# 77 - Village of Geneseo (SUNY)

August 2016

# Notice

# NY Prize Task 5 Milestone Deliverable:

# Village of Geneseo Final Report



Submit to:
**NYSERDA**
New York State Energy Research and Development Authority

Submit by:
Willdan Energy Solutions
on behalf of the Village of Geneseo

WILLDAN
Celebrating 50 years of service

August 1, 2016

Stephen Hoyt, Project Manager
NYSERDA
17 Columbia Circle
Albany, NY 12203-6399

Re: NY Prize Plattsburgh Final Report

Dear Mr. Hoyt:

Willdan Energy Solutions presents the enclosed report for Geneseo, New York. Our report documents baseline site information, microgrid technical and financial analysis, and cost benefit analysis, organized by NYSERDA-defined tasks. Please refer to the Executive Summary for an overview of our analysis and findings.

To discuss any aspect of this report, or to arrange a personal meeting, please call me at 914-633-6490 or send an e-mail message to rbraun@genesysengineering.net. We appreciate the opportunity to work with you and with the Plattsburgh Community on this important project.

Sincerely,

WILLDAN ENERGY SOLUTIONS

Robert J. Braun
Principal

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# Executive Summary

This study evaluated the feasibility of a community microgrid for the SUNY Geneseo campus and the surrounding Village of Geneseo. The microgrid would be interconnected with Rochester Gas & Electric's (RG&E's) distribution system. The village facilities included in the study were the village offices at 119 Main Street and the wastewater treatment plant. The building housing the village offices also houses the village court and police, and it serves as a command center during emergencies. It currently does not have backup power and is located across the street from campus. The wastewater treatment plant is located approximately a mile from campus and serves both the village and the university. Specific university buildings that were of particular interest in the study were the campus health center and Schrader Hall, which contains both the campus police headquarters and a gymnasium that can serve as a community shelter during emergencies.

The distributed generation that was evaluated as part of this study included CHP generation at the university's central heating plant and a solar installation adjacent to campus. In addition, enhanced biogas production at the wastewater treatment plant was studied. The idea there was to divert to the underutilized digester at the plant food waste from campus dining halls and local grocery stores as well as possibly manure from local farms. This waste would be used to increase the production of biogas, and then this biogas would be used to generate power. The biogas that is currently being produced at the plant from sewage sludge is simply being flared.

As the study progressed, it was decided that the most logical microgrid for Geneseo would be a campus microgrid, not a community microgrid. The SUNY campus is served by two dedicated feeders whereas the 119 Main Street location and the wastewater plant are served by a third and fourth feeder, both of which share load with other residential and commercial facilities. The wastewater treatment plant is approximately half a mile from campus and over a mile from the substation. While 119 Main Street is very close to campus, lines from both locations would need to cross roads. In addition, both locations have relatively small electric loads that would more easily be served by backup generators, or, in the case of the wastewater treatment plant, self-generation. The cost-benefit analysis in Task 4 was run both with and without 119 Main Street, and it was found that excluding this location improved the cost-benefit balance. The cost-benefit analysis included in this document does not include 119 Main Street.

The recommended course of action for SUNY Geneseo, given limited funding, is to pursue each of the pieces of the proposed microgrid separately and then eventually to consider tying them together into a microgrid if conditions warrant. The CHP installation at the central heating plant could make use of the existing steam loop for its waste heat. An independent analysis by the DOE's Technical Assistance Partnership program estimated that a 2 MW CHP installation would have a 12.5 year payback period and 14.3% IRR before incentives. With incentives, the estimated payback period drops to 6.3 years. A CHP installation would have environmental benefits in that the emissions would be less than the Upstate New Yok grid average. Although the cost of the solar installation pushed the costs higher than the benefits in the cost-benefit analysis for the no-outage scenario, the university is currently soliciting

proposals for a solar Power Purchase Agreement (PPA). If an attractive PPA can be negotiated, then the solar installation would make economic sense as well as having attractive environmental benefits. Finally, although biogas production is not generally viable at small plants such as the Geneseo plant, initial analysis shows that there may be some potential there if low or break-even returns are acceptable in order to receive sustainability benefits. However, the economic viability is highly dependent on assumptions such as costs and gas yields, which are difficult to pin down without further investigation and testing. We recommend that Geneseo proceed with a small-scale pilot project to test the technical and economic viability of biogas production and power generation at the plant.

# Task 1: Develop Microgrid Capabilities

*Table 1. Geneseo Community Microgrid – Existing and Proposed Overview*

| Category | Existing Resources | Proposed/Suggested Improvement | Justification |
|---|---|---|---|
| Load | 6.66 MW Peak | Building energy efficiency<br>LED street lighting<br>Load curtailment | Resilience<br>Reduced winter load<br>Minimize size of generation and amount of purchased power |
| Distributed Energy Resources (DERs) | Backup Generators | Combined Heat and Power (CHP)<br>Energy Storage<br>Solar<br>Biogas generation | Demand Response<br>Resilience<br>Renewable Sources<br>Reduced winter load |
| Electrical and Thermal Infrastructure | Radial path 4.16kV<br>Customer circuit 4.16kV | High Reliability Distribution System<br>Self-healing | Resilience<br>Reliability |
| Master Controller and Building Controls | Some building controls | Connected master controller<br>Upgraded building controls<br>Smart charger/inverter for batteries/solar | Resilience<br>Optimal utilization of microgrid assets |
| IT/Communication Infrastructure | Manual meters<br>Some system -level load metering | Advanced Metering Infrastructure (AMI)<br>900 MHz mesh network<br>Fiber optic backbone<br>Control interface for DER | Resilience<br>Reliable real time information<br>Remote Control |

## Introduction

SUNY Geneseo has completed a feasibility study for a microgrid that would be interconnected with the Rochester Gas and Electric (RG&E) distribution system. The primary team members for this project were the applicant, the State University of New York at Geneseo (SUNY Geneseo), a four-year liberal arts college with a student population of about 5,400; and two partners, the Village of Geneseo, the county seat of Livingston County, NY with a population of nearly 8,000; and Campus Auxiliary Services, SUNY Geneseo's self-operated 501(c)(3) nonprofit organization, responsible for the campus's dining services, waste management, and residence hall services. The goal of the microgrid would be to increase resiliency for the stakeholders, particularly with the increased threat of outages and severe weather due to climate change. A second goal would be to reduce the environmental impact of the stakeholders and move them towards more sustainable operations.

This study found that a campus microgrid, rather than a community microgrid would be more suitable for SUNY Geneseo. It would include core buildings such as the campus health center, dormitories, and Schrader Hall where the campus police station and a large gymnasium that could temporarily house community members in the event of an emergency are located. Originally, the village building at 119 Main Street – which houses the village offices, court, and police; is considered an important emergency facility; and has no backup generation – was considered for inclusion, but its relatively small load and the large expense involved in tying it into the microgrid infrastructure precluded its inclusion. In addition, the Village of Geneseo's wastewater treatment plant was considered for inclusion in the microgrid. Again, due to its small size and high infrastructure costs, the study conclude that the cost did not justify the limited benefit in including the plant. However, further study could be done to clarify whether small scale on-site generation at the plant would be justified.

This project involved screening available microgrid and smart grid technologies to determine which ones would be most beneficial to the stakeholders and then evaluating them for technical and financial feasibility, suitability for the region, and compatibility with the existing infrastructure. The selected technologies were evaluated in detail using tools such as the Distributed Energy Resources Customer Adoption Model (DER-CAM). DER-CAM helped determine parameters such as local generation technology and sizing as well as producing cost and savings estimates. This study looked at CHP installations between 2.5 and 2.8 MW.

## Campus Microgrid

Willdan proposes a campus microgrid for SUNY Geneseo which would provide economic benefits and enhance the operation, reliability, and resiliency of the electrical distribution system, while reducing its carbon footprint. This microgrid would include combined heat and power (CHP) generation at the campus central heating plant and solar generation on land adjacent to the university campus. The microgrid control infrastructure would include a master controller that would enable seamless islanding and resynchronization. Seamless islanding and resynchronization is defined as automatic separation from the grid on loss of utility power and automatic restoration of grid power after an outage on the grid side is cleared. Islanding can be implemented both for economic and for reliability purposes.

The proposed microgrid would have a number of resiliency benefits for the stakeholders. Resiliency is particularly important for the university as a prolonged power outage could have significant cost and safety implications due to the unique nature of a university, which serves as both a residential community for students and well as a workplace and school. SUNY Geneseo is one of the largest institutions in the region and includes buildings with large capacities, such as Schrader Hall, which contains the campus police station and a large gymnasium that could temporarily house community members in the event of an emergency. The ability to keep Schrader Hall, as well as the healthcare center, dorms, and dining halls, powered and to maintain the operation of the wastewater treatment plant will greatly bolster resiliency for the campus and village. The microgrid will boost resiliency by diversifying and decentralizing power generation, providing more options in the event of an outage, and by including intelligent control, which can help the electrical infrastructure better deal with system faults.

During emergency operating conditions, the microgrid master controller would optimize generation and load to provide uninterrupted power to critical loads, through the use of DERs and load shedding schemes in order to ensure safe and reliable operation of the buildings that matter most in emergency situations. Long term outages will be mitigated by a natural gas fed combined heat and power (CHP) plant, which will maintain a black-start capability in the event the outage occurs when the CHP facility is not active. This plant will rely on robust natural gas pipelines and produce enough power to serve all of the critical facilities, campus street and security lighting, and some residential load. This added resiliency will keep emergency responders and residents safe and provide the microgrid facilities with heat and power when they need them most.

The reliability of the electric distribution system would be improved through improvements to the grid infrastructure, with the goal being to make the grid more fault-tolerant and self-healing. A fault-tolerant grid can sense and clear faults with virtually no impact on building loads. It does this by reducing the number of single points of failure in the electrical and communications networks and by adding alternate sources of generation to serve both critical and non-critical loads.

In addition to increased resiliency and reliability, the Geneseo microgrid would produce economic benefits in the form of added revenue streams from demand response, alternate generation sources, and participation in ancillary service markets such as fast regulation and operating reserve markets. There would also be savings from efficiency measures to reduce overall load. Based on the price of electricity and the availability of Distributed Energy Resources (DERs), the master controller will optimally dispatch the units to provide the cheapest, cleanest, and most reliable energy possible to the microgrid facilities.

In addition to increasing reliability, the microgrid will help SUNY Geneseo further its sustainability and carbon reduction efforts. This is important to the university as an organization that desires to play its part in the larger society and work for the common good. It also makes the university more attractive to both prospective and current students, thereby supporting the university's efforts in recruiting and retention. This has direct financial benefits as well as benefits to the university's reputation. The various forms of proposed generation provide a number of environmental benefits. CHP greatly increases the efficiency of power generation – raising it from approximately 33% to 75-85%. Solar is a clean and renewable energy resource. Biogas production at the wastewater treatment plant will eliminate the current emissions and waste associated with flaring methane, and it will help reduce the amount of organics in the waste stream by diverting some or all of Campus Auxiliary Services' organic waste and possibly that generated by community partners, including grocery retailers, restaurants, local agriculture/dairy, and community residents, to the underutilized anaerobic digester at the wastewater treatment plant.

