ensure a beneficial, cost effective, and desired project.	construction (see Section 3.5.2). They will work closely with Siemens and Power Analytics during the physical construction and installation of system components.	will own the system (see Section 3.2) and maintain primary responsibility for its function. All system electricity, thermal, and ancillary sales will be managed by Sherburne Electric.
Village of Sherburne	The Village has a dual role in development, serving as the municipal oversight of the electric company and the main conduit to representatives of the critical and important facilities and other interests in the town. This effort is spearheaded by the Village Mayor, who is responsible for local outreach.	As the owner of Sherburne Electric, the Village will maintain ultimate oversight for all construction activities within the Village. As the liaison, the Village will coordinate with all local and state parties as needed.	As the owner of Sherburne Electric, the Village will maintain ultimate oversight for all microgrid activities within the Village. As the liaison, the Village will coordinate with all local, regional, and state parties as required.
Booz Allen	BAH is responsible for the delivery of the Feasibility Study, Engineering and Design, and their component parts. This includes serving as the central clearinghouse of data, design, and proposal development as well as the key POC for NYSERDA on this task.	BAH will serve in an advisory and organizational role, working in a similar prime contractor capacity to provide overall design, costing, and construction management services.	BAH would serve in an outside, advisory capacity upon completion of the microgrid and during its operation.
Siemens	Siemens is the engineering and technology partner of the 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 (PA) is the energy software solution partner. 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.
Suppliers	There are no suppliers during the development phase; however, project partners and suppliers Siemens and Power Analytics are	Booz Allen has been in discussions with several vendors about their distributed energy resources and	The vendors selected to provide hardware and software components of the microgrid will remain engaged to ensure the

	Roles and Responsibilities		
Team Member	**Project Development**	**Construction**	**Operation**
	closely involved in feasibility and design portions of the project.	microgrid hardware and software solutions.	stable and efficient function of the equipment and microgrid.
Financiers/Investors	Outside finance advisors will be retained to assist the bond offering. Financing assistance will also be provided by NYSERDA through NY Prize.	Outside finance advisors will be retained to assist the bond offering and drawdown of funds.	Outside finance advisors will be retained to assist with any issues in bond repayment that may arise.
Legal/Regulatory Advisors	Legal and regulatory advice is housed within Booz Allen and outside counsel.	Legal and regulatory will be a combination of Booz Allen, the Village, and outside counsel as necessary.	Legal and regulatory will be the existing Village regulatory and legal counsel.

3.3.3 Financial Strength

Sherburne and Sherburne Electric are financially strong. Both maintain a B+ credit rating and the ability to issue bonds on the municipal bond market. Sherburne Electric posted a debt/equity ratio of 18% in the fiscal year ending 2/28/2015, well under the S&P benchmark for merchant power operators. It is also a well-capitalized utility. Sherburne Electric has approximately $10 million worth of fixed assets against which they can borrow and long-term debt of only $900,000. Cash accounts currently amount to about $800,000. This indicates a healthy company that is content with slow, stable growth. Distribution, system operation, and maintenance costs have stayed fairly steady over these years, but Sherburne Electric paid approximately $600,000 more for electricity in FY 2013 than they did in FY 2012. Sherburne Electric currently purchases base load electricity from the NYPA year round and supplements with electricity from the NYMPA in the winter months when demand is higher (November-April). This is not a sustainable growth plan because all incremental electricity purchases will be from NYMPA and thus more expensive than the Sherburne baseload purchase. Sherburne Electric will need to renegotiate the amount of electricity purchased from the NYPA during the winter months, implement energy efficiency programs to curtail load, or invest in generation capability to avoid paying steadily higher prices as the Village's demand for electricity increases. The microgrid is an opportunity to mitigate NYMPA purchases and provide a more sustainable financial path forward. With increased revenues from proposed generation assets and the subsequent reduction in power purchased from the NYMPA and NYPA, the company should enjoy stable cash flows for the foreseeable future.

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. As detailed in Section 2.6.2 above, the AMI in Sherburne will support remote connection and disconnection of loads based on a Supervisory Control and Data Acquisition based control center. The proven efficacy of the proposed microgrid components and the extensive AMI and IT infrastructure in Sherburne enhance the replicability and scalability of the design. Section 2.6.2 discusses the technical components of the microgrid and the reason for selection.

Sherburne Electric will be required to maintain the proper functioning of the grid, as described below. A critical mass of registrations is required to ensure service purchasers, both of electricity and thermal resources, are receiving the best value. Critical mass will be achieved with the registration of the identified customers and will not need to expand to further facilities. The microgrid is a classic shared value entity; both the utility and customers will benefit financially and the continued success of the grid requires the support of both. The microgrid will be operated by Sherburne Electric, who will have decision-making authority for all questions surrounding the grid that are not automatic elevations to the State or Public Service Commission. Decisions on the proper level of generation from local assets, load following, and other similar issues will be addressed automatically in real-time by the logic controllers and microgrid control system as detailed in Section 2.7.1.

Sherburne Electric 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, and will have ongoing assistance from Siemens, Power Analytics, and other suppliers. 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 ensuring an ample supply of natural gas to the CHP unit, either through the construction of its own pipe extension or through a third party vendor.

The utility will be responsible for the collecting electricity, steam tariffs, and microgrid tariffs. All electricity billing will continue to be conducted via the regular Sherburne Electric billing mechanism and cycle. Purchasers of electricity services will be charged through their regular bills, as the utility is the owner and operator of microgrid and the distributed energy resources. Additional fees may be imposed based upon microgrid participants as a percentage of their tariff. However, given the extremely limited amount of time forecasted in island operation and the commensurately limited time that the customers will need to rely on the microgrid, this will be no more than 1%. These fees will be agreed to by contract and with the approval of the PSC. Metering will continue to be done 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 payments on the bonds issued to support construction. Depending on the final financing structure, the Village may bear some financing costs because the liabilities and equities of the utility are ultimately owned by the Village. However, revenues are expected to cover debt costs. See Section 3.5.2 for additional information.

3.4.1 Barriers to Completion

The barriers to entry for Sherburne Electric in constructing and operating the microgrid are primarily financial. The high capital costs and relatively long payback make the investment a difficult one; however, the combination of increased revenues from thermal sales, peak shaving, and rebates/subsidies allow for a positive net present value (NPV) business case. Lack of incentives is not currently a barrier to market entry, but it may become one in the near future. Particularly the availability of NY Prize Phase II and II funding is anticipated to be very competitive, but will be necessary for the viability of the Sherburne microgrid.

The second barrier to entry for Sherburne Electric for this project design is the lack of a natural gas pipeline into the Village. This will be an additional expense, but it is not prohibitive and will be overcome to bring the project online. Surrounding communities have faced a similar needs to extend the gas distribution infrastructure and have been able to successfully do so. This extension of the gas infrastructure will occur whether or not the microgrid is constructed, so it is not included in the proposed microgrid cost of construction.

Electricity participants on the Sherburne microgrid face limited barriers to entry. They each have AMI technology installed, and it will be upgraded by the utility before the microgrid becomes operational, and the microgrid is being designed to ensure sufficient load capacity for each of the identified critical and important facilities. As outlined in Section 3, electricity customers will be charged through the existing metering and billing mechanisms. There will be costs associated with microgrid completion; however, they are not intended to be exclusionary and should not preclude participation based on the cost. Steam off-takers have an expanded barrier to entry in the current lack of steam distribution infrastructure. The installation and operation of the new infrastructure will be the responsibility of Sherburne Electric, and it is planned to coincide with the construction of the CHP unit to which they will connect. Both of the customer barriers to entry are surmountable. Refer to Section 3.5.1 for detailed costs and revenues, and Section 3.2.3 for stakeholder benefits and value propositions.

3.4.2 Permitting

There will be required air quality permits pursuant to Federal law and the Clean Air Act. The Village will need to approve the siting of generation and control facilities. Village permits will likely be required for the construction of the steam conveyance. The Project Team does not anticipate further permitting requirements. See Section 3.6.2 for further details.

3.5 Financial Viability (Sub Task 3.5)

The distributed energy resources assets included in the microgrid design will produce significant revenue streams from electricity and steam sales to customers, and potential electricity sales to NYSEG. These assets will require significant investment costs as well as normal operation and maintenance. Municipal bonds will provide the majority of the required capital outlay for the project construction phase, along with NY Prize Phase III funding. This section will discuss the revenues, costs, and financing options associated with the microgrid project in more detail.

3.5.1 Revenue, Cost, and Profitability

The microgrid has a number of savings and revenue streams, as outlined in Table 25 below. Capital expenditures for the Sherburne microgrid are estimated at $9,800,000 with an additional $1,100,000 in operating expenditures each year. The operating expenses reflect generator fuel and the maintenance of the generation and microgrid assets. Revenues are estimated to be approximately $1,430,000 each year, and savings from avoided NYMPA purchases will total approximately $600,000. Table 24 reflects the operating and capital costs summarized above.

Table 24. Savings and Revenue Streams

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

Description of Savings and Revenues	Savings or Revenue	Relative Magnitude	Fixed or variable
Thermal sales to industrial off-takers	Revenue	~$530,000/yr[6]	Fixed (PPA)
Electricity sales to customers during normal operation	Revenue	~$900,000/yr	Variable
Electricity sales to customers during islanded operation	Revenue	$1000/yr	Variable
NYMPA purchases avoided	Savings	$600,000/yr[7]	Variable
Microgrid participation tariff	Revenue	1%	Variable
	Total Revenues	**~$1,430,000**	

See Table 25 for a description of the capital and operating costs.

Table 25. Capital and Operating Costs

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

Description of Costs	CapEx or OpEx	Relative Magnitude	Fixed or Variable
2 MW Reciprocating CHP	Capital	$4,400,000	Fixed
2 MW Solar PV	Capital	$4,400,000	Fixed
Substation Equipment	Capital	$520,000	Fixed
Distributed Equipment	Capital	$440,000	Fixed
IT Infrastructure	Capital	$120,000	Fixed
	Total CapEx	**$9,800,000**	
Generator Fuel	Operating	$800,000/yr	Fixed (PPA)
Asset Maintenance	Operating	$330,000/yr	Variable
	Total OpEx	**$1,100,000/yr**	

See Table 26 for a description of the available state incentive programs.

[6] Based on average steam sale price per MMBTU and the volume of offtake.
[7] Based on 2.5MW of continuous generation within the grid, average monthly NYMPA purchases, and NYMPA monthly bills. Will be partially offset by natural gas purchases and CHP pay-down.