Although a campus microgrid design would make SUNY Geneseo ineligible for further NY Prize funding, if another funding source were to become available, then the university would work on securing funding and designing and building the microgrid. The college is qualified and motivated to build a microgrid. In 2014, it established the Office of Sustainability with two full-time staff members dedicated to the green efforts of the campus and assuring compliance with the Governor's Executive Order 88 (EO-88), which requires that all SUNY campuses decrease the average source energy use intensity in buildings by at least 20% by April 1, 2020. This proposed feasibility study is a step toward compliance with EO-88. The campus has successfully used NYSERDA funding to renovate four major buildings on campus: Doty Hall, Letchworth Dining Hall, Baily Hall, and Monroe Residential Hall.

## Load

### Existing Resources

There are approximately 8,000 people living in the Village of Geneseo and the surrounding rural area. The population to be directly served by the microgrid fluctuates with the school year as the SUNY Geneseo College has a student population of about 5,400.

*Table 2. Electric Load by Feeder*

| Substation | Circuit | Load Served | Peak Load (MW) |
|---|---|---|---|
| 167 @ 4.16 kV | 1209 | Village offices and other residential/small commercial | 1.16 |
| 167 @ 4.16 kV | 1211 | WWTP and other residential/small commercial | 1.77 |
| 167 @ 4.16 kV | 1208 | SUNY campus | 1.23 |
| 167 @ 4.16 kV | 1210 | SUNY campus | 2.5 |

Circuits 1208 and 1210 are owned by SUNY Geneseo, and, as table 2 indicates, the peak demand on these circuits is about 3.7 MW. The SUNY facilities targeted for the microgrid, including the Schrader Sports and Recreation Center, the Lauderdale Health Center, the central heating plant, and Campus Auxiliary Services, are included in this load. Circuit 1211 serves the wastewater treatment plant, along with some residential and other loads within the RG&E system.

### Consequences

Geneseo is vulnerable to bulk power outages as extreme weather conditions become more common. The facilities considered for the microgrid are all fed off of three feeders from a single substation, presenting reliability issues due to lack of redundancy. However, RG&E reports that there is spare capacity in the system, and as the area is not expanding quickly, capacity is not anticipated to be an issue.

### Opportunities

Willdan will explore using a microgrid to island the campus system in the event of an outage and energize connected critical facilities, some of which lack backup power. A microgrid that would allow the system to island and indefinitely energize the area, even on a rotating basis, would dramatically improve resilience. In addition, RG&E can reduce winter peaks supplied by the bulk power supply and broaden participation in demand-response programs.

### Proposed/Suggested Improvements

A community microgrid would help provide additional capacity and resiliency in Geneseo's system. A new CHP plant and demand response would help to mitigate the reliance on power from the utility grid. Demand response would be enabled by upgrades in building control technology to allow for more direct control of the curtailable and shiftable loads. In order to minimize the size of the required generation, efficiency projects, such as upgrading lighting to use LED technology, should be undertaken.

### Benefits

The proposed improvements would have several benefits. Critical facilities would remain powered on even in emergency situations when the power supply from the utility grid is lost. Efficiency projects would reduce electricity bills and could also help reduce maintenance and, in the case of better lighting, improve safety. Direct control of electric loads would not only improve the reliability of the distribution system but would facilitate more effective participation in ancillary service markets such as frequency regulation and demand response.

### Barriers

Building the microgrid would require investment in generation resources and grid infrastructure. A more comprehensive review of the exact equipment installed must be done to determine any necessary reconfiguration of the existing distribution network and communication system.

## DERs

### Existing Resources

The existing generation located within the proposed microgrid is backup generators that are used in grid outages. These generators consist of both diesel- and natural gas (NG)-fueled generators, distributed among various campus buildings and retain about a week of fuel for or rely on NG pipelines for around

2.8 MW of generation. Backup generation details are provided in figure 2 and in table 3. Two of the facilities that have been designated as critical facilities for the microgrid – the Schrader building and the Lauderdale Health Center – do not have backup generation.

*Table 3. SUNY Facilities and their respective backup generators*

| Facility | Backup Capacity (kW) | Backup Type (kW) |
|---|---|---|
| Bailey | 250 | Diesel |
| College Union | 45 | Natural Gas |
| DOTY | 450 | Natural Gas |
| Erwin | 100 | Natural Gas |
| Heating Plant | 150 | Natural Gas |
| ISC | 450 | Natural Gas |
| Letchworth | 200 | Diesel |
| Milne Library | 12.5 | Natural Gas |
| Red Jacket | 85 | Natural Gas |
| Saratoga Heating Plant | 250 | Diesel |
| South Hall | 130 | Natural Gas |
| Welles | 18.5 | Natural Gas |
| Erie | 40 | Natural Gas |
| Genesee | 35 | Natural Gas |
| Jones | 30 | Natural Gas |
| Jones (Cogen) | 30 | Natural Gas |
| Livingston (Cogen) | 30 | Natural Gas |
| Nassau | 35 | Natural Gas |
| Niagra | 35 | Natural Gas |
| Onondaga | 60 | Natural Gas |
| Putnam | 35 | Natural Gas |
| Seneca | 250 | Diesel |
| Stueban | 15 | Natural Gas |
| Suffolk | 35 | Natural Gas |
| Wayne | 35 | Natural Gas |
| **Total:** | **2,806** | **Diesel: 950**<br>**Natural Gas: 1,856** |

The wastewater treatment plant has a portable 350 kW diesel generator that it shares with the water plant. This has been a reliability issue for the wastewater plant as it takes engineers 4 hours to hook up the generator in the event of an outage, and in the event that both the wastewater plant and water plants are without power, the water plant receives priority.

### Consequences

While the critical loads have an average demand of about 3 MW and back-up generation totaling around 2.8 MW of generation, the designated critical facilities do not have backup generation, and the wastewater treatment plant only has a shared backup generator. In addition, the university pays to maintain and test the backup generators and doesn't see any value added beyond emergency situations. Finally, it is worth noting that over one third of the generation runs off of diesel fuel, which has higher emissions than natural gas, increases the carbon footprint of the university, and must be stored or shipped into the village in the event of an outage.

### Opportunities

This feasibility study explored replacing some or all of the backup generation with a single 2-4 MW natural gas-fed Combined Heat and Power (CHP) plant located in SUNY Geneseo's central heating plant. The electricity provided from the CHP plant could cover the electricity needs of the currently vulnerable critical facilities, and the heat could be used to feed the existing steam loop that serves the central campus in winter and provide domestic hot water and absorption chilling for the College Union and Clark Services building, both of which are adjacent to the central heating plant, in the summer. The study also looked at adding food waste from the campus dining halls to the digester at the wastewater treatment plant in order to increase methane production. The methane that is currently being produced is flared. The study analyzed utilizing this methane and any additional gas produced from the food waste. Possible uses are power generation at the plant, negotiating a contract with RG&E to inject it into their existing piping, or using it to fuel vehicles at the plant. The additional food waste, estimated at 587,813 lbs/year, would increase the gas production from an estimated 4.3 million $ft^3$/year to 6.8 million $ft^3$/year. These numbers do not include any food waste being added to the digester during the summer months when the university is not in session. However, this reduction in summer feedstock could be offset by collecting food waste from local grocery stores and farm waste from local farms. Finally, the study evaluated solar. The university is currently negotiating with a nearby landowner for solar siting.

## Proposed/Suggested Improvements

### DER Technology

Table 4 includes the screened technologies and their barriers and opportunities specific to the Village of Geneseo. Based on an initial screening, this feasibility study evaluated CHP (including a black start capability), anaerobic digestion, and solar. Battery storage was evaluated as a means of storing solar energy, thereby increasing the resiliency of the microgrid. Battery sizing was determined as part of Task 2. Due to the limited space available on campus for wind turbines and the minimal elevation drop of the Genesee river in the vicinity of campus, wind and hydro were not given further consideration.

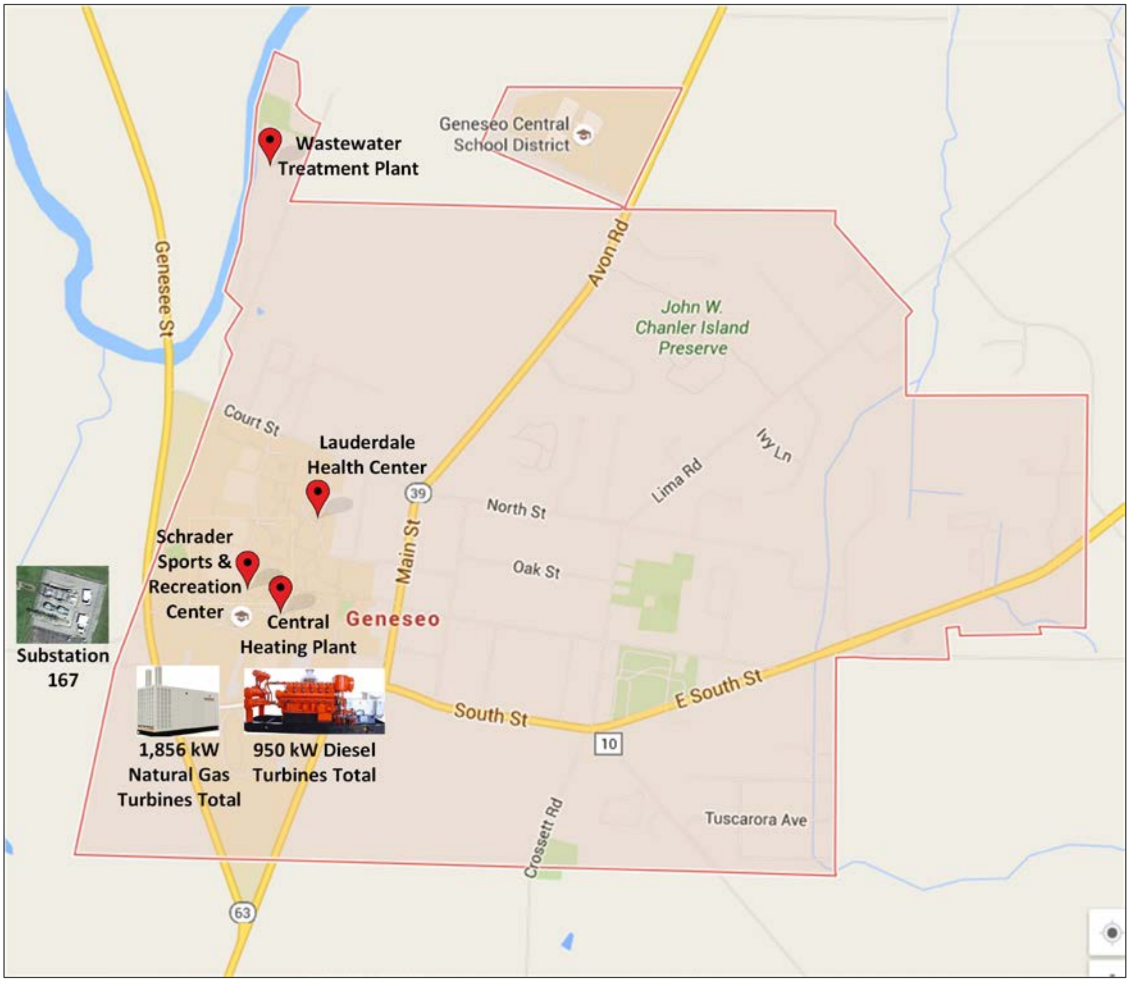


*Figure 1. Critical Load and Existing DER Map of Geneseo*

*Table 4. Distributed Energy Resources*

| Type | Description | Barriers | Opportunities |
| --- | --- | --- | --- |
| Combined Heat and Power (CHP) | 2-5 MW NG-fired reciprocating engine used to generate electricity for microgrid and heat for exiting steam loop and possibly absorption chilling and DHW for College Union and Clark in the summer | Space, capital cost, cost of NG, heating infrastructure | Reliability and resiliency. Financial savings. |
| Solar | 2 MW solar array located on land near substation | $/kW of solar is greater than electricity price | Clean, reduce daytime peak load |
| Electric Storage | Batteries used to store PV-generated electricity in order to increase reliability | Space, capital cost | Fast regulation, provides power during NG spool up |
| ICE Distributed Generation (ICE DG) | 2.8 MW of existing diesel- and NG-powered backup generation for many campus buildings | Cost, range of use, maintenance. Diesel has more emissions than NG and solar. | Black start for CHP, provides power during NG spool up |
| Alternative Fuel Sources | Biogas production at WWTP from dining hall and other food waste as well as existing sewage flow | Supply, cost | Increase sustainability by eliminating waste stream, eliminating flaring of gas at WWTP, and increasing production of renewable fuel |

## Barriers

Additional modeling was performed to determine the optimal size and capacity of the proposed units and to evaluate siting and financial feasibility. The SUNY Geneseo central heating plant is shut down every summer for extensive maintenance. The installation of CHP at the plant, if it is to operate year-round, would require additional personnel.

# Electrical and Thermal Infrastructure

## Existing Resources

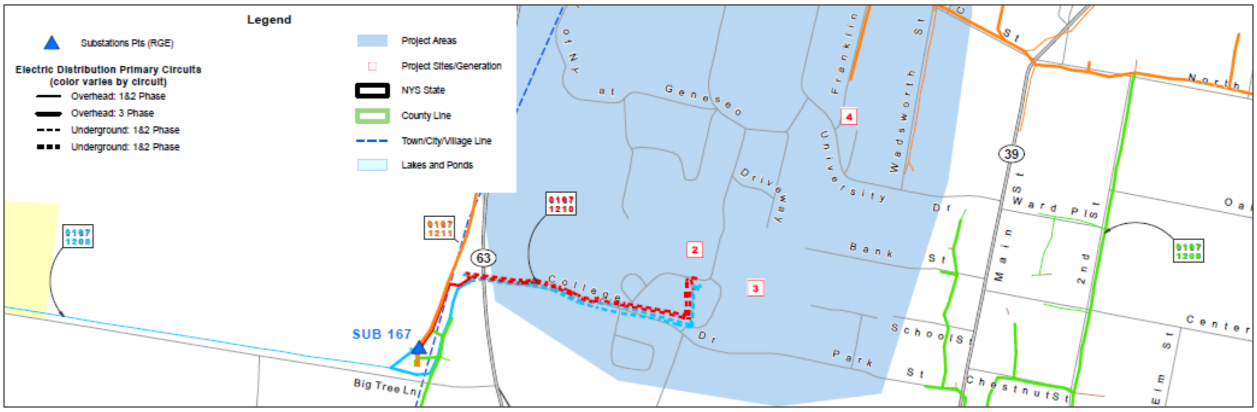


*Figure 2. Geneseo's Substation in Reference to the SUNY Geneseo Campus (in Blue)*

RG&E owns and operates the distribution system within the village to serve approximately 8,000 residents. Geneseo is fed off of one substation with total capacity of over 7 megawatts. The substation, seen in figure 3, is called substation 167. Substation 167 feeds the SUNY campus from feeders 1208 and 1210, the wastewater treatment plant from feeder 1211, and the village offices from feeder 1209. The circuits are all 4.16 kV radial path circuits. There is no distribution automation (DA) on any of the circuits.

The central heating plant serves 19 buildings via a steam loop through the middle part of campus (generally the buildings between College Drive and the southern part of University Drive in figure 3). Most of the other buildings on campus, a large portion of which are dorms and dining halls, are heated by standalone hot water boilers or by ground source heat pumps. The central heating plant has four boilers that run on natural gas with a #2 fuel oil backup, and the total capacity of the plant is 80,000 lbs/hr. Steam is produced at 75 PSI. The plant was built in 2001, and the boilers are shut down every summer for extensive maintenance and overhaul. During the winter of 2015, the average heating demand was approximately 25 MMBtu/hr with a peak of approximately 50 MMBtu/hr.

Most of the residence halls have no cooling. The academic and other buildings that do have cooling are cooled either by DX rooftop units, standalone chillers, or ground source heat pumps. In particular, the MacVittie College Union has two 100-ton chillers that could be replaced with an absorption chiller served by a CHP installation at the central heating plant. The CHP installation could also serve the domestic hot water needs of MacVittie and the adjacent Clark Services Building. The feasibility of this was evaluated in subsequent tasks.

### Consequences

The mechanical switches and protection that serve the Geneseo electrical distribution system are outdated and potential sources of reliability issues. The mechanical switches will operate reliably in the event of an emergency, but the utility has no visibility into the system outside of customer calls to complain and on site system operators. This could extend the time of outages from minutes to hours.

### Opportunities

Geneseo has a relatively outdated electrical system with spare capacity but room for improvement as far as relay and protection as well as operational insight into their grid. As the primary system operators for around 8,000 customers and over 6.5 MW of load, phasing in reliability upgrades such as digital substations and automatic reclosers could see massive reliability improvements as well as economic benefits for Geneseo residents, RG&E and especially the SUNY Geneseo campus.

## Proposed/Suggested

Willdan proposes a loop-based community microgrid for Geneseo. This new distribution network has a meshed structure which can operate as loop or radial, though it is normally operated as radial (i.e., with no loop) so as to make the protection coordination easier (upstream to downstream) and to make the distribution design easier. Also, an Automatic Transfer Switch (ATS) is proposed to be deployed within the microgrid, which has the capability of network reconfiguration in case of emergency or outage.

### Benefits

The Geneseo community microgrid can operate in either grid-connected mode or island mode. The distribution network can be easily reconfigured for reliability purposes, minimizing the system loss to 3 to 4 cycles (~40ms). The critical loads can be served by multiple feeders. With the ATS, the community microgrid would be able to automatically isolate those buildings or distribution cables affected by an outage, instead of spreading the outage to the whole distribution system.

### Barriers

The distribution network will need further upgrades which may incur extra investment costs. Also, automatic smart switches are needed for fast automatic switching. Existing radial path feeders will have to be modified for closed loop configuration. Additional communication infrastructure will be needed.

## Master Controller and Building Controls

### Proposed/Suggested Improvements

A major element of the Geneseo community microgrid is its master controller. The master controller applies hierarchical control via supervisory control and data acquisition (SCADA) software to ensure reliable and economic operation of the microgrid. It also coordinates the operation of on-site generation, storage, and individual building controllers. The intelligent switching and advanced coordination technologies of the master controller through advanced communication systems facilitate rapid fault assessments and isolations.

Figure 4 shows the microgrid elements, functions, and control tasks associated with each criterion. In order to achieve the optimal economics, microgrids apply coordination with the utility grid and economic demand response in island mode. Functionally, three control levels are applied to the microgrid:

- Primary control which is based on droop control for sharing the microgrid load among DER units.
- Secondary control which performs corrective action to mitigate steady-state errors introduced by droop control and procures the optimal dispatch of DER units in the microgrid.
- Tertiary control which manages the power flow between the microgrid and the utility grid for optimizing the grid-coordinated operation scheme.

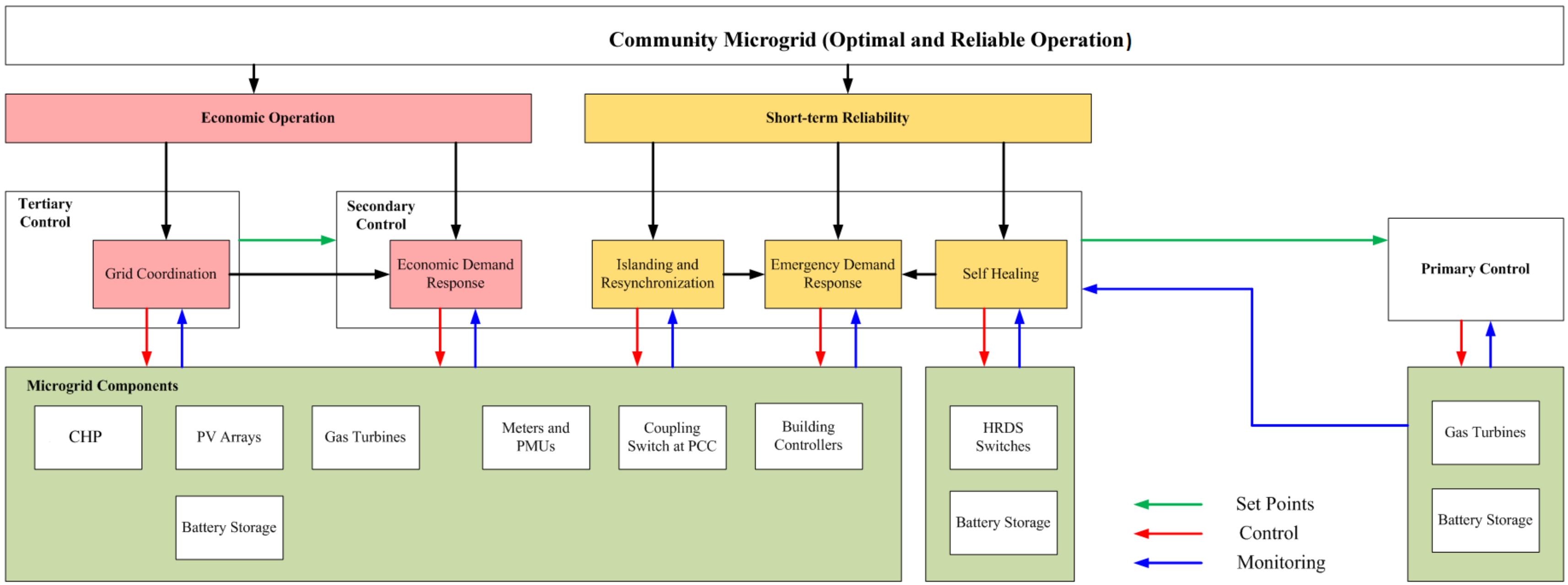


*Figure 3. Objectives and functions for the control and operation of the Geneseo Community Microgrid*