Table 26. Available Incentive Programs

Table includes all state 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
NYISO Emergency Demand Response Program (EDRP)	~$9,000-$30,000 (yearly)	Preferred
NYISO Day Ahead Demand Response Program (DADRP)—this requires predetermined commitments to reducing load (microgrid may or may not participate)	~$30,000-$60,000 (yearly)	Preferred

3.5.2 Financing Structure

The development phase is characterized by the negotiation and execution of the construction financing and debt structure and agreements with any equity partners. Project design and development will be funded through Phase II of the NY Prize Community Microgrid Competition, and no financing from private equity or the bond markets will be required. Sherburne Electric and Sherburne will provide needed in-kind services consisting primarily of system expertise and support and any additional funds required to complete Phase II design work. Development will conclude with formal contract relationships between the utility and the customers of the microgrid, available and relevant rate and tariff information from the PSC, and firm financing for the construction of the project (described below). The selection and contracting of individual hardware and software vendors will occur during development.

Construction is characterized by the build out of the project, using the funds sources from NYSERDA for Phase III of the NY Prize Community Microgrid Competition and supplemented by the utility and Village. Due to the large capital cost of the project (estimated to be approximately $9.8 million), the utility cannot support a cash outlay, so it will initiate a bond offering on the bond market for the outstanding amount less NY Prize funding. Issues to be addressed during the negotiations related to the bond terms include:

1.) limits of the basic security
2.) flow-of-funds structure
3.) rate (or user-charge) covenant
4.) priority of revenue claims
5.) additional-bonds tests
6.) other relevant covenants

The bonds will be backed by the revenues generated by Sherburne Electric during the operation of the microgrid. The revenue sources will include the cash flows generated from electricity sales, thermal sales, cash saved from foregone NYMPA purchases, any potential sales of electricity to NYSEG, and any standby fees or tariffs imposed for participation in the microgrid.

Taking into account NY Prize funding, the project should generate sufficient cash flows to satisfy the obligations due to bondholders. We estimate those financing obligations to be approximately $175,000/year. The particulars of the debt financing, including the interest rate and repayment schedule, will be based on the specific conditions of the market at the time of the issuance and the final amount needed by the utility to implement the microgrid.

The operational phase will be characterized by positive revenue streams and a gradual pay-down of project finance principal and interest. Structured as a typical infrastructure project, the microgrid revenue model will be built for a 30-year period. The project is expected to generate sufficient cash flows to cover the maintenance costs of the microgrid and generation assets and debt service payments.

In the event that Sherburne is unable to secure the required financing for sole ownership, a lease-leaseback (lease-to-own) financing arrangement is also an option. In a lease-leaseback arrangement, the Village would lease a parcel of land to a Contractor for the purpose of constructing the generation assets and new control equipment for the Village. The microgrid would then be leased back to the Village for a stipulated period of time, after which the property reverts to Sherburne's control and the microgrid to Sherburne's ownership. The benefit of the arrangement is the decreased debt load on the Village's balance sheet and the continued availability of bonding capacity for other projects.

3.6 Legal Viability (Sub Task 3.6)

The ownership and regulatory considerations in Sherburne, due to the municipal ownership of the project, are fairly straightforward. The utility will fully own assets and access, and regulatory issues are minimal. Electricity and related services will continue to be regulated by the NYPSC, while steam is likely to fall outside of the state regulatory regime. As a municipal utility that is not exporting power on an interstate basis, Sherburne Municipal Electric is not subject to oversight by the Federal Energy Regulatory Commission.

3.6.1 Ownership and Access

The microgrid will be owned by Sherburne Electric, and, by extension, Sherburne. Microgrid equipment, including generation, will be installed on city and/or utility owned land, minimizing any concerns about property rights and access limitations.

3.6.2 Regulatory Considerations

Because the proposed microgrid is not exporting power at transmission voltage, FERC regulation is not applicable.[8] In contrast to other states, however, New York does regulate its municipal utilities through Public Service Commission (PSC) oversight. Thus, electric and steam production are regulated by the state. However, pursuant to New York Public Service Law § 2, there are certain exceptions to regulated "steam corporations," including an exception in cases where steam is "made or produced by the maker solely from one or more co-generation or

[8] http://www.ferc.gov/about/ferc-does/ferc101.pdf

alternate energy production facilities or distributed solely from one or more of such facilities to users located at or near a project site." Further, New York Public Service Law § 5(c) states that the PSC regulates "persons" who furnish steam for heat or power. However, pursuant to New York Public Service Law § 2, "person" is further defined as an:

> "Individual, firm or co-partnership ***other than*** an individual, firm or co-partnership generating electricity, shaft horsepower, useful thermal energy or gas solely from one or more co-generation, small hydro or alternate energy production facilities or distributing electricity, shaft horsepower, useful thermal energy or gas solely from one or more of such facilities to users located at or near a project site." (Emphasis added.)

In this case, the steam production will arise from a co-generation facility and will serve facilities close to the project site and, as such, will not be regulated by the NY PSC.

Regarding electricity generation, Sherburne Electric must generally comply with New York Public Service Law, as well as CRR-NY Title 16, Chapter II, Electric Utilities. Specific to customer privacy, Sherburne Municipal Electric must comply with the customer privacy protections outlined in 16 CRR-NY 6-2.1-11. These two sections of code are currently being met by Sherburne Electric. Privacy concerns will not be an issue for the Sherburne microgrid, since all sensitive communication with customer AMIs will be encrypted, and any sensitive information about loads, AMI tags, or related information will be protected by Sherburne Electric privacy protocols on the use of the existing AMI infrastructure.

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 has adopted the 2009 IECC for residential construction and the 2012 IECC for commercial applications.

Due to the vertically integrated ownership model of the proposed micro-grid, the distributed energy resources will be owned directly by Sherburne Municipal Electric, instead of an independent third-party. Thus, traditional DER policies, such as net metering, do not apply. However, as noted above, tariff regulation through PSC regulations will apply to the power produced by utility-owned DER. Village ownership of the microgrid facilities, including the new generation, will expedite the process to approve construction because all land intended to be used for new facilities is municipally owned.

3.7 Project Commercial and Financial Viability Conclusions

The Sherburne microgrid project is financially feasible as currently proposed. The microgrid will include a mix of residential, government, healthcare, and retail facilities and will be owned and operated by Sherburne Electric. The vertically integrated ownership model affords Sherburne a seamless integration of generation, microgrid controllers, and distribution infrastructure and allows the utility to capture the full suite of revenue streams, estimated at $1,430,000 per year.

The model will also maintain the current billing and rate capture mechanisms as Sherburne Electric is already the energy provider to all customers of the microgrid. With the exception of steam purchase agreements, there will be no change in the fundamental relationship between microgrid customers and the utility. The annual costs associated with operation and maintenance are estimated at $1,100,000, and the project is revenue positive to a +/-30% approximation. While the cash benefits will accrue largely to Sherburne Electric, the industrial steam off-takers will see a direct reduction in costs associated with replacing No. 2 oil based steam with CHP generated steam. 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, as all construction of generation and microgrid equipment will occur on city and utility owned land. 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, and with an acknowledgement of the risks present in the development of this project. The Project Team assumes the natural gas infrastructure will be extended to Sherburne independent of the microgrid, and the possibility that it is not extended is a risk to the microgrid and the installation of CHP. Steam off-takers are assumed to remain present with sufficient demand to consume most or all of the thermal resources generated by the CHP; any deviation would negatively affect project economics. We also assume that upgraded AMI infrastructure is going to be installed independent of the microgrid, a necessary step to support the remote connect and disconnect capabilities that underlie the proposed project. If they are not installed, the control systems will have to be redesigned to account for that reality.

4. Cost Benefit Analysis

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

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

4.1 Facility and Customer Description (Sub Task 4.1)

The Sherburne microgrid will include nineteen facilities from various rate classes and economic sectors. NYSERDA designates three primary rate classes based on type of facility and annual electricity consumption: residential, small commercial (less than 50 MWh per year), and large commercial (greater than 50 MWh per year). Thirteen of the proposed microgrid facilities belong to the large commercial rate class, four are small commercial facilities, and two are residential buildings. The large commercial buildings account for approximately 96% of the microgrid's annual electricity demand, with small commercial and residential facilities requiring approximately 500 MWh of electricity per year (see Table 27).

Seven public facilities, three health facilities, two industrial/manufacturing plants, two retail stores, three commercial facilities, and two residential buildings will be connected to the microgrid. The retail stores sell gasoline and groceries, while the commercial facilities provide banking, insurance, and communications services. The average electricity demand per facility is 620 MWh/year, with the majority of facilities requiring less than 500 MWh/year. Facilities belonging to the public sector represent the largest projected electricity loads, comprising more than 48% of the microgrid's total annual electricity usage and aggregating a peak demand that may rise as high as 1.7 MW. Industrial and manufacturing facilities require the most energy per facility and together represent 28% of the microgrid's annual electricity demand. Retail and commercial facilities also account for a significant percentage of the microgrid's annual electricity demand (27%), together requiring approximately 3,150 MWh per year.

Most of the facilities included in the microgrid are single ratepayer buildings, with the notable exceptions of Grace Manor and Sherburne Senior Housing (two residential facilities that include 53 living units collectively). The Elementary, Middle, and High Schools are clustered as a single rate-paying entity (Sherburne-Earlville Central Public Schools).

The generation assets included in the microgrid design will be capable of meeting 100% of average aggregate facility energy usage during a major power outage, but they may approach their generation limits if several large facilities simultaneously reach peak energy use. In these situations, the backup diesel generators may need to come online to supply additional electricity.

Some non-critical facilities do not operate 24 hours a day, such as NBT Bank of Sherburne and the US Postal Service that will only operate eight hours per day during both grid-connected and island mode. However, some critical facilities that normally operate less than 24 hours per day may need to operate continuously in emergency island-mode situations. The critical facilities may extend their normal services or provide a fundamentally different set of services. For example, the school complex normally requires electricity for lighting, electrical appliances, and heating/cooling during the daytime hours. However, if it serves as a community shelter in emergencies, its electricity usage window will extend 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 27.

Table 27. Facility and Customer Detail Benefit[9]

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.

	Facility Name	Rate Class	Facility Description	Economic Sector	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Required Per Day During Major Power Outage[10]
1	Village Municipal Building (Village office, Fire Department, Police Department, and Ambulance)	Small Commercial	Local municipal building, headquarters of Fire and Police departments	Public	46.134	0.0486	100%	24
2	Sherburne Electric and DPW	Large Commercial	Local municipal building	Public	118.84	0.1312	100%	24
3	Sherburne-Earlville Central Public Schools (Elementary, Junior High, and Senior High Schools)	Large Commercial	Local schools servicing the students of Sherburne	Public	4,374.5	1.456	100%	24
4	Wastewater Treatment Plant	Large Commercial	Wastewater treatment facility	Public	206.8	0.0704	100%	24
5	Railroad Crossing gates/signal	Small Commercial	Railroad crossing gate	Public	1.2	0.0002	100%	24

[9] Load data from Sherburne Electric.