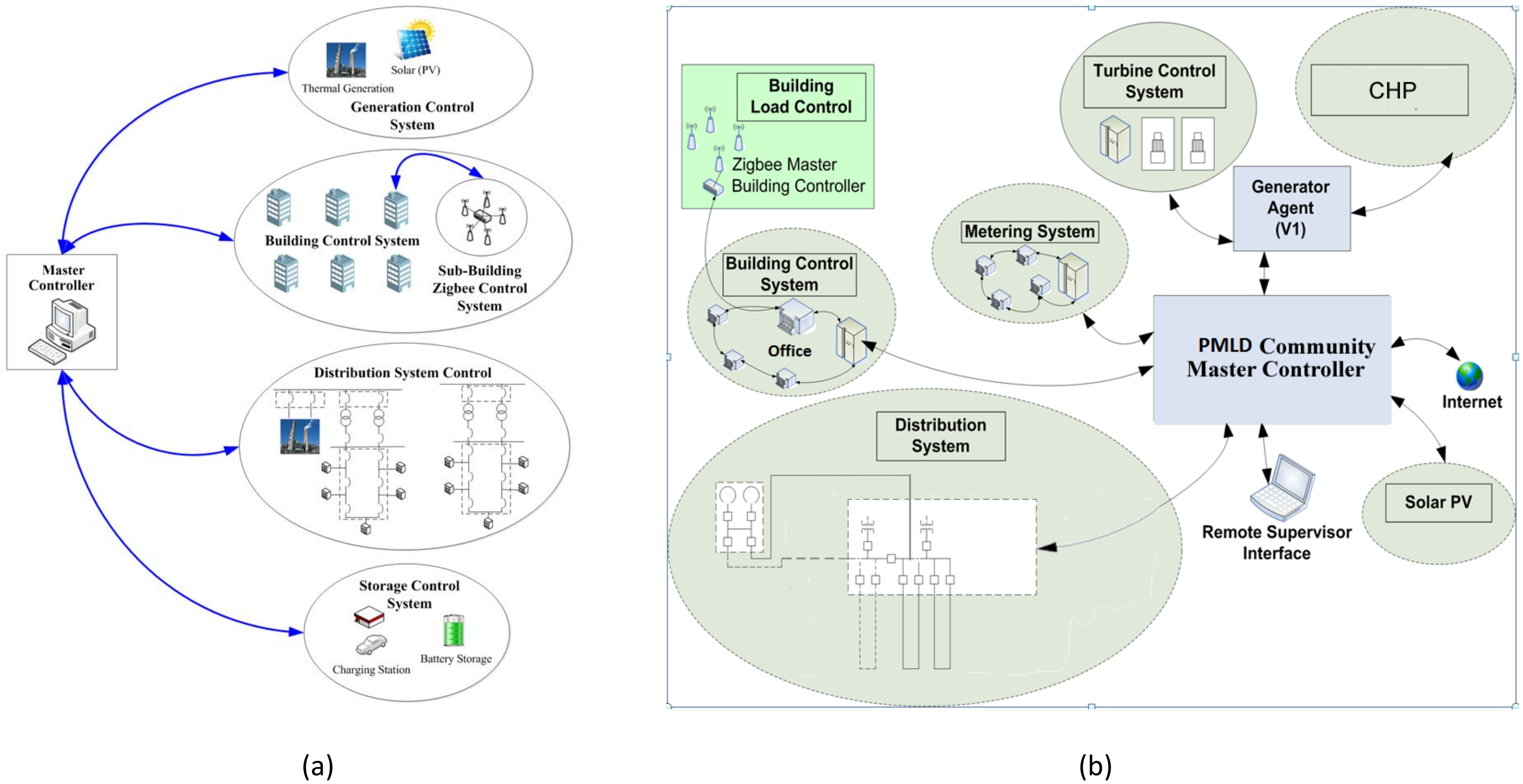


*Figure 4. Architecture of Master Controller for Geneseo Community Microgrid*

The hierarchical secondary control approach would receive information from loads and power supply entities as well as information on the status of the distribution network and procure the optimal solution via an hourly unit commitment and real-time economic dispatch for serving the load in the normal operation mode and in contingencies. Figure 5 shows the hierarchical framework of the master controller proposed for Geneseo's microgrid project. In figure 5, the monitoring signals provided to the master controller indicate the status of DER and distribution components, while the master controller signals provide set points for DER units and building controllers. Building controllers will communicate with sub-building controllers and monitoring systems to achieve device-level rapid load management.

The hierarchical protection configuration strategy for community microgrid mainly contains four-level protection: load way, loop way, loop feeder way and microgrid level.

### Benefits

The microgrid master controller offers the opportunity to eliminate costly outages and power disturbances, supply the hourly load profile, reduce daily peak loads, and mitigate greenhouse gas production. The master controller will include the implementation of additional functions for load shedding and coordinating demand response signals with the other controllers for peak demand reduction. In demand response mode, the utility master controller will shut off loads according to predetermined load priorities. Part of the load shedding will be accomplished by shutting off power to an entire building through smart switches and the rest will be accomplished by communicating directly with specific loads distributed across the community via the SCADA network and building controllers.

### Barriers

In order to implement the proposed community microgrid in Geneseo, the distribution network would need an upgrade which would incur additional investment, and automatic smart switches are needed for fast automatic switching. The functions of the community microgrid would depend a lot on the implementation of a reliable communication system.

## IT/Communication Infrastructure

Any modern utility or system operator relies heavily on their communication infrastructure to monitor and control their grid assets. For a microgrid master controller and microgrid operators, this architecture enables real time control, rapid digestion of critical grid information, and historical data for analysis and reporting. As part of a feasible microgrid, assessment and upgrade of the equipment and protocols used in the microgrid area will be performed.

## Existing Resources

RG&E owns and operates two substations and many miles of distribution lines, serving around 20,000 residents. A large majority of those customers are individually metered; however, these meters are read manually every month by a meter reader. The SUNY campus has a single meter with submeters on the dorms. RG&E has no existing SCADA system and does not have smart switches or digital substations or any communications infrastructure associated with these resources.

### Consequences

A limited communications architecture can lead to increased frequency and duration of outages if problems must occur and be reported rather than having symptoms trigger notifications to grid operators of the location and scope of the issue. Limited information and delay in this information leads to man hours wasted and longer outages, putting strain on residential customers and potentially costing commercial customers significant amounts of money. Systems could have telltale signs of issues for weeks, but operators may not discover these until they have caused damage and outages to the electric grid or substations, costing the utility money and potentially endangering employees and customers.

### Opportunities

The microgrid would benefit from an Advanced Metering Infrastructure (AMI) expansion, which would involve adding wireless communication infrastructure to each meter in the microgrid to allow for automatic and digital meter reads. The key advantage of this expansion would be the network addition, which often utilizes the 900 MHz ISM band and relies on communication between integrated Network Interface Cards (NICs) that form a mesh network, allowing signals to hop between any installed meters to reach their ultimate destination and increases the propagation range of the signal in proportion to the number and dispersion of integrated NIC Smart Meters. The integrated NICs are connected to a local Access Point (AP) that transmits the metering and control signals for the campus streetlights over a cellular wireless network back to the utility data center, where it can be fed into a Supervisory Control and Data Acquisition (SCADA) platform for use in billing or monitoring the overall grid.

RG&E-controlled AMI would also provide opportunity for community demand response aggregation, in which RG&E will be able to remotely control non-critical loads at the customer level to maximize economic benefit and/or reduce strain on the grid.

## Proposed/Suggested Improvements

The Geneseo community microgrid would be connected efficiently through the use of modern communication architectures and equipment, enabling a master controller to optimize the microgrid control and giving operators the tools they need to perform their daily duties. This network would leverage the AMI network and include the campus streetlights, upgraded to LED and equipped with smart photocells or integrated NICs that individually meter and control each streetlight, as seen in figure 6.

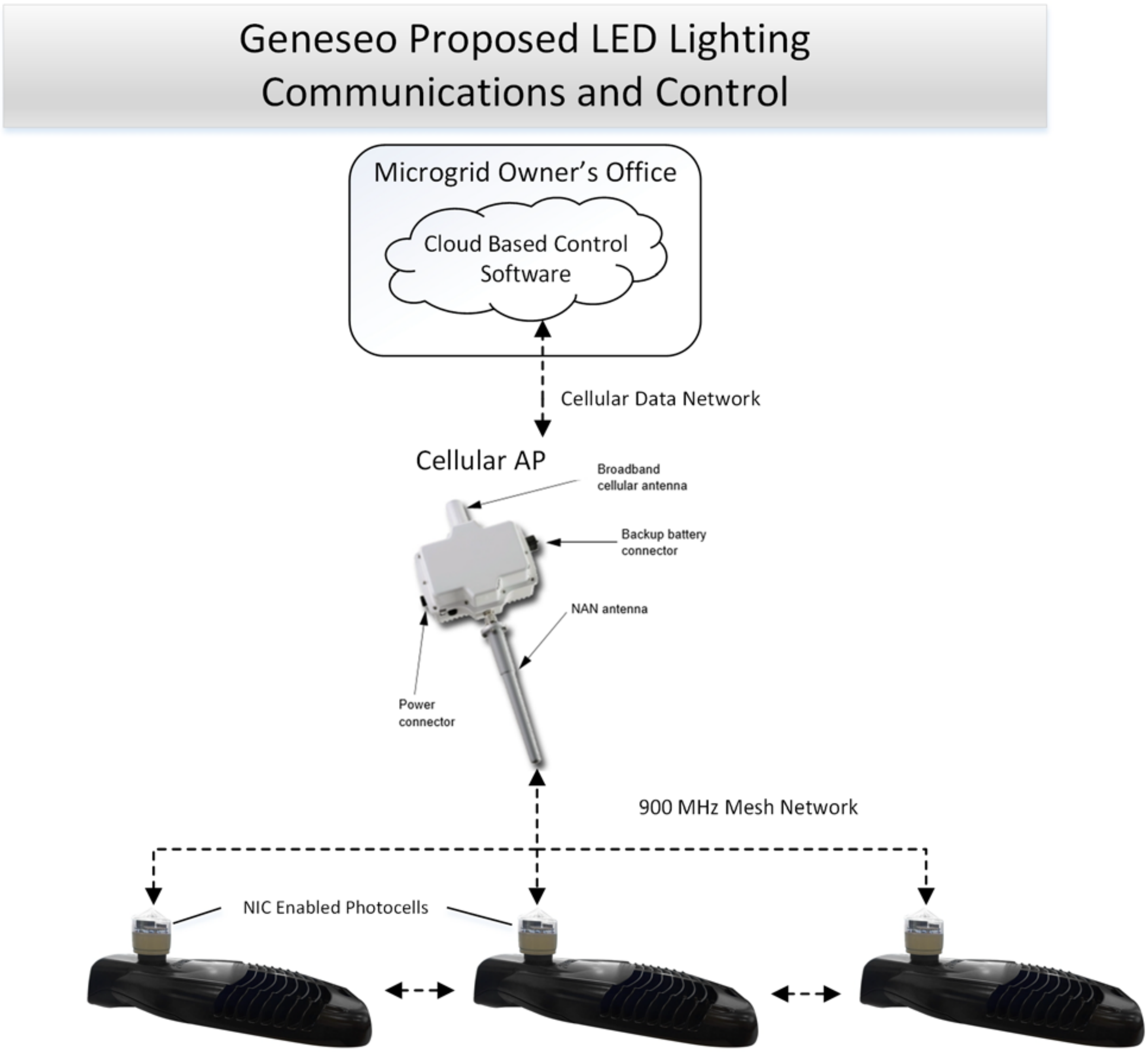


*Figure 5. Geneseo Proposed LED Lighting Communications and Control Diagram*

In addition to meters and streetlights, circuit breakers, relays, reclosers and other switchgear are vital to the control of the microgrid. While some distributed switchgear can utilize a similar wireless infrastructure, with data being fed through substations instead of through a cloud network, the control equipment is more vital to the safe operation of the microgrid and would ideally use a fiber optic backbone between the RG&E data center and substation 167. The substation relays may have to be upgraded to communicate using the DNP3 protocol over TCP/IP, the de facto standard for modern utility communications, which will be used to monitor and control the proposed DER as well.

Once in the data center, the data will be fed into an upgraded or added SCADA system to allow operators to access, visualize, and control, all of the microgrid assets.

## Benefits

Utilizing a fully connected microgrid, with every vital piece of equipment monitored and controlled remotely, the master controller will be able to optimize load and generation automatically and in real time; the microgrid operators will be able to view the status, create reports, and plan future developments; and maintenance will be able to quickly assess and address any issues.

## Barriers

A more extensive review of existing communications and control equipment needs to be performed to determine the exact quantity and specification of the upgrade; RF testing will need to be performed to determine the layout of the wireless network proposed. Training would have to be done on the SCADA system and the newly implemented relays, and personnel may need to be hired to maintain the network and communications equipment. A review of costs of the current system, including streetlight usage and maintenance data, current metering system costs and inaccuracies, and outage information will have to be performed to determine exact cost savings of upgrading to the new system.

# Task 2: Develop Preliminary Technical Design Costs and Configuration

## Introduction

The goal of the microgrid would be to increase resiliency for the stakeholders so that they can better handle electric grid outages, particularly with the increased threat of outages and severe weather due to climate change. At the same time, the microgrid would aim to provide a reasonable return on investment and to reduce the environmental impact of the stakeholders' power consumption.

There have been a number of critical buildings identified that would receive particular benefit from a microgrid. On the SUNY Geneseo campus these include the Lauderdale Health Center and Schrader Hall, which houses the campus police station and a large gymnasium that could temporarily house community members in the event of an emergency. Neither of these buildings currently have backup generation. Also, the Village building at 119 Main Street, which houses the Village offices, court, and police station and which would serve as a "command center" during an emergency does not currently have backup generation. Finally, the Village's wastewater treatment plant currently shares a portable generator with the water plant and receives lower priority, so that in the event of a widespread outage, the wastewater treatment plant is without power.

This project involved screening available microgrid and smart grid technologies to determine which ones could be most beneficial to the stakeholders and then evaluating them for technical and financial feasibility, suitability for the region, and compatibility with the existing infrastructure. The selected technologies were evaluated in detail using tools such as the Distributed Energy Resources Customer Adoption Model (DER-CAM). DER-CAM will help determine parameters such as local generation technology and sizing as well as producing cost and savings estimates.

## Sub Task 2.1 Proposed Microgrid Infrastructure and Operations


*Figure 6. Existing Generation simplified equipment layout diagram*

The proposed microgrid would incorporate a Combined Heat and Power (CHP) installation at SUNY Geneseo's central heating plant and a solar installation on land near RG&E's substation 167. The Point of Common Coupling (PCC) would be located at substation 167. In addition, two absorption chillers would be installed in SUNY's MacVittie College Union in order to better utilize the heat produced by the CHP installation during the summer months. The existing backup generators on the SUNY campus would also be utilized as part of the microgrid. The microgrid layout is shown in figure 6, and tables 5 and 6 show the existing backup generation and the proposed new generation, respectively.

*Table 5. SUNY Facilities and their respective backup generators*

| Facility | Backup Capacity (kW) | Backup Type (kW) |
|---|---|---|
| Bailey | 250 | Diesel |
| College Union | 45 | Natural Gas |
| DOTY | 450 | Natural Gas |
| Erwin | 100 | Natural Gas |
| Heating Plant | 150 | Natural Gas |
| ISC | 450 | Natural Gas |
| Letchworth | 200 | Diesel |
| Milne Library | 12.5 | Natural Gas |
| Red Jacket | 85 | Natural Gas |
| Saratoga Heating Plant | 250 | Diesel |
| South Hall | 130 | Natural Gas |
| Welles | 18.5 | Natural Gas |
| Erie | 40 | Natural Gas |
| Genesee | 35 | Natural Gas |
| Jones | 30 | Natural Gas |
| Jones (Cogen) | 30 | Natural Gas |
| Livingston (Cogen) | 30 | Natural Gas |
| Nassau | 35 | Natural Gas |
| Niagra | 35 | Natural Gas |
| Onondaga | 60 | Natural Gas |
| Putnam | 35 | Natural Gas |
| Seneca | 250 | Diesel |
| Stueban | 15 | Natural Gas |
| Suffolk | 35 | Natural Gas |
| Wayne | 35 | Natural Gas |
| **Total:** | **2,806** | **Diesel: 950**<br>**Natural Gas: 1,856** |

*Table 6. Proposed DERs and Existing Backup Generation Units*

| Location | DERs (KW) | Fuel Type | Backup (kW) | Fuel Type | Average Demand (kW) |
|---|---|---|---|---|---|
| SUNY Geneseo Campus | 2,600 | Natural Gas | 1,856 kW | Natural Gas | 2,623 kW |
| | | | 950 kW | Diesel | |
| Wastewater Treatment Plant | 200 | Natural Gas | - | - | 28 |
| **Total** | **2,800** | | **2,806** | | **2,719** |

Normal operating conditions would see reliability improvements, through infrastructure reconfiguration, such as a High Reliability Distribution System (HRDS) which senses and clears faults with virtually no impact on building loads, to a self-healing and more fault tolerant grid, by reducing the number of single points of failure by adding redundancy to the electrical and communications networks, and by adding alternate sources of generation to serve critical and non-critical loads. In addition to increased reliability, the microgrid would reap economic benefits in the form of added revenue streams from demand response, alternate generation sources, and energy efficiency measures to reduce overall energy costs, as well as participating in ancillary service markets such as fast regulation and operating reserve markets. Based on the price of electricity and availability of Distributed Energy Resources (DERs), the master controller will optimally dispatch the units to provide the most cost-effective, cleanest, and most reliable energy possible to both the critical and the non-critical microgrid facilities.

During emergency operating conditions, the microgrid master controller would optimize generation and load to provide uninterrupted power to critical loads, through the use of DERs and load shedding schemes that ensure safe and reliable operation of the buildings that matter most in emergency situations. Long term outages will be mitigated by a natural gas-fed combined heat and power (CHP) plant and natural gas-fired generators, which will maintain a black-start capability in the event the outage occurs when the CHP facility is not active. The plant will rely on robust natural gas pipelines and produce adequate power to serve all of the critical facilities and public street and security lighting. This added resiliency will keep emergency responders and residents safe and provide the microgrid with heat and power when it needs it most.

*Table 7. Microgrid Operational Modes*

| Conditions | Microgrid Operational Mode | Reasons | PCC Status | Non-Critical Load[1] |
|---|---|---|---|---|
| Normal | Grid Connected | - | Closed | ON |
| Emergency | Grid Connected | Grid Parallel Disturbance | Closed | ON/OFF |
| | Grid Connected | Internal Fault | Closed | ON/OFF |
| | Unplanned Island | Utility side outage | Open | ON/OFF |
| | Planned island | Approaching storm or threat | Open | ON/OFF |

Willdan proposes a community microgrid for the Village of Geneseo, which will enhance the overall operational reliability of the electrical distribution system. A master controller will configure the system into different modes, shown in table 7 based on input from either the system or the operator. The modes of operation are:

- **Grid connected (normal)** – system operates local generation on price signals, power quality needs, and projected electric loads for the day.
- **Unplanned Island mode** – system is able to match local generation with demand
  - Black start capability
  - Recover within a few minutes with an Uninterruptible Power Supply (UPS) Battery or diesel backup to protect critical loads
- **Planned island mode** – In case of approaching storm or threat, system isolates and becomes islanded from the whole grid
- **Grid connected (Grid Parallel Disturbance/Emergency)** – In this case UPS and battery inverters protect key facilities while generation starts in anticipation of more significant events. In this case normal economic optimization features are disabled. Local system conditions are monitored and loads, generators, and power quality devices are operated to maintain the system within set point conditions
- **Grid connected (Internal Fault)** - include smart switches which sense and isolate the fault while rerouting power to ensure power to all loads

[1] Critical loads should be ON all the time. Non-critical load will be shed using the grid-level circuit breakers or AMI during the time of on-site power outage.

By providing a microgrid master controller, the microgrid would be capable of seamless islanding and resynchronization for economic, reliability, or resilience purposes. Seamless islanding and resynchronization is defined as automatic separation from the grid on loss of utility power and automatic restoration of grid power after an outage on the grid side is cleared.

## Sub Task 2.2 Load Characterization

### Geneseo Overall Load Background

*Table 8. Electric Load by Feeder*

| Substation | Circuit | Peak Load (MW) |
|---|---|---|
| 167 @ 4.16 kV | 1209 | 1.16 |
| 167 @ 4.16 kV | 1211 | 1.77 |
| 167 @ 4.16 kV | 1208 | 1.23 |
| 167 @ 4.16 kV | 1210 | 2.5 |

Circuits 1208 and 1210 are owned by SUNY Geneseo, and, as table 8 indicates, the peak demand on these circuits is about 3.7 MW. Detailed hourly load information for the campus, as seen in figure 7, shows the campus peak in September as high as 5 MW, the value that was used in the simulations and throughout the report. The difference in SUNY metering data and this chart could be attributed to additional SUNY loads not served by these feeders, to coincident vs non coincident peaks, or to differences in years or time periods in which this data was taken. The SUNY facilities targeted for the microgrid, including the Schrader Sports and Recreation Center, the Lauderdale Health Center, and the central heating plant are included in this load. Circuit 1211 serves the wastewater treatment plant, along with some residential and other loads within the RG&E system.