[10] The Booz Allen team estimated these numbers based on the facility's expected function during a power outage. For example, the Fire Department will operate continuously to provide fire safety, infrastructure, and emergency management services to the City.

	Facility Name	Rate Class	Facility Description	Economic Sector	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Required Per Day During Major Power Outage[10]
6	Village of Sherburne Wastewater Pump Station	Small Commercial	Wastewater pump station	Public	20.27	0.0119	100%	24
7	US Postal Service	Small Commercial	Small post office	Public	30.81	0.0151	100%	~8
8	Chenango Memorial Hospital Health Clinic	Large Commercial	Affiliated clinic of nearby hospital	Health	70.32	0.0496	100%	24
9	Basset Healthcare	Large Commercial	Family clinic	Health	108.42	0.0410	100%	24
10	Service Pharmacy	Large Commercial	Pharmacy	Health	69.43	0.0401	100%	~12
11	Southern Tier Pet Nutrition	Large Commercial	Pet food manufacturer	Industry	2,722.8	0.863	100%	~8
12	Egg Low Farms Inc.	Large Commercial	Manufacturer of egg products	Manufacturing	504	0.352	100%	~8
13	Mirabito's Gas Station	Large Commercial	Gas station	Retail	187.64	0.0432	100%	~12
14	Big M Supermarket	Large Commercial	Grocery store	Retail	864.96	0.18	100%	~12
15	NBT Bank of Sherburne	Large Commercial	Local branch of a bank	Commercial	83.44	0.0244	100%	~8
16	Frontier Communications	Large Commercial	Branch of internet, TV, and phone service provider	Commercial	1,229.4	0.237	100%	~8
17	NYCM Insurance	Large Commercial	Branch of insurance company	Commercial	782.16	0.2968	100%	~8

	Facility Name	Rate Class	Facility Description	Economic Sector	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Required Per Day During Major Power Outage[10]
18	Grace Manor (low-income housing)	Residential	22 low income housing units	Residential	223.2	0.0429	100%	~12
19	Senior Housing	Residential	31 assisted living units	Residential	180	0.03782	100%	~18
	Totals	**----**	**19 total facilities**	**----**	**11,824.31**	**4.11**	**100%**	**----**

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates DERs, including two existing diesel generators, a proposed natural gas-fired CHP generator, and a solar PV array. The proposed CHP unit and solar PV array will produce an average of 1.98 MW of electricity throughout the year,[11] and the existing diesel generators at Frontier Communications and NYCM insurance will provide up to 1.5 MW of backup generation capacity during emergencies.

Supplied by the proposed natural gas pipeline, the CHP unit will provide nearly all of the microgrid-connected facilities' electricity and most of the industrial facilities' thermal energy. It will capture waste heat from the electricity turbine and use this heat to produce approximately 21,000 million British Thermal Units (MMBTU) of steam per year,[12] which will be used by the industrial facilities at Egg Low Farms and Southern Tier Pet Nutrition during both grid-connected and island mode. 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 up to 48 MWh of electricity per day, which would provide over 100% of the microgrid's average daily demand. Assuming a heat rate of 9.5 MMBTU/MWh,[13] the CHP unit will incur a fuel cost of approximately $44/MWh.[14]

Limited by weather conditions and natural day-night cycles, the 2 MW solar PV array is expected to produce around 2,450 MWh per year. Because many outages are caused by severe weather events, solar panels cannot be relied upon to provide energy during emergency outages without supplementary battery storage. However, on average the solar array will produce 6.7 MWh of electricity per day, which represents 18.7% of average daily electricity demand from microgrid-connected facilities. Maintenance costs for the solar array will be around $40,000 per year,[15] which means the total cost of producing solar electricity will be about $34/MWh.[16]

The existing diesel generators at Frontier Communications and NYCM Insurance 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 generators at Frontier Communications and NYCM have nameplate capacities of 1 MW and 0.5 MW, respectively. This aggregate 1.5 MW of backup generation capacity could be vital in emergency situations, or when the solar array or CHP unit go offline for maintenance. The Booz

---

[11] **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)

[12] 2 MW CHP thermal output will be ~1760 MMBTU per month (Siemens estimate)

[13] 2013 EIA average for natural gas fired Gas Turbine (http://www.eia.gov/electricity/annual/html/epa_08_02.html)

[14] **Price of natural gas**: $4.83 per Mcf (average CHGE supply price from 2013-2015). Many other utilities do not provide supply charge of natural gas; the team therefore adapted this estimate to Sherburne.

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

[16] **Capital cost**: $4,400,000 (Siemens estimate for 2 MW solar array)

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

Allen team predicts that the backup generators will operate approximately 20% of the time during the 1.9 hours of projected grid outage per year,[17] for a total of around 0.55 MWh per year.[18] Together the diesel backup generators require around 107 gallons of diesel fuel per hour of operation.[19] In the event of a major power outage (i.e., an outage that lasts for hours or days), these generators could produce a maximum of 36 MWh/day—however, assuming that the CHP and solar array will require backup power during only 20% of emergency outage hours, this figure drops to a more realistic 6-8 MWh/day. See Table 28 for a detailed list of all proposed and existing distributed energy resources in Sherburne.

[17] Grid outage data from DPS 2013 Electric Reliability Performance Report (NYSEG average CAIDI).

[18] In 2014, the average load in Sherburne was 1.5 MW and the peak was around 4 MW. On a typical August day, the average load was around 1.4 MW, and the peak combined load was ~1.8 MW. The CHP will provide a maximum of 2 MW and we cannot rely on the solar PV array for any significant contribution. Assuming that the typical August 24 hour load profile does not radically change shape in other months (i.e., peak demand occurs for roughly the same number of hours each day), the combined load of microgrid facilities will exceed the CHP's capacity for approximately 4-6 hours per day. This translates to operating the diesel generators during roughly 20% of outage time.

[19] **Diesel generator heat rate**: ~0.071 gallons/kWh (reported by NYCM Insurance and Frontier Communications)

Table 28. 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 0.4 effective hours of operation per year for diesel backup generators.

Distributed Energy Resource Name	Location	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Expected Daily Production During Major Power Outage (MWh)	Potential Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
							System fuel	Units of MMBTUs
DER1 - Diesel backup generator	Frontier Communications	Diesel	1.0	0.4	4.8	24	71 Gallons	9.83 MMBTUs
DER4 - Diesel backup generator	NYCM Insurance	Diesel	0.5	0.2	2.4	12	71 Gallons	9.83 MMBTUs
DER2 - Proposed Natural Gas-fired CHP	Land behind the Firehouse	Natural Gas	2.0	14,892	40.8	48	9.26 Mcf	9.5 MMBTUs
DER3 - Proposed 2 MW PV Array	2100 distribution line, near Sherburne-Earlville Central Public Schools	N/A	2.0	2,452.8	6.72	16[20]	N/A	N/A
PV Array	Sherburne Electric Rooftop Solar	N/A	0.01	12.26	0.033	0.08	N/A	N/A
PV Array	School Rooftop Solar	N/A	0.01	12.26	0.033	0.08	N/A	N/A

[20] 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

Assuming nearly continuous operation over their 20 year lifespans, electricity generated by the proposed CHP and solar array will cost marginally more than Sherburne Electric's current average electricity purchases. However, this estimate does not include the CHP's thermal energy output, which essentially represents an incidental source of revenue and allows Sherburne Electric to maintain their current retail prices while realizing profit from the CHP. By providing constant electricity generation, the proposed assets will reduce Sherburne Electric's reliance on expensive supplemental electricity in the winter months and will provide peak load reduction in the summer months. As a municipally-owned utility, Sherburne Electric purchases cheap electricity (at around $15/MWh) from the NYPA during the summer months. However, from November to April, Sherburne Electric purchases approximately 2,000 MWh/month from NYMPA at a rate of around $90/MWh. Thus electricity from the microgrid's generation assets will replace electricity that on average costs Sherburne Electric $52-53/MWh throughout the year.[21] Projected assets will generate electricity at a total cost of around $53/MWh[22] and should sell electricity at the average Sherburne Electric price of $51/MWh.[23]

Residential customers with usage over 1,000 kWh per month and commercial customers with peak demand under 10 kW currently experience higher rates during the winter (November to April) than the summer. The development of the microgrid is not expected to reduce the rates paid by customers in the winter, but that decision ultimately remains with Sherburne Electric.

The proposed solar arrays will be at their most productive on days with peak solar irradiance when peak demand events are common, thus providing peak load support when it is most needed. They will provide around 0.28 MW of load support on average over the course of a year. However, their generation depends on weather conditions and time of day, therefore solar arrays are not a reliable source of peak load support.

See Table 29 for the maximum generation capacities of the proposed DERs.

[21] ($90/MWh + $15/MWh)/2 = $52.50/MWh. This assumes that DERs directly offset NYMPA and NYPA purchases.

[22] Total cost per MWh = $\frac{(Cap\ Ex + Net\ Present\ Value\ of\ yearly\ operating\ costs)}{Total\ electricity\ production\ (20\ years)}$ where NPV assumes a discount rate of 7% (industry standard for energy finance projects).

[23] Calculated from Sherburne Electric Financial statements. This number represents the weighted average of electricity sold to residential, industrial, and commercial customers.

Table 29. 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 generators were not included because their output is too small (existing solar PV arrays) or they are not expected to generate electricity outside of emergency island mode situations (existing diesel generators).

Distributed Energy Resource Name	Facility Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
Proposed Natural Gas CHP Recip.	Land behind the Firehouse	Maximum of 2	No
Proposed 2 MW PV Array	2100 distribution line, near Sherburne-Earlville Central Public Schools	Maximum of 2	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. Unfortunately, this will not be feasible in Sherburne because entering island mode will require more than 850 remote meters to disconnect themselves from the electricity supply. As such, the microgrid will only enter island mode during a larger grid outage when these 850 customers would lose power due to a system outage. 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. Additionally the solar array's variable production prevents reliable participation in DR programs.

4.3.3 Deferral of Transmission/Distribution Requirements

The 2.2 MW of average local generation produced by the DERs will reduce the amount of electricity imported from the larger NYISO and NYSEG 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,[24] they can only transmit a limited amount of power. As demand for electricity in Sherburne increases, the lines might need to be supplemented to handle additional load.

The same is true for distribution capacity investments on a local, feeder-by-feeder basis. However, constructing DERs could actually increase the distribution capacity investment cost in certain cases (e.g., if the assets are placed in remote locations and thus expensive to connect to the local grid). As Sherburne has ample capacity within the town, construction of DERs will not require a significant distribution capacity investment.

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

4.3.4 Ancillary Service

None of the existing and proposed generation resources in Sherburne 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 Sherburne grid. For example, the CHP will provide frequency regulation as a by-product of its operation. The Sherburne microgrid connected facilities will receive the benefits from provided ancillary services, but these will not be paid services and will not generate any new revenue streams—no services are being bought or sold. Instead, provision of ancillary services will represent a direct value to microgrid connected facilities.