System reliability and stability benefits to the utility are based upon solving projected distribution system configuration and loading constraints. In most cases, the utility distribution system has adequate system capacity and contingency capability to serve loads on both a normal and contingency basis. For the utility to accrue benefits from a community microgrid, the microgrid must provide constraint relief that the utility system does not provide. The microgrid could help provide reliability for areas of the community that are critical during major outages, such as the SUNY Geneseo Campus, the WWTP, and the Village office building.

The Village of Geneseo's loads can be separated into the broad load categories, critical and non-critical, with critical facilities including the wastewater treatment plant, the Village offices, the Lauderdale Health Center, the Schrader Sports and Recreation Center, and the central heating plant, and non-critical facilities including some of the other buildings that are part of the SUNY Geneseo Campus.

There are approximately 8,000 people living in the Village of Geneseo and the surrounding rural area. The population to be directly served by the microgrid fluctuates with the school year as the SUNY Geneseo College has a student population of about 5,400.

Geneseo is vulnerable to bulk power outages as extreme weather conditions become more common. The facilities considered for the microgrid are all fed off of three feeders from a single substation, presenting reliability issues due to lack of redundancy.

Figure 7 shows the hourly load profile of the total system load that will be served by the microgrid. The hourly load is broken down by month to reflect the drastically different usage and demand by month. It can be seen that the heating load in February causes the daily load profile to be raised significantly more than the levels of that in June, however September is the peak month. This is evidence of both electric air conditioning as well as electric load from ground source heat pumps in the Geneseo critical facilities. In addition, summer months tend to produce a daily demand curve with one wide peak, starting at 8 AM, ending at 8 PM, and peaking around 2 PM. This wide peak can be attributed to electric air conditioners working hard against the warming rays of the sun. In contrast, many of the winter months have a pronounced twin peak, with one centered around 3 PM and one centered around 7 PM. These correspond to the classroom daytime peak and the residence hall evening peak electricity consumption times. It is also interesting to note that June, a month when students tend to be done with spring classes and not yet starting summer classes, has a significantly reduced base load despite being one of the warmer months of the year.

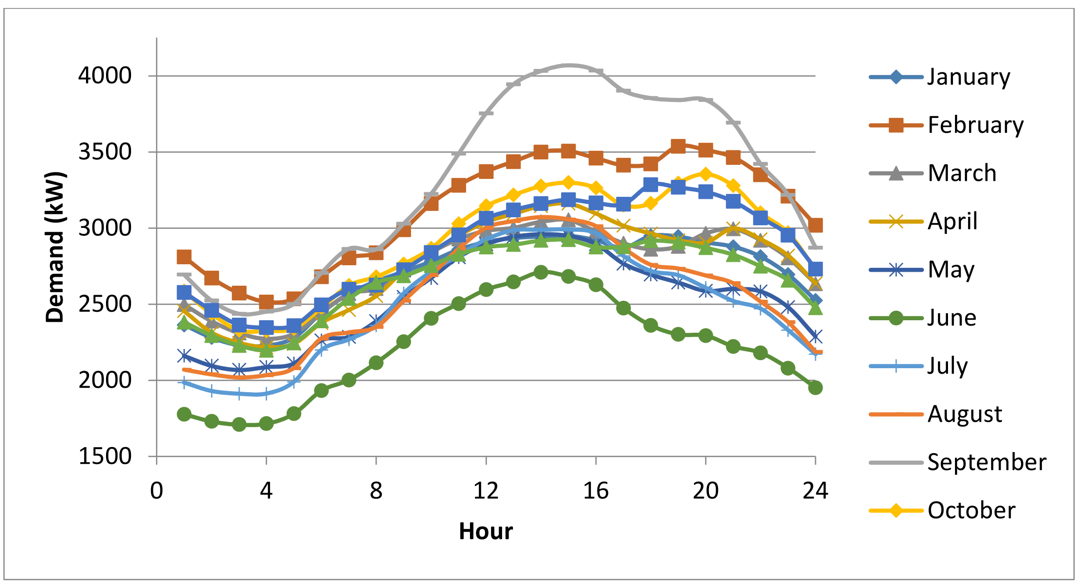


*Figure 7. Geneseo Average Daily Load by Month*[1]

[1] Hourly load was available for the SUNY Geneseo Campus but not for the WWTP so the hourly profile of the campus was scaled to reflect the load of both.

The load in each critical facility can be separated into the following load categories, with associated opportunities, as shown in table 9. The thermal loads are also considered separately.

*Table 9. Electrical Load Type*

| Type | Description | Opportunities |
|---|---|---|
| Lighting | General, task, exits, and stairwells, decorative, parking lot | Load curtailment |
| | Security and emergency | Non-critical load |
| Transportation | Elevators, dumbwaiters, conveyors | Non-critical load |
| Appliances | Business and copying machines, receptacles for vending machines, and general use | Load curtailment and shifting |
| Data processing | Desktop computers, central processing and peripheral equipment, and uninterruptible power supply (UPS) systems, including related cooling | Non-critical load |
| Space conditioning | Cooling, cleaning, pumping, and air-handling units | Short term load curtailment and shifting |
| Food preparation | Cooling, cooking, special exhausts, dishwashing, disposing | Load curtailment |
| Plumbing and sanitation | Water pumps, hot water heaters, sump and sewage pumps, incinerators, and waste handling | Short term load curtailment and shifting |
| Special loads | For equipment and facilities in mercantile buildings, restaurants, theaters, recreation and sports complexes, religious buildings, health care facilities, laboratories, broadcasting stations | Non-critical load |
| Fire protection | Fire detection, alarms, and pumps | Non-critical Load |
| Miscellaneous loads | Security, central control systems, communications; audio-visual, snow-melting, recreational, or fitness equipment | Non-critical load |

The detailed load information and locations for all the critical buildings are shown in table 10 and figure 8, respectively.

*Table 10. Critical Buildings*

| Critical Facilities | Average kW (2014) |
|---|---|
| 119 E Main St | 13 |
| WWTP | 28 |
| SUNY Geneseo Campus | 2,623 |
| **Total** | **2,732** |

Figure 7 shows the hourly load profile of the total system load that would be served by the microgrid. Figures 9, 10 and 11 show DER-CAM simulation results for the critical buildings in the microgrid under normal base conditions with no added generation, which represents the hourly load (kW) for critical building on a typical day in January. It can be seen that there are peaks around 8 AM and around 7 PM due to residential customer's electricity consumption.

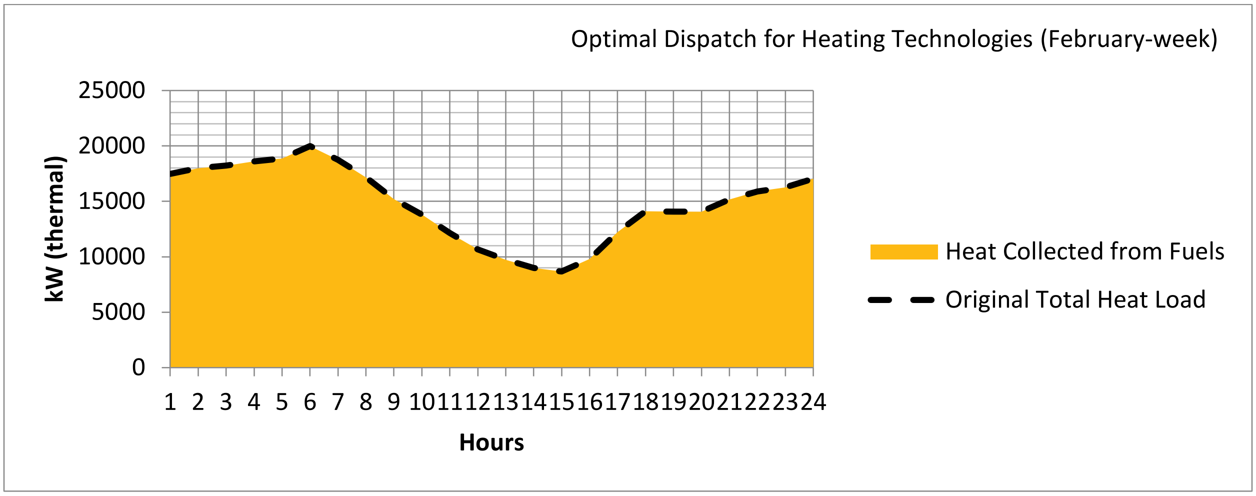


*Figure 9. Total Original Electric Load for Critical Facilities – (February Week)*

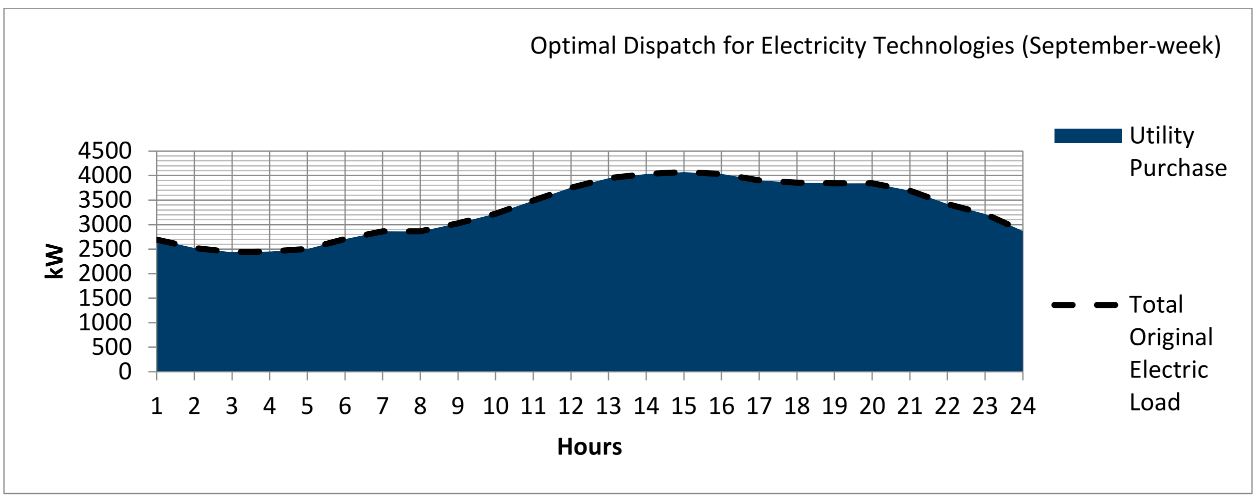


*Figure 10. Total Original Electric Load for Critical Facilities – (September Week)*