4.3.5 Development of a Combined Heat and Power System

Egg Low Farms and Southern Tier will be steady and reliable customers for nearly 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 almost meet the combined average monthly thermal energy demand of these two facilities, which is around 1,920 MMBTUs (although it rose as high as 3,100 MMBTUs in 2014).[25] Variation in thermal energy demand was likely due to seasonal changes in heating and manufacturing needs.

By purchasing steam from the CHP unit, Egg Low Farms and Southern Tier Pet will reduce their energy costs and greenhouse gas (GHG) emissions. The facilities currently use Number Two (No. 2) fuel oil boilers to generate steam for production purposes. By purchasing steam at $18.50/MMBTU[26] instead of fuel oil at its current cost of $27/MMBTU,[27] Egg Low Farms and Southern Tier Pet Nutrition will save around $8.50/MMBTU in fuel costs for a total of $179,520 per year. The CHP also contributes to a net reduction in their GHG emissions by replacing around 21,120 MMBTUs of fuel oil with co-generated steam every year. The CHP unit will therefore produce significant savings for the industrial off-takers, revenue for its owners, and indirect benefits to the community (by reducing emissions).

Sherburne Electric will provide the capital outlay for construction of new steam infrastructure. Trenching for the new pipe will cost approximately $5 per foot, while capital expenditures will amount to around $10 per foot.[28] If the CHP unit is housed behind the municipal building at

[25] Data supplied by Southern Tier Pet Nutrition and Egg Low Farms.

[26] The Project Team expects a price of $18.50/MMBTU to be the optimal price to pass on savings to steam off takers while realizing substantial revenue for the microgrid owners. The $18.50/MMBTU is subject to change given Sherburne Electric's desired pricing.

[27] EIA: http://www.eia.gov/todayinenergy/detail.cfm?id=3450

[28] **Trenching cost:** Travis DuBois, Sherburne Electric

West State St. (the current proposed location), it will require 2,100 feet of steam piping to distribute co-generated steam to Southern Tier Pet Nutrition and Egg Low Farms. The total cost of developing steam infrastructure in Sherburne will therefore be around $31,500. The industrial facilities will not bear any of this cost.

4.3.6 Environmental Regulation for Emission

The microgrid's generation assets will drive a net increase in GHG emissions in Sherburne. The proposed generation assets will produce around 17,400 MWh of electricity and 21,100 MMBTU of thermal energy per year. The CHP unit and backup diesel generators will emit approximately 8,200 $MTCO_2e$ (metric tons CO_2 equivalent) per year,[29] while the solar arrays emit nothing. The current New York State energy asset mix would emit approximately 6,300 $MTCO_2e$ to produce the same amount of electricity[30] and No. 2 Fuel Oil boilers would emit around 1,550 $MTCO_2e$ to produce the same amount of thermal energy.[31] The microgrid's generation assets will therefore result in a net increase of around 350 $MTCO_2e$.

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

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

Table 30 catalogs the CO_2, SO_2, NO_x, and Particulate Matter (PM) emissions rates for the natural gas and diesel generators.

Capital Expenditure: Cost of 1" steel pipe, "Miscellaneous Industrial Costs", Michigan State Government, https://www.michigan.gov/documents/Vol2-36UIP12MiscellaneousIndustrialCosts_121081_7.pdf

[29] **CHP Emissions Rate**: 0.55 MTCO2e/MWh (EPA, http://www3.epa.gov/chp/documents/faq.pdf)
Backup Diesel Generator Emissions Rate: 0.72 $MTCO_2e$/MWh (assuming 161 lb CO_2e per MMBTU; EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11)

[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.

[31] **Average emissions rate for No. 2 Fuel oil boilers**: 0.073 $MTCO_2e$ per MMBTU. Info from EIA (161 lb CO_2 per MMBTU; http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11)

Table 30. 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 - Diesel generator	Frontier Communications	CO_2	0.7196[32]
		SO_2	0.1911[33]
		NO_x	2.9074[34]
		PM	0.2046[34]
DER4 - Diesel generator	NYCM Insurance	CO_2	0.7196
		SO_2	0.1911
		NO_x	2.9074
		PM	0.2046
DER2 - Proposed Natural Gas-fired CHP	Land behind the Firehouse	CO_2	0.553
		SO_2	0.0000067[35]
		NO_x	0.00055[34]

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 North Substation, South Substation, and across the rest of the microgrid:

- A control system to provide a single point of control for operating the microgrid and synthesizing real-time electricity data from the connected facilities.
- IEDs to interface with the 44 kV utility breaker at both substations as well as the smaller 8.3 kV distribution feeders.
- Automated distribution switches installed throughout the Village 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 $523,000 at the North and South Substations, $441,000 for switches, breakers, and switchgear distributed throughout the grid, and $120,000 for the communications cabling.[36] The team estimates the 2 MW solar PV

[32] **Diesel Generator Emissions rate**: 0.72 $MTCO_2e$/MWh (assuming 161 lb CO_2e per MMBTU; EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11)

[33] Michigan Department of Environmental Quality; Environmental Science and Services Division. "Potential to Emit, Diesel Fired Generator Calculation Worksheet"

[34] EPA, http://www3.epa.gov/chp/documents/faq.pdf

[35] CHP calculator, EPA

[36] Estimates from Siemens, Inc.

array and 2 MW CHP unit carry an installed cost of $4.4 million and $4.4 million,[37] respectively. This brings the total installed capital cost to approximately $9.88 million, not including interconnection fees and site surveys. The estimated capital cost does not account for any financial incentives or tax credits that may lower the overall cost of the microgrid. See Tables 31 through 33 below for estimated installed costs for each microgrid component.

The team estimates nearly every piece of microgrid equipment has a useful lifespan of 20 years. The only component with a shorter lifespan will be the microgrid control system (Siemens SICAM PAS or equivalent), which will be replaced by more advanced software after 7-8 years. See Table 31 for each component's projected lifespan.

Table 31 details the capital cost of the North and South Substations. These substations include equipment such as the microgrid control system, IEDs, and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid.

Table 31. Capital Cost of North and South Substations

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

North and South Substations				
Capital Component	**Quantity**	**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 under all operating modes
Microgrid Control Center (Siemens MGMS or equivalent)	1	$ 300,000	20	Interface to existing AMI metering infrastructure to provide data trending and forecasting of renewable generations, loads and AMI/SCADA interface, interface to NYISO for potential economic dispatch
IED – Utility voltage (Siemens 7SJ85 Siprotec 5 or equivalent)	1	$ 5,000	20	Combined programmable logic controller (PLC) automation and protection device for interfacing with 44 kV utility breaker
Automated Circuit Breaker	5	$ 50,000	20	Upgraded breakers on all 5 distribution feeders to enable interface with microgrid IED
IED – Distribution Feeders (Siemens 7SJ85 Siprotec 5 or equivalent)	1 Primary PLC 5 Modules	$ 8,000	20	Combined PLC automation and protection device with 5 sub-modules interfacing with each 8.3 kV

[37] CHP Capital Cost: $2,200/kW, pro-rated from Siemens 2.5 MW CHP estimate
Solar PV Capital Cost: $2,200/kW, Siemens 2 MW Solar PV estimate

North and South Substations				
Capital Component	**Quantity**	**Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
				distribution feeder circuit breaker
Centralized Generation Controls (Woodward EasyGen or equivalent)	1	$ 2,000	20	Serves as the primary resource for coordinating the paralleling of all remotely located generators
Automated Circuit Breaker	4	$ 40,000	20	Upgraded breakers on 4 normally closed distribution feeders to enable interface with microgrid IED
IED – Utility voltage (Siemens 7SJ85 Siprotec 5 or equivalent)	1	$ 5,000	20	Combined PLC automation and protection device for interfacing with 44 kV utility breaker
IED – Distribution Feeders (Siemens 7SJ85 Siprotec 5 or equivalent)	1Primary PLC 3 Modules	$ 8,000	20	Combined PLC automation and protection device with 3 sub-modules interfacing with each normally closed 8.3 kV distribution feeder circuit breaker behind TX3
IED – Distribution Feeder (Siemens 7SJ)	1	$ 5,000	20	Combined PLC automation and protection device interfacing with the one normally closed 8.3 kV distribution feeder circuit breaker behind TX2
Total installation cost	-	$ 50,000	-	Installation of capital components in the microgrid

The total installed capital cost of the switches, breakers, and switchgear distributed throughout the microgrid is estimated to be $441,000. The distributed equipment will replace most of the existing manual switches in Sherburne and enable each generator in the microgrid to synchronize to the system's frequency.

Table 32. Capital Cost of Distributed Equipment

Table shows the estimated costs and lifespan of the equipment associated with the required Distributed Equipment of the microgrid.

Distributed Equipment				
Capital Component	Quantity	Installed Cost ($) (+/- 30%)	Component Lifespan (Years)	Purpose/Functionality
PV interface switches	3	$ 5,000	20	Microgrid controls switches that will work with the PV system inverters
Automated Distribution Switches	12	$ 120,000	20	These switches will replace most of the existing manually operated switches in the Village
IED – Distribution Switches (Siemens 7SC80 or equivalent)	12	$ 60,000	20	Combined PLC Automation and Protection device interfacing with Automated Distribution Switches
Generation Switchgear	3	$ 150,000	20	Each generator will have the required grid-paralleling switchgear, enabling each unit to synchronize to the system's frequency
Generation Controllers (Woodward EasyGen or equivalent)	3	$ 6,000	20	Engine-generator control and protection with peer-to-peer paralleling functionality
Installation Costs	-	$100,000	-	Installation of capital components in the microgrid

Table 33. 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
2.0 MW PV System	1	$ 4,400,000	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,[38] 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.[39] The total installation cost of cabling is approximately $5.65 per foot for Cat-5e cables and approximately $4.65 per foot for fiber optic cables.[40] The two new network switches will cost approximately $750 each.[41] The Project Team will use the existing cabling infrastructure to install the communications cables, thereby avoiding the high costs of trenching the proposed lines. After installation of IT infrastructure, the network will require configuration. The Project Team estimates that Network Switch/VLAN configuration will cost approximately $1,200.[42] The estimated total cost for the microgrid IT infrastructure is around $120,000.[43]

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 34 below.

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

[39] Commercially available LC connectors, $3.80 per connector

[40] **Installation costs for Cat5e**: $5.45/ft.
Installation costs for fiber optic: $4.40/ft (Siemens; assumes use of existing duct bank system)
Component cost for Cat5e: $0.14/ft (commercially available).
Component cost for fiber optic: $0.24/ft (commercially available)

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

[42] Project Team estimates that configuration will take approximately eight hours at $150/hr.

[43] The Project Team estimates that ~2,300 feet of Cat 5e and ~24,000 feet of fiber optic cable will be necessary (approximate distances between distributed equipment and nearest Network Switches).

Table 34. 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 ($)[44]	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**

4.4.3 Operations and Maintenance Cost

The proposed DERs will incur fixed operations and maintenance (O&M) costs, including salary for microgrid employees and fixed annual service operations. However, as Sherburne Electric will own and operate the microgrid, it will avoid fees to external parties.

Annual service for the CHP unit will cost around $208,500 per year.[45] The utility will also incur $47,000/year in total costs for annual fixed system service agreements for the solar PV array and backup diesel generators.[46]

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 diesel fuel usage of the backup diesel generators is difficult to predict because they will be used only during some emergency outage situations. The average price of diesel fuel in New York State from 2013-2015 was $3.51 per gallon, which translates to an average fuel cost of approximately $0.25/kWh.[47] The high price of diesel fuel, along with increased GHG emissions, discourages extended use of the diesel generators.

The solar PV array will not require fuel to operate, and it should not require service outside of the normally scheduled maintenance. Normally scheduled downtime should cost approximately $20/kW per year.[48]

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[49]

---

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

[45] **CHP O&M**: $0.014/kWh. (Siemens)

[46] $5,000 for solar PV array ($20/kW per year) and $4.60/kW per year for backup diesel generators (Electric Power Research Institute, "Costs of Utility Distributed Generators, 1-10 MW")

[47] **Heat rate**: 0.071 gallons/kWh (supplied by generator owners)

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

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

Table 35 outlines all fixed operations and maintenance (O&M) costs associated with normal operation of the DERs.

Table 35. Fixed Operating and Maintenance Cost

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

Fixed O&M Costs ($/year)	Cost Components
~ $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
~$4,600	Diesel Generator (Frontier) Service Agreement – Annual costs of maintenance and servicing of unit
~$2,300	Diesel Generator (NYCM) Service Agreement – Annual costs of maintenance and servicing of unit
~ $40,000	Solar PV System Service Agreement – Annual costs of maintenance and servicing of unit
~ $200	Sherburne Electric Rooftop Solar PV System Service Agreement – Annual costs of maintenance and servicing of unit
~ $200	School Rooftop Solar PV System Service Agreement – Annual costs of maintenance and servicing of unit
$70,000	Non-DER Microgrid Components Service Agreement - Annual costs of maintenance and servicing of components

4.4.4 Distributed Energy Resource Replenishing Fuel Time

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

At full operation, the 1 MW diesel generator at Frontier Communications will require 71 gallons of diesel fuel per hour. Frontier Communications has a 1,000 gallon diesel storage tank installed,[50] so at a 100% level of output this generator can operate for 14 hours without replenishing its fuel supply. Cutting output to 50% increases the maximum operation time to 28 hours.

The 500 kW generator at NYCM insurance will require 36 gallons of diesel fuel per hour when operating at full capacity. NYCM has a larger 1,400 gallons storage tank installed,[51] so at a 100% level of output this generator can operate for 39 hours without replenishing its fuel supply. Cutting output to 50% increases the maximum operation time to 78 hours.

The solar PV array does not require fuel for operation, but its output depends on weather and time of day. Table 36 shows the fuel consumption and operating times for all of the microgrid DERs.

[50] As reported by the facility

[51] As reported by the facility

Table 36. Maximum Fuel Operating Time for Distributed Energy Resource

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

Distributed Energy Resource	Location	Energy Source	Maximum Operating Time in Islanded Mode without Replenishing Fuel (hours)	Fuel Consumption During this Period	
				Quantity	Unit
DER1 - Diesel generator	Frontier Communications	Diesel	14	1,000	Gallon
DER4 - Diesel generator	NYCM Insurance	Diesel	39	1,400	Gallon
DER2 - Proposed Natural Gas-fired CHP	Land behind the Firehouse	Natural Gas	N/A	N/A	MMBtu
DER3 - Proposed PV Array	2100 distribution line, near Sherburne-Earlville Central Public Schools	N/A	N/A	N/A	N/A
PV Array	Sherburne Electric Rooftop Solar	N/A	N/A	N/A	N/A
PV Array	School Rooftop Solar	N/A	N/A	N/A	N/A

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

4.5.1 Backup Generation Cost during a Power Outage

All four proposed generators will serve as backup generators in the event of an extended power outage. The CHP will be the most reliable and productive of the DERs, providing a maximum of 2 MW to the microgrid at any given time. Because the CHP will use natural gas from the proposed pipeline as fuel, disruptions to its fuel source are unlikely. Running at full capacity, the CHP can generate approximately 48 MWh per day, using around 552 Mcf (538 MMBTU) of natural gas. The CHP will not require startup or connection costs in order to run during island mode and should not incur any daily variable costs other than fuel.

The solar array will be available for backup generation during a power outage, but its production is too inconsistent for it to qualify as a true backup generator. Extreme weather is responsible for many emergency outages in New York State, and such weather will greatly reduce the output of the solar panels. However, when high state-wide electricity demand on the sunniest days of summer causes outages, the solar panels will be at their most productive and could provide up to 2 MW of load support to the Sherburne microgrid. Table 37 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

The backup diesel generators will only come online when the 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 1.6 MW during 2014, the CHP and solar array should be capable of satisfying the microgrid's power demand in most situations. Operation of the 1 MW generator during 20% of outage hours will produce an average of 4,800 kWh per day while the 500 kW generator will produce around 2,400 kWh/day. The two generators will require around 340 and 170 gallons of fuel per day (respectively) at this level of production. One-time startup costs or daily non-fuel maintenance costs for either of the diesel generators are not anticipated.

Table 37. Cost of Generation During a Power Outage

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

Location	Distributed Energy Resource	Energy Source	Nameplate Capacity (MW)	Expected Operating Capacity (%)	Maximum 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		
Frontier Communications	DER1 - Diesel backup generator	Diesel	1.0	100%	24	1,700	Gallons	N/A	$6,650[52]
NYCM Insurance	DER4 - Diesel backup generator	Diesel	0.5	100%	12	850	Gallons	N/A	$3,300[46]
Land behind the Firehouse	DER2 - Proposed Natural Gas-fired CHP	Natural Gas	2.0	100%	48	552	Mcf	N/A	$2,700
2100 distribution line, near Sherburne-Earlville Central Public Schools	DER3 - Proposed PV Array	N/A	2.0	14%	16[53]	N/A	N/A	N/A	$110
Sherburne Electric Rooftop Solar	Existing Solar PV Array	N/A	0.01	14%	0.033	N/A	N/A	N/A	$0.55
School Rooftop Solar	Existing Solar PV Array	N/A	0.01	14%	0.033	N/A	N/A	N/A	$0.55

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

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

4.5.2 Cost to Maintain Service during a Power Outage

There are no costs associated with switching the microgrid to island mode during a power outage other than the operational costs already accounted for in Table 36. Please refer to Table 36 for one-time and ongoing costs of microgrid generation per day. The proposed microgrid has the capacity to support all the connected facilities, which means even those facilities with backup generators will not have to rely on or pay for on-site backup power. Facilities not connected to the microgrid will experience power outages and may need emergency services depending on the severity of the emergency event. Any other cost incurred during a wide spread power outage will be related to the emergency power (i.e. portable generators) rather than electricity generation costs.

4.6 Services Supported by the Microgrid (Sub Task 4.6)

Many of the facilities to be connected to the microgrid are municipal government buildings that serve the entirety of the population in Sherburne (such as the Fire Department, Police Department, Wastewater Treatment Plant, etc.). Others, like the Sherburne-Earlville Central Public Schools, serve a smaller population for most of the year but provide critical services to the entire population during emergency situations. For estimates of the population served by each critical facility, see Table 38.

Backup power supplied by the microgrid should provide 100% of each facility's electricity demand during outage situations. However, if backup power from the microgrid is not available, the critical services provided by these facilities will be severely hampered. Some critical services do not require electricity (e.g., driving a police car to the scene of a crime), while others are completely dependent on a stable power supply (e.g., receiving a 911 call or local water sanitizing operations). Based on the portfolio of services that each facility provides and the electricity dependency of each service, Table 38 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 38. Critical Services Supported

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

Facility Name	Population Served by This Facility	Percentage Loss in Service During a Power Outage[54]	
		When Backup Power is Available	When Backup Power is Not Available
Village Municipal Building (Village office, Fire Department, Police Department, and Ambulance)	~ 4,000	0%	50%
Sherburne Electric and DPW	~ 4,000	0%	100%
Sherburne-Earlville Central Public Schools (Elementary, Junior High, and Senior High Schools)	~ 500	0%	75%
Wastewater Treatment Plant	~ 4,000	0%	100%
Sherburne Wastewater Pump Station	~ 4,000	0%	100%
Chenango Memorial Hospital Health Clinic	< 250	0%	85%
Basset Healthcare	< 250	0%	85%

The Sherburne microgrid will include two residential facilities: Grace Manor and Senior Housing. Grace Manor is a low-income housing complex that includes 22 units (70 residents). Senior Housing is an assisted living facility with 31 housing units (40 residents). As an assisted living facility, Senior Housing requires a stable supply of electricity for life-sustaining medical equipment. Its connection to the microgrid and access to backup power is therefore quite important. In a power outage situation, some 110 residents, including around 40 vulnerable seniors whose medical equipment depends on stable electricity supply, would be left without power.

4.7 Industrial Economics Benefit-Cost Analysis Report

The following is a direct cost-benefit analysis deliverable from Industrial Economics (IEc). IEc was hired by NYSERDA to conduct a benefit-cost analysis of each feasibility study. The benefit-

[54] Booz Allen estimated % loss based on energy demands and services provided for Emergency Services, Municipal Services, Health Services, and Education Services based on previous research by NIH and CDC. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1497795/; http://www.ncbi.nlm.nih.gov/pubmed/15898487; http://emergency.cdc.gov/disasters/poweroutage/needtoknow.asp)

cost analysis of the Sherburne microgrid was delivered to the Project Team on February 23, 2016.

4.7.1 Overview

As part of NYSERDA's NY Prize community microgrid competition, the Village of Sherburne has proposed development of a microgrid that would serve 19 facilities within the Village, including:

- The Village Municipal Building, which supports the Village office, Fire Department, Police Department, and Ambulance services;
- Sherburne Municipal Electric and DPW;
- The Sherburne-Earlville Central Public Schools (Elementary, Junior High, and Senior High Schools);
- Two manufacturing facilities: Southern Tier Pet Nutrition and Egg Low Farms, Inc.;
- Two residential facilities: Grace Manor, a low-income housing complex with 66 units, and a senior housing facility with 31 assisted living units; and
- Several publicly or privately owned and operated facilities, including a wastewater treatment plant, a wastewater pump station, a railroad crossing gate and signal, a post office, a gas station, a bank, a supermarket, a service pharmacy, the Chenango Memorial Hospital Health Clinic, a Basset Healthcare facility, Frontier Communications, and NYCM Insurance.