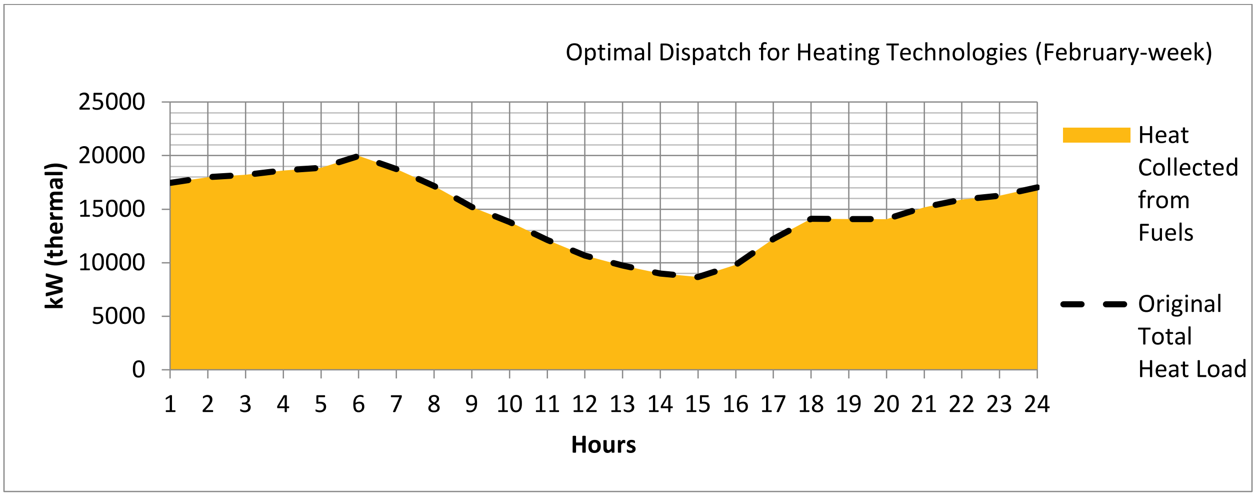


*Figure 11. Total original heating load for Critical Facilities*

In addition to providing resiliency for critical loads, Willdan's proposed microgrid could provide economic and reliability benefits for the SUNY Geneseo Campus and the wastewater treatment plant while the microgrid is islanded during a prolonged outage in the bulk power system.

In addition to increased reliability, the microgrid would reap economic benefits in the form of added revenue streams from demand response, alternate generation sources, and energy efficiency measures to reduce overall energy costs, as well as participating in ancillary service markets such as fast regulation and operating reserve markets

Capacity programs are a key component to keep electric power flowing in New York State, especially during periods of high electric demand. As an example, Capacity & Energy is a partnership between NYPA, the participant and Con Ed. This option is appropriate for customers capable of providing load reductions for payment during the summer, the winter, or throughout the year. For the facility's pledged capacity, the payment will be 85% of the average NYISO monthly auction clearing price for each month enrolled. For verified performance by the facility during an event, the greater of $0.50/kWh or 100% of the market price during each hour of the event is paid. The customer will also be paid 100% of the market price for participating in mandatory one-hour tests. The microgrid average load is 2,732 kW, and the load in each facility can be further separated into the load categories shown in table 9. The microgrid may participate in a demand response program, either Capacity or Energy Reduction, by shifting load to off-peak hours (midnight - 8:00 AM). This can be accomplished through actions like running appliances during the night or reducing the energy consumption of loads that have adjustable levels like lighting or space conditioning.

## Sub Task 2.3 Distributed Energy Resources Characterization

### Background

The characteristics of the existing generation units and the proposed DERs for DER-CAM simulation are assumed and listed in table 11 and table 12, respectively. General parameters for the existing backup generators such as investment cost (cap cost), variable operation cost (O&M Var), and efficiency are picked up from the DER-CAM database as input for the simulations. The total capacity of existing backup generators is 1,856kW which includes four diesel generators (950 kW) and 21 natural gas-fired generators (1,856 kW). A 70 kW biogas-fired generator (the gas generation potential and therefore the generator size would vary significantly based on the design of the project) could potentially be installed in the waste water treatment plant, which could provide the electricity for the plant.

*Table 11. Main Parameters of Existing Backup Generators*[1]

| Location | Capacity (kW) | Cap Cost ($/kW) | O&M Var ($/kWh) | Efficiency | Backup Only | Fuel Type |
|---|---|---|---|---|---|---|
| Bailey | 250 | 865 | 0.015 | 0.32 | Yes | Diesel |
| College Union | 45 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| DOTY | 450 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Erwin | 100 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Heating Plant | 150 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| ISC | 450 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Letchworth | 200 | 865 | 0.015 | 0.32 | Yes | Diesel |
| Milne Library | 12.5 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Red Jacket | 85 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Saratoga Heating Plant | 250 | 865 | 0.015 | 0.32 | Yes | Diesel |
| South Hall | 130 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Welles | 18.5 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Erie | 40 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Genesee | 35 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Jones | 30 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Jones (Cogen) | 30 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Livingston (Cogen) | 30 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Nassau | 35 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Niagara | 35 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Onondaga | 60 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Putnam | 35 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Seneca | 250 | 865 | 0.015 | 0.32 | Yes | Diesel |
| Stueben | 15 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| Suffolk | 35 | 1200 | 0.015 | 0.32 | Yes | Natural Gas |
| **Total** | **2806** | **Diesel: 950 Natural Gas: 1,856** | | | | |

[1] Input data is provided by DER-CAM.

*Table 12. Main Parameters of Candidate CHP units[1]*

| Location | Capacity (kW) | Cap Cost ($/kW) | O&M Var ($/kWh) | Efficiency | Alpha[1] | Fuel Type |
|---|---|---|---|---|---|---|
| CHP Option 1 | 500 | 1200 | 0.011 | 0.32 | 1.4 | Natural Gas |
| CHP Option 2 | 250 | 1200 | 0.011 | 0.32 | 1.4 | Natural Gas |
| CHP Option 3 | 100 | 1200 | 0.011 | 0.32 | 1.4 | Natural Gas |

CHP was considered in step sizes of 500 kW, 250 kW, and 100 kW, to obtain precise simulation results. CHP investment costs were obtained from EIA[2] and from NREL[3,4].

Existing DERs located in the proposed microgrid are used primarily as backup generators in the event that utility power is interrupted. Four of the backup generators are diesel generators and 21 of them are natural gas (NG) fired backup generators, distributed among the critical facilities. The backup diesel generators retain about a week of fuel for 950 kW of capacity. Existing DER and the load it serves are shown in table 6, and the main backup generators are also shown in figure 6.

The proposed Geneseo Community Microgrid focuses on providing electricity for the critical buildings while improving the overall reliability and resiliency. Total average critical building demand is about 2,732 kW (table 10), which is calculated based on the hourly electricity load data of SUNY Geneseo (from 12/11/2014 to 12/10/2015). The installation of 2,800 kW of CHP along with the existing natural gas-fired backup generators would be able to adequately serve the entire load, depending on the level of load shedding implemented. Given the current price of electricity, solar PV is not suggested by the DER-CAM simulation, although it may be more feasible once incentives and available financing options are taken into account. SUNY Geneseo is currently investigating the installation of 2 MW of solar PV. The WWTP has the potential to generate biogas through anaerobic digestion by using sludge from the wastewater treatment plant as well as food waste from the campus or the surrounding community. This gas could be combined with a generator for onsite power generation or transported to the central heating plant for use at the university. Initial estimates put the potential volume produced in a year around 6.8 million cubic feet. The estimated capital cost is $1,000,000, but the cost would vary significantly based on the project design.

[1] Alpha: Heat-to-power ratio for CHP.
[2] http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf
[3] http://www.nrel.gov/docs/fy11osti/48595.pdf
[4] http://www.nrel.gov/docs/fy13osti/56776.pdf

The proposed CHP could be installed at the central heating plant. There is currently space available next to the plant. The heat produced from the proposed CHP can utilize the existing thermal infrastructure and supplement the existing heating plant. This report provides a general figure of the proposed community microgrid assuming that the space for the proposed CHP installation is available. The exact size and capacity of the proposed units to ensure feasibility are subject to financial and space constraints.

Figures 12 and 13 show the same time period and load being served, but includes the proposed CHP being optimally dispatched throughout the day. It can be seen that the heating load is entirely served by heat collected from DG (CHP) and that the electricity curve is flattened throughout the day by the dispatch of the CHP unit for electricity for self-consumption. It is more economical for Geneseo to depend on local DER for supplying its power consumption. Figure 14 shows the heat dispatch during peak heat load month (winter season). It was seen that a significant portion of the heating load could be provided by the CHP thereby providing economic and environmental benefits.

Existing DERs located in the proposed microgrid are used primarily as backup generators or black-start generators in the event that utility power is interrupted. Diesel generators are not good to be used as a constant source for electricity generation through the year due to the limited reserve of diesel. Willdan proposes 2,800kW CHP in order to supply power to the critical facilities in case of a grid outage and improve the reliability and resiliency of Geneseo's distribution system. Along with the existing NG-fired backup generators, the total generation capacity would be enough to supply power for critical electrical loads in winter peak hours.

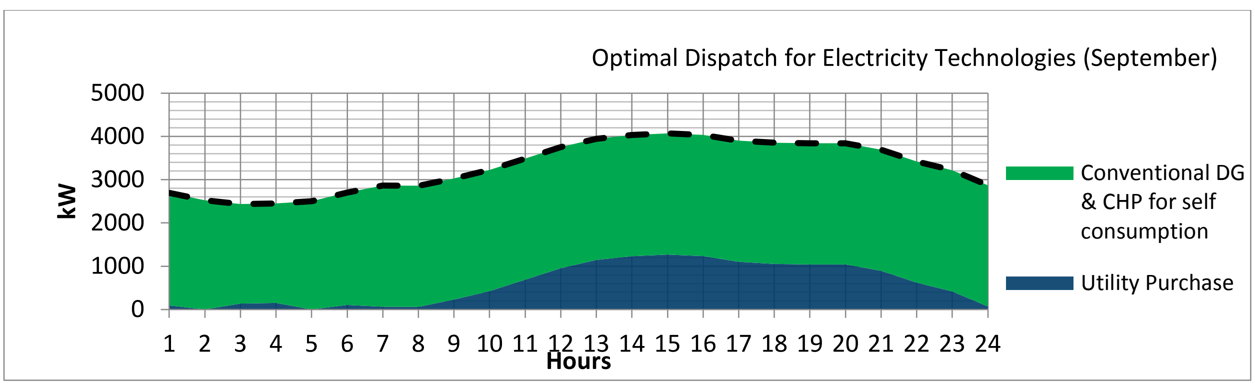


*Figure 12. Post Investment Average Electricity Dispatch for Critical Facilities*