The microgrid would be powered by two new distributed energy resources: a 2.0 MW natural gas-fired CHP unit that would be installed on the land behind the firehouse, and a 2.0 MW photovoltaic array that would be located near the Sherburne-Earlville Central Public Schools. In addition, the microgrid would incorporate two currently installed backup diesel generators – the first at Frontier Communications, with a capacity of 1.0 MW, and the second at NYCM Insurance, with a capacity of 0.5 MW. The town anticipates that the natural gas unit and photovoltaic system would produce electricity for the grid during periods of normal operation. In contrast, the diesel generators would produce power only during an outage, when the microgrid would operate in islanded mode. The system as designed would have sufficient generating capacity to meet average demand for electricity from the 19 facilities during a major outage.

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

4.7.2 Methodology and Assumptions

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

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

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

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[55] 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 stakeholders (e.g., customers, utilities). When facing a choice among investments in multiple

[55] 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 (EPA) 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.]

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.[56]

4.7.3 Results

Table 39 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 3.6 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

Table 39. BCA Results (Assuming 7 Percent Discount Rate)

ECONOMIC MEASURE	EXPECTED DURATION OF MAJOR POWER OUTAGES	
	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 3.6 DAYS/YEAR
Net Benefits - Present Value	-$8,240,000	$75,500
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	-3.5%	7.0%

[56] 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 4 and Table 40 present the detailed results of the Scenario 1 analysis.

Figure 4. Present Value Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

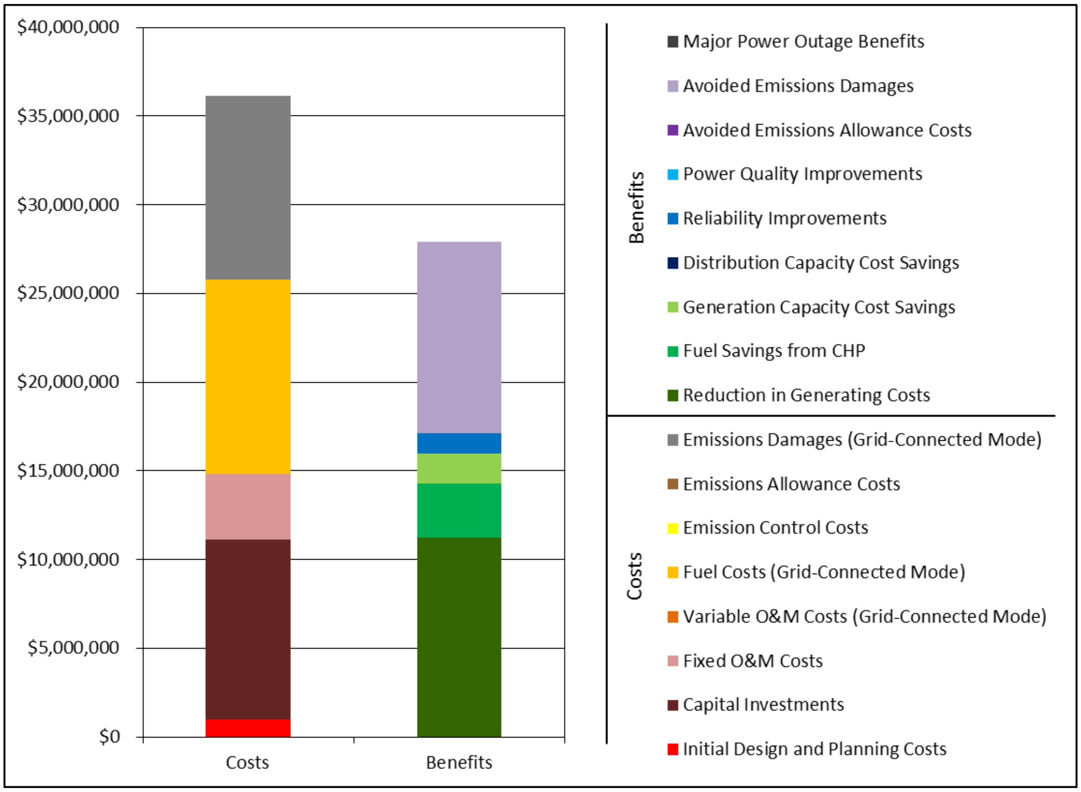


Table 40. Detailed BCA Results, Scenario 1

(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	$10,100,000	$836,000
Fixed O&M	$3,690,000	$326,000
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)	$10,300,000	$675,000
Total Costs	**$36,100,000**	
Benefits		
Reduction in Generating Costs	$11,200,000	$992,000
Fuel Savings from CHP	$3,050,000	$269,000
Generation Capacity Cost Savings	$1,680,000	$149,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$1,130,000	$100,000
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$5,880	$519
Avoided Emissions Damages	$10,800,000	$703,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$27,900,000**	
Net Benefits	**-$8,240,000**	
Benefit/Cost Ratio	**0.8**	
Internal Rate of Return	**-3.5%**	

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 $10.1 million, including costs associated with installing a microgrid control system; equipment for the substation that would be used to manage the microgrid; the IT infrastructure (communication cabling) for the microgrid; and the new 2.0 MW natural gas unit and 2.0 MW photovoltaic array. Operation and maintenance of the entire system would be provided under fixed price service agreements, at an estimated annual cost of $326,000. The present value of these O&M costs over a 20-year operating period is approximately $3.7 million.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the proposed gas-fired CHP unit. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the Project Team and projections of fuel costs from New York's State Energy Plan (SEP), adjusted to reflect recent market prices.[57] 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 $675,000 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 $10.3 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 Village of Sherburne'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 $11.2 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. The reduction in demand for electricity from bulk energy suppliers, coupled with a reduction in demand for heating fuel, would also avoid emissions of CO_2, SO_2, NO_x, and particulate matter, yielding emissions allowance cost savings with a present value of approximately $6,000 and avoided emissions damages with a present value of approximately $10.8 million.[58]

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

---

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

[58] 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 (EPA). [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.

generation or distribution capacity.[59] 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 1.98 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 $1.7 million over a 20-year operating period.

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 $100,000 per year, with a present value of approximately $1.1 million 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:[60]

- System Average Interruption Frequency Index (SAIFI) – 1.03 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 118.2 minutes.[61]

The estimate takes into account the number of small and large commercial or industrial customers the project would serve; the distribution of these customers by economic sector; average annual electricity usage per customer, as provided by the Project Team; and the prevalence of backup generation among these customers. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.[62] 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 of project costs. Accordingly, the analysis moves to Scenario 2,

---

[59] 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.

[60] www.icecalculator.com.

[61] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for New York State Electric & Gas.

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

taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

Scenario 2

Benefits in the Event of a Major Power Outage

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[63,64]

As noted above, the Village of Sherburne's microgrid project would serve a number of residential, commercial, industrial, and critical service facilities, including fire, emergency medical, hospital, police, wastewater, and water services. The project's consultants indicate that at present, only two facilities, Frontier Communications and NYCM Insurance, are equipped with backup generators; these units can support the ordinary level of service at the two facilities. Operation of the Frontier Communications unit costs approximately $1,700 per day. Operation of the NYCM Insurance unit costs approximately $2,000 per day. The remaining 17 facilities could maintain service by bringing in portable generators; costs are listed in Table 41 below. In the absence of backup power – i.e., if the backup generator failed and no replacement was available – all the facilities would experience between 50 and 100 percent loss in service capabilities (see Table 41).

[63] 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.

[64] 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.

Table 41. Backup Power Costs and Level of Service, Scenario 2

FACILITY NAME	COST OF MAINTAINING SERVICE WITH PORTABLE GENERATOR ($/DAY)	PERCENT LOSS IN SERVICE WHEN BACKUP GENERATION IS NOT AVAILABLE
Village Municipal Building (Village office, Fire Department, Police Department, and Ambulance)	$672	75%
Sherburne Electric and DPW	$1,393	100%
Sherburne-Earlville Central Public Schools (Elementary, Junior High, and Senior High Schools)	$13,134	75%
Wastewater Treatment Plant	$996	100%
Railroad Crossing gates/signal [65]	$720	100%
Village of Sherburne Wastewater Pump Station	$284	100%
US Postal Service	$322	50%
Chenango Memorial Hospital Health Clinic	$758	90%
Basset Healthcare	$626	75%
Service Pharmacy	$626	75%
Southern Tier Pet Nutrition	$8,161	100%
Egg Low Farms, Inc.	$3,325	100%
Mirabito's Gas Station	$672	75%
Big M Supermarket	$1,675	75%
NBT Bank of Sherburne	$526	75%
Frontier Communications	NA [66]	100%
NYCM Insurance	NA [67]	100%
Grace Manor (low-income housing)	$672	50%
Senior Housing	$626	75%

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:

- Frontier Communications and NYCM Insurance would rely on their existing backup generators, continuing to provide 100 percent of service capabilities while the generators

[65] The project consultants believe it is unlikely that a portable generator would be used to operate the railroad crossing gates and signal. Instead, it is likely that a Sherburne police officer would be dispatched to the crossing at an estimated cost of $720 per day.

[66] This facility is already equipped with a backup generator. As the baseline for this analysis, we assume that if the existing backup generator fails (15 percent failure rate), the facility would experience a total loss of service.

[67] This facility is already equipped with a backup generator. As the baseline for this analysis, we assume that if the existing backup generator fails (15 percent failure rate), the facility would experience a total loss of service.

operate. If the backup generators fail, the facilities would experience a total loss of service.

- The remaining facilities (with the exception of the railroad crossing gates and signal) would rely on portable generators, experiencing no loss in service capabilities while the units are in operation. If the portable generators fail, the facilities would experience a loss in service between 50 and 100 percent, as shown in Table 42.
- Traffic at the railroad crossing would be directed by a Sherburne police officer, resulting in no impact while the officer is present. If the officer is not present, the crossing would be fully inoperative.
- In all cases, the supply of fuel necessary to operate backup generators would be maintained indefinitely.
- At each facility, there is a 15 percent chance that the backup generator would fail.

The economic consequences of a major power outage also depend on the services the facilities of interest provide. The analysis varies by facility, as described below:

- For fire services, the analysis calculates the impact of an outage on property losses, lives lost, and injuries suffered due to fires, due to an anticipated increase in response time. The methodology assumes that the population normally served by the non-functioning fire station would rely on the next-closest provider able to serve this population. In Sherburne's case, the nearest alternative provider is 13 miles away.
- For Emergency Medical Services (EMS), the methodology also assumes that the population normally served by the non-functioning service provider would rely on the next-closest (13 miles) provider able to serve this population. This impact is calculated based on an anticipated increase in fatality rates due to the increase in response time.
- For hospital services, the methodology assumes that services will be provided by the next-closest provider (in this case, 19 miles away). The value is calculated based on the extra time spent getting to an emergency department (ED) or waiting to be seen, the extra distance traveled to get to the ED, and the increased risk of death from acute myocardial infarction or unintentional injuries, due to increased time before ED treatment.
- For police services, the analysis calculates the impact of a loss in service using standard FEMA values for the costs of crime, the baseline incidence of crime per capita, and the impact of changes in service effectiveness on crime rates.
- For residential facilities, the analysis assumes that the residents being served would be left without power; the impact is valued as a social welfare loss.
- For wastewater services and water services, the methodology again assumes that the population usually served would be left without either service. The impact of the loss in

service includes both the lost economic productivity due to a loss of commercial wastewater and water services, and the welfare loss from lost residential service.

- For Frontier Communications, the value of service is estimated at approximately $31,000 per day. This figure is based on the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and an assumed eight hours of microgrid demand per day during an outage.[68]
- For NYCM, the value of service is estimated at approximately $26,000 per day. This figure is also based on the U.S. Department of Energy's ICE Calculator, and an assumed eight hours of microgrid demand per day during an outage.[69]
- For the Sherburne-Earlville Central Public schools, the value of service is estimated at approximately $91,000 per day. This figure is based on the school district's budget for the 2015-2016 school year, scaled to an average daily value.[70]
- For the senior housing facility, the value of service is approximately $2,600 per day. This figure is based on an estimate of the facility's capacity (31 assisted living units) and state data on the average rate for assisted living care in the Utica area (approximately $41,000/patient/year, scaled to an average daily value and prorated to account for the 18 hours of microgrid demand per day likely during an outage).[71]
- For the remaining facilities, combined, the value of service is $440,000 per day. Again, this figure is based on the U.S. Department of Energy's ICE Calculator, and an average 9.4 hours of microgrid demand per day during an outage.[72]

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for all facilities is approximately $205,000 per day.

Summary

Figure 5 and Table 42 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 3.6 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.

68 http://icecalculator.com/
69 ibid.
70 Sherburne-Earlville Central School Board of Education Meeting, Board of Education – 2015-2016 Budget. (Pg. 5 of http://www.secsd.org/Board/agendas1415/42815.pdf). Note that this value is at best a rough approximation of the social welfare loss attributable to a loss of power at the school, as it does not account for the potential to reschedule lost school days when power is restored; the impact of disruptions in schedule on the productivity of teachers, school administrators, or children's caregivers; the effect of an extended outage on the cost of operating and maintaining the school; and other factors that would more accurately characterize the impact of a loss of service during an extended outage.
71 https://www.genworth.com/corporate/about-genworth/industry-expertise/cost-of-care.html
72 http://icecalculator.com/

Figure 5. Present Value Results, Scenario 2

(Major Power Outages Averaging 3.6 Days/Year; 7 Percent Discount Rate)

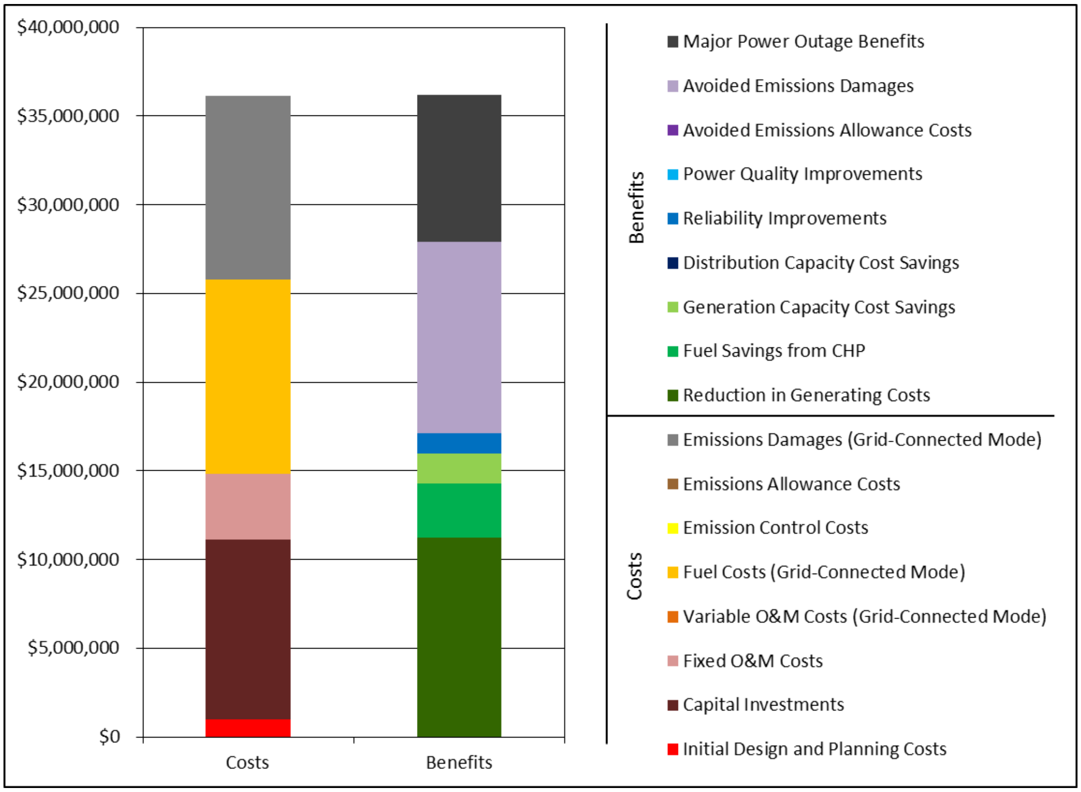


Table 42. Detailed BCA Results, Scenario 2

(Major Power Outages Averaging 3.6 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	$10,100,000	$836,000
Fixed O&M	$3,690,000	$326,000
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)	$10,300,000	$675,000
Total Costs	**$36,100,000**	
Benefits		
Reduction in Generating Costs	$11,200,000	$992,000
Fuel Savings from CHP	$3,050,000	$269,000
Generation Capacity Cost Savings	$1,680,000	$149,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$1,130,000	$100,000
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$5,880	$519,000
Avoided Emissions Damages	$10,800,000	$703,000
Major Power Outage Benefits	$8,320,000	$736,000
Total Benefits	**$36,200,000**	
Net Benefits	**$75,500**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**7.0%**	

The Project Team assumed an average electricity sales price of $0.052 per kWh in Sherburne. This is the weighted average cost of Sherburne Electric's purchases from NYPA and NYMPA purchase agreement that would be offset with the proposed generation assets. As Sherburne Electric is a municipal utility in a small footprint, existing purchases can be offset by new generation on a one-to-one price and volume basis, particularly as Sherburne Electric will own the new assets. 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 may be an appropriate price for intermittent and unreliable grid sales to an investor-owned utility, it is inappropriate for a municipal utility which will own and operate its own generation assets. In the Mohawk NYISO Zone, the LBMP is $33.63 per MWh[73], or $0.034 per kWh, an approximately 45% reduction in price from the foregone cost to Sherburne Electric. The benefit gained from generation capacity costs avoided does not bring this discrepancy 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 distributed energy resources set that is financially self-sufficient at the LBMP.

5. Summary and Conclusions

This section concludes with the Project Team's lessons learned, benefits analysis and conclusion and path forward based on all four of the previous work streams summarized above.

5.1 Sherburne Lessons Learned

It has been the Project Team's experience that working with a municipal utility is more efficient and expedient than working with the investor-owned utilities (IOUs) in New York. Sherburne Electric is absolutely supportive of the microgrid project and, with no service territory beyond the Village and its immediate environs, was able to devote significant attention and assistance to the Project Team. Data requests were fulfilled within a few hours to a few days, and the quality and detail of the information provided was generally high. Certain information, such as detailed cost breakdowns of purchased electricity, system peaks, and price variations, helped the Project Team create a final product that was more detailed than other projects in the Team's portfolio. Moreover, the close relationship between the Village and the utility meant there was widespread community buy-in before the Project Team began work in Sherburne. This was critical to getting all 19 facilities on board for the effort.

In terms of challenges, the costs of a community microgrid complete with on-site generation and a full suite of new control and network infrastructure are quite high. If the local intention for distributed energy resources assets is to serve a large number of facilities, the capital expenditure may become burdensome. In a community such as Sherburne, with fewer than 1,000 utility customers serviced by a small MOU, the ability to take on this financial burden is limited. In the absence of NY Prize Phase III funding, the financial case for the Sherburne microgrid is poor. Also, if natural gas prices rise significantly, the project may realize losses on every hour of operation.

That Sherburne Electric will serve as the owner and operator assuages some of the cost concerns by housing all revenue streams and all costs under one organization and allows the revenue generating DER assets to support the installation of switches, SCADA, and other components that do not directly produce revenue. It also allows Sherburne Electric to serve the microgrid-connected facilities at minimal additional cost because the utility is a government entity, not a for-profit IOU. The vertical integration allows all DERs, meters, and customers within the

[73] Average according to IEc cost-benefit model

microgrid to be seamlessly integrated, which would be a more complex undertaking with multiple asset owners distributing power on an IOU's network. The ownership and organizational burdens are further simplified because there are no required contracts beyond steam off-take agreements and microgrid participation agreements. No new electricity PPAs, revenue or cost-sharing agreements, or ownership consortiums are necessary to stand up the Sherburne microgrid. Unfortunately, the operational and financial advantages enjoyed by a vertically integrated microgrid are not portable to communities without municipal utility service given the larger, less focused nature of regional IOUs and the inability of such utilities to own distributed energy resources assets.

The addition of new distributed energy resources assets is relatively straightforward in Sherburne, but it is more complicated in other communities that are considering similar microgrid designs. At present, there is no natural gas infrastructure in the Village to make the natural gas-fired CHP a feasible solution. However, a nearby gas line extension is currently in the planning stages (independent of the microgrid project) and should be in place by the completion of the Sherburne microgrid. The 2 MW solar PV requires significant open space. While this is available in semi-rural Sherburne, it is not available in suburban or urban settings, including other communities within this Project Team's portfolio. These physical and infrastructural constraints are not prohibitive in Sherburne, but in communities in which there is no natural gas availability or space for solar, the generation options are highly constrained. Any solution that has small to moderate solar installations and no natural gas-fired generation will rely on more expensive technologies and may not provide baseload support to the grid.

Lastly, the presence of AMI across the entirety of the Sherburne Electric service territory greatly expands the possibilities for the microgrid design and the facilities that can be included. Because remote-disconnect AMI can selectively disconnect loads during an outage, the proposal was able to consider facilities not immediately physically or electrically adjacent. This functionality allowed the Project Team to propose a diverse mix and larger number of facilities. As a consequence, the microgrid is unable to island for economic reasons, but is a significantly stronger resource for the Village during grid outages. Without AMI, communities restricted to microgrids that exist on single feeders are likely to have fewer and less diverse connected facilities.

5.1.1 Statewide Lessons Learned

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

Technical. The existing electrical and natural gas infrastructure is the chief determinant of what is possible. In Sherburne, the possible was expansive due to municipal ownership of the utility, the presence of AMI across the town, and a relatively small existing grid. Elsewhere, the electrical feeder structure was the first filter through which prospective facilities were screened;

for reasons of power flow, redundancy, and general system operations, utilities have not been supportive of laying new lines to connect different feeders, particularly if they are of different voltages. This limits the number and diversity of facilities that may be connected in the microgrid, as the feeders do not always follow expected alignments. Further, and with good reason, utilities generally required proposed microgrids to be placed on the ends of feeders. The practical reason for this is to avoid isolating non-microgrid facilities "downstream" of the microgrid, which could cause power supply problems for the non-connected facilities and therefore be a liability for the utility. While this is an understandable concern, it also limits the placement of the grid.

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

Financial. Within the Project Team's portfolio of communities, the most financially viable projects have natural gas availability and steam off-takers. Natural gas generation is cost efficient, provides highly reliable revenue streams through electricity sales, and offers steam sales as an added revenue stream unavailable to a PV 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, but the microgrid control components may require a million dollars or more of capital investment. It will often be difficult to convince investors to finance the non-revenue-generating assets when they could alternatively install and operate a profitable DER.

The most lucrative microgrids may be those that 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 allow for 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 given the electricity that could be generated and sold with an at-capacity generator.

Policy. State policy does not currently address microgrids in a cohesive or holistic manner, nor have utility programs adequately recognized microgrid operations in their policies. Demand response, in particular, is a potentially lucrative revenue stream in New York; however, current policies do not address microgrid participation in demand response programs. For instance, interpretations of the existing NYISO and Con Ed DR programs suggest that microgrids could take payments for islanding the microgrid in times of high demand on the larger NYSEG grid. This scenario, while advantageous from a load shedding perspective, would also remove the microgrid connected generation simultaneously, leaving the macrogrid in a net-neutral position vis-a-vis the microgrid. While the nature of DR payments in such situations is not clear, the Project Team expects 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 Team's revenue analysis.

Local community involvement is an important contributor to microgrid design success. Though even the most robust community engagement may not overcome highly unfavorable infrastructure, it is nonetheless imperative for steady forward progress. In Sherburne, as mentioned in Section 3.1, total buy-in from the municipality and the utility paved the way for an extensive and diverse mix of facilities. In other communities, the Team has been in close and frequent contact with administrators, elected officials, and non-governmental community representatives; this type of engagement is necessary not only to build support amongst 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 with relatively less engagement, it is difficult to make firm recommendations, and the Project Team runs the risk of suggesting solutions that are, for whatever reason, unpalatable to the community.

Scalability. Scalability is governed by three factors. The structure of the electrical infrastructure, as defined in the technical lessons learned section above, is a key criteria to expansion of the microgrid. At some point of expansion, it becomes necessary to link multiple feeders, which means having proximate feeders of the same voltage and connected to desirable facilities is an important criteria. Second, widespread AMI infrastructure makes expansion far less complicated and allows for the selective disconnect of facilities that are not microgrid participants. The usefulness of this approach is evident in Sherburne, where the microgrid will include 19 non-contiguous facilities. Without AMI, the Sherburne microgrid would not be feasible as it is proposed. Lastly, as the microgrid grows larger, more switches and controls will need to be installed, connected, and maintained to allow for a smooth islanding and grid-reconnect process. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are likely to push back if microgrids grow to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the utilities to find acceptable footprints that both meet the goals of NYSERDA while respecting the operational concerns of local utilities that the NY Prize footprints remain somewhat contained.

5.1.2 Stakeholder Lessons Learned

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

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

Investor owned utilities in the Project Team’s portfolio, covering each community outside of Sherburne, were uniformly against allowing a third party operational control of utility-owned infrastructure. This is understandable, however it engenders a particularly difficult situation if the utility is not supportive of microgrid development. In such situations, the microgrid will be forced to construct duplicative infrastructure, with is both prohibitively expensive and against the spirit of the NY Prize. Utilities which support the integration of their infrastructure to the extent technically possible allow for more expansive microgrid possibilities.

Academics. Academic considerations in microgrid development may center around two areas. First, research into a relatively small grid system with multiple generators (some spinning, some inverter-based), temporally and physically variable loads, and multidirectional power flows may inform better designs and more efficient placement of generation and controls relative to loads. The second is optimizing financial structures for collections of distributed energy resources and control infrastructure. To-date, most microgrids in the United Stated have been campus-style developments in which the grid serves a single institution and it can be easily segregated from the macrogrid; community microgrids consisting of multi-party owned facilities and generation are a new concept and literature on how best to own and operate such developments is not yet robust.

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

NYSERDA. NYSERDA awarded 83 Phase I feasibility studies, providing a wide canvas for jumpstarting microgrid development in the state but also placing administrative burdens on the utilities and on NYSERDA itself. As NYSERDA is aware, the timelines for receiving information from utilities were significantly delayed compared to what was originally intended, and this has impacted the ability of the Project Team to provide deliverables to NYSERDA on the original schedule. As mentioned in the Utility 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 requires 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 and as well as power supply and reliability problems. Additionally, many communities which 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 various benefits to a variety of stakeholders associated with the project. The microgrid will provide more resilient energy service, lower peaking emissions, ensure critical and industrial facilities remain operational during grid outages, and support the goals of New York's REV.

5.2.1 Environmental Benefits

New York State's generation mix is very clean, with primary energy sources being hydropower and nuclear. Therefore, having a microgrid primarily powered by a natural gas fired CHP will increase the overall emissions per kilowatt hour (kWh). However, the natural gas CHP is cleaner than most peaking assets, usually coal plants, which come online when statewide demand is high. At the local level, the CHP will yield a net decrease in emissions because the thermal energy produced with its waste heat will replace No. 2 fuel oil-fired boilers. The proposed microgrid also offers a platform for expanding renewable generation in the future.

5.2.2 Benefits to Local Government

The Village government will benefit from the expansion of local, distributed energy resources that will help create a more resilient grid in the area. In the long term, the microgrid could catalyze the development of businesses that put a high premium on the reliability of its electricity supply. Newly available steam, at more affordable prices than fuel oil, may also induce new industry to locate to the Village, providing employment opportunities and enhancing the local tax base. The Project Team briefed the community on the results of the analysis in person in Albany, NY on February 10, 2016 and again by phone on March 4, 2016.

5.2.3 Benefits to Residents of Sherburne

Residents of Sherburne stand to gain from access to a broad range of critical services anytime the microgrid is forced into islanded operation by an outage on the grid. On a regular basis, they will benefit from the ability of the local utility to reinvest savings in expanding the resiliency of the local grid. Even if they are not formally connected to the microgrid, all residents of Sherburne and nearby surrounding communities will have access to food, banking, healthcare, and municipal services in the event of an outage. During at outage event at present, each of these services is either partially or wholly unavailable; the proposed microgrid provides for unencumbered electrical service to the aforementioned services during a grid outage. And due to the particular design proposal, the diversity of the services will be significant.

5.2.4 Benefits to Industrial Stakeholders

Local industry stands to gain significantly from the cheaper and abundant steam that will be created by the CHP unit, offsetting both costs and emissions as compared to fuel oil usage. These benefits will accrue to Egg Low Farms and Southern Tier Pet Nutrition. Each will have the opportunity to lock in steam purchases through long-term purchase agreements, thereby avoiding the volatility of No. 2 fuel oil prices and the emissions associated with fuel oil consumption. The manufacturing facilities will further benefit from the ability to remain open during grid outages, avoiding losses to down time or inventory spoilage and allowing local workers to continue to work and draw wages even during a long-term outage.

5.2.5 Benefits to Commercial Customers

Commercial customers of the microgrid will benefit from the reliability and resiliency of the microgrid and ability to stay in business during any macrogrid outages. These facilities include banking, a grocery store, a gas station, insurance, and small healthcare facilities. They represent many of the specific services required by residents during an emergency situation. Moreover, any future steam users would have potential access to steam produced at far cheaper costs than internal boilers. The commercial facilities will further benefit from the ability to remain open during grid outages, avoiding losses to the businesses do to down time or inventory spoilage, and allowing local workers to continue to work and draw wages even during a long-term outage.

5.2.6 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 supports the goals of REV and provides a more resilient overall grid. A successful implementation of the Sherburne microgrid will provide a proof of concept of ownership and operation for municipal utilities across the State. It would further make the case for widespread AMI installation and the flexibility attendant with microgrids that do not require a presence on a single feeder in a sequential arrangement. In addition, the lessons learned described in Section 3 are widely applicable to the further development of REV and future NY Prize efforts into Phase II and III.

5.3 Conclusion and Recommendations

The Project Team has concluded the proposed Sherburne microgrid is technically feasible, and is financially feasible with the award of the full NY Prize rebate. The microgrid meets all of the NYSERDA required capabilities and most of its preferred capabilities as outlined in the SOW for this contract.

Major risks include constructing the natural gas infrastructure that will be necessary to fuel the 2 MW CHP natural gas-fired generator and utilizing AMI remote disconnect meters to control loads. The AMI remote disconnect, a cutting-edge technology, is not fully ready from a technical standpoint. Barriers include determining how the AMI meters will tie into the SCADA control system and how quickly remote reconnect can be achieved from control systems signals. However, the Booz Allen Hamilton team expects this functionality to be operational by the time of construction.

As a replicable and scalable model in the municipal utility context, the Sherburne microgrid will help pave the way for similar projects in other small communities with industrial presence. Using Sherburne as an example, other communities serviced by municipally owned utilities can adopt vertical integration ownership models for microgrids of their own. In addition, the successful completion of this vertically integrated microgrid will demonstrate the tangible value of microgrid projects to potential investors. And if the Sherburne microgrid is fully executed and developed, it will prove out the viability and value proposition of microgrids within the service territory of municipal utilities.

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

Finally, the project will demonstrate the widely distributed benefits of microgrids paired with distributed energy resources assets. The utility will see increased revenues and grid performance, customers will see stabilized electricity and steam prices provided by a more reliable grid system, the community will reap the positive benefits of living in and around the microgrid, and industrial customers will benefit from reduced energy costs and the value of avoided outages. For these reasons, the Project Team recommends this project for consideration as a Phase II NY Prize community.

Appendix

Metering data for typical 24-hour August load profiles were provided by Sherburne Electric Department. They are included in this feasibility study to show which facilities have highest and lowest load demands at different times of the day. Analyzing these load demand curves has allowed the team to develop a better overall understanding of the generation capacity needed to sustain the microgrid. 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.

One Lines and Load Profiles removed for public consumption