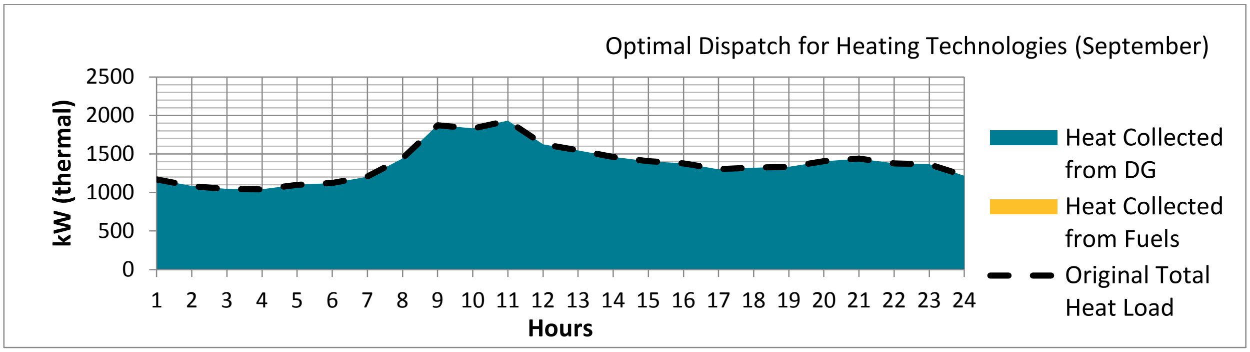


*Figure 13. Post Investment Average Heating Dispatch for Critical Facilities[1]*

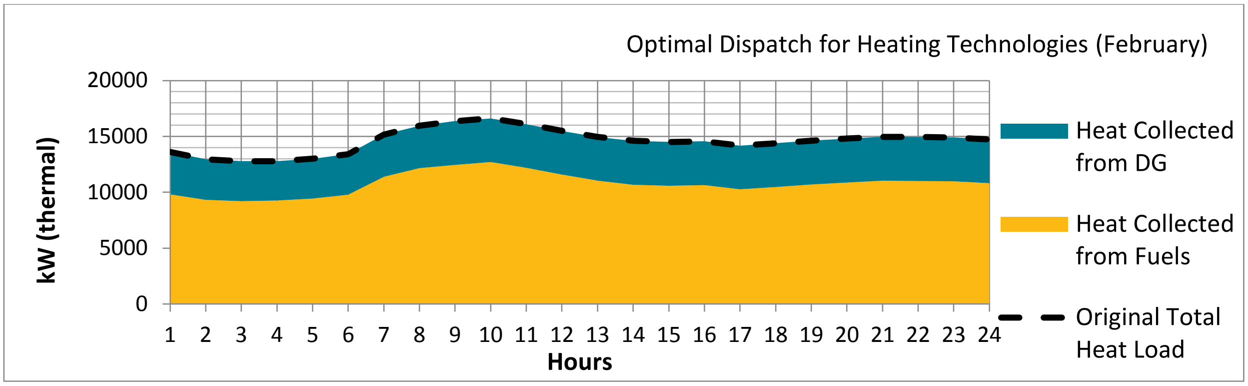


*Figure 14. Post Investment Average Heating Dispatch for Critical Facilities in Winter Season[2]*

Furthermore, based on preliminary sensitivity analysis for the critical facilities, the microgrid is highly sensitive to increases in the electricity price (figure 15). When the electricity price increases, it is economical for Geneseo to install more CHP to supply its electrical load plus its heating load and to dispatch CHP for generating electricity instead of purchasing electricity from the grid. The levelized cost of energy (LCOE) for solar is around $0.125/kWh, where the LCOE is calculated as (Total life Cycle Cost/Total Lifetime Energy Production)[3]. This LCOE is higher than the LCOE of CHP ($0.076/kWh[4]), so DER-CAM will not propose any solar installation instead of CHP. If attractive incentives or financing are available for solar, or if CHP becomes less attractive for any reason, then solar PV and a battery system would be an option to be considered. These costs and benefits will be explored in Task 4. As shown in figure 15, the operation cost doesn't show a significant increase as electricity increases since the proposed microgrid is mainly dependent on the local DERs for supplying power, which are not sensitive to the electricity price.

[1] The heat load unit is converted to kWh based on the requirement of DER-CAM input data format. Here 1 therm=29.3001 kWh is applied for the convert.
[2] DER-CAM Simulation Results, the ratio between kWh and Therm is 29.3.
[3] http://solarcellcentral.com/cost_page.html
[4] http://www.epa.gov/sites/production/files/2015-7/documents/combined_heat_and_power_frequently_asked_questions.pdf

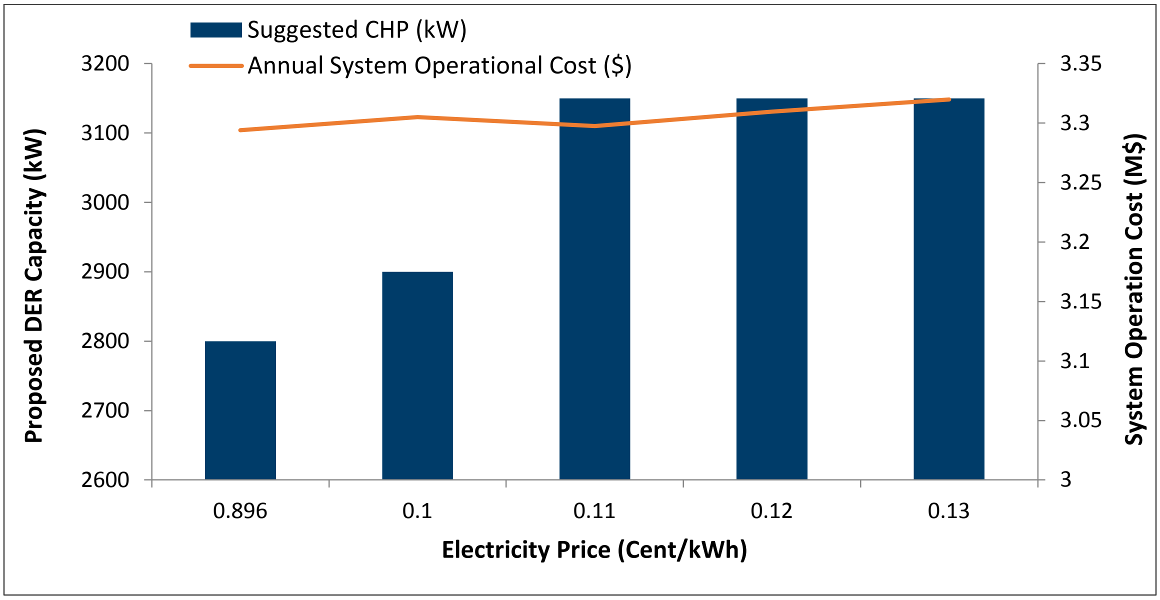


*Figure 15. Sensitivity Analysis Results for Electricity Price*

In order to simulate the reliability and resiliency of the critical facilities, the following scenarios are simulated for different conditions. The simulation results for all the scenarios are summarized in table 13. The more expensive option of solar and battery is enabled in Scenarios 2-5. In New York State, the incentive for solar installation is $0.80/W to $0.50/W at present[1]. So the potential incentives which could be received for the solar installation in Scenarios 2-5 are $0.325million, $0.65 million, $0.975million, and $1.3million respectively, would cover part of the investment cost.

- **Scenario 1**: One week islanding
- **Scenario 2**: One week islanding with 500 kW solar and 250 kW battery.
- **Scenario 3**: One week islanding with 1000 kW solar and 500 kW battery.
- **Scenario 4**: One week islanding with 1500 kW solar and 750 kW battery.
- **Scenario 5**: One week islanding with 2000 kW solar and 1000 kW battery.

[1] http://ny-sun.ny.gov/For-Installers/Megawatt-Block-Incentive-Dashboard

*Table 13. Serving Critical Facilities with Islanding in Peak Load Season*

| Scenario | Proposed CHP Capacity (kW) | Proposed Solar Capacity (kW) | Proposed Battery Capacity (kW) | Operation Cost (K$) | Investment Cost (K$) | Averaged Investment Cost ($/kW) |
|---|---|---|---|---|---|---|
| 1 | 2,800 | 0 | 0 | 3,296.8 | 3,361 | 1.24 |
| 2 | 2,600 | 500 | 250 | 3,355.1 | 4,846 | 1.456 |
| 3 | 2,600 | 1,000 | 500 | 3,409.6 | 6,571 | 1.63 |
| 4 | 2,600 | 1,500 | 750 | 3,465.1 | 8,296 | 1.71 |
| 5 | 2,500 | 2,000 | 1,000 | 3,515.4 | 9,901 | 1.82 |

While the critical facilities have a peak demand of about 5,006 kW[1] and the total capacity of DERs are 2,806 kW (table 11), it can be seen that the backup generation is not enough to power all the critical facilities during an emergency. This means that a number of vital critical facilities would be out of power in the event of an emergency. In addition, the community pays to maintain and test the backup generators, or runs risk of the generators not working when needed, and doesn't see any value added beyond emergency situations. Finally, it is worth noting that one MW of the backup generation runs off of diesel fuel, which is a relatively non-clean fuel source that reduces the quality of the air and increases the carbon footprint of Geneseo, and must be stored or shipped into the village in the event of an outage. In order to fully utilize the heat produced by the CHP, new heat infrastructure may need to be added, or the existing heat infrastructure may need to be upgraded, which would cause extra investment cost. The addition of a range of DERs, including long term sources like CHP would allow Geneseo to operate as a microgrid, take advantage of new revenue streams such as Demand Response and Fast Regulation Markets. The planned generation capacity and distribution automation capabilities are expected to dramatically increase available capacity for demand-response, increase resiliency through on-site generation, and reduce charges associated with high winter heating loads. Distribution of these additional resources close to or within the school system, will ensure that critical facilities will remain powered on in emergencies, providing Geneseo with peace of mind. Heat produced by the CHP plants would be utilized for space heating in the winter months and likely would be tied into the campus central heating plant. In addition, the CHP could feed domestic hot water (DHW) loops during summer months. A small natural gas generator, located at the WWTP, could provide resilience to this necessary public service.

In order to optimize the selection and operation of distributed energy resources, DER-CAM is applied here for microgrid simulations. A case in which maintaining the critical load's power with a one week disruption of power supply from the utility grid is presented here to show the investment options for addressing system resilience. Table 14 and figures 16-21 present the DER-CAM simulation results. DER-

[1] SUNY Geneseo Hourly Load Data (12/11//2014 – 12/10/2015) provide by ConEd.

CAM suggested 2,800 kW of CHP to supply power to all critical loads even during a seven day outage in utility grid. Shown in figure 16, the left pie chart shows that most of the electricity within the proposed community microgrid would be provided by local DERs and a small portion of the total electricity would be purchased from utility grid. The middle pie chart in figure 16 shows a total of 2,800 kW of CHP is proposed by DER-CAM, which would be enough to serve the critical facilities' electricity and heating demand during the islanding time period, helping to improve the community overall resiliency as result. It can be seen from figure 16 that all the critical loads can be satisfied by the new added DERs along with the existing generation resources. The local DERs can also provide power to critical loads during grid-connected mode shown in figure 17 which would improve the energy resilience of the critical facilities. It can be seen that the critical facilities would mainly be served by the proposed CHP, even in grid-connected mode.

*Table 14. The Annual Costs Savings by the Investment for Supplying the Loads in Geneseo with Islanding in Peak Load Day (September)*

| | Base Case (no investment) | Investment Case (investment) | Saving |
|---|---|---|---|
| Total Annual Energy Costs (k$) | 3,811 | 3,293.2 | 13.6% |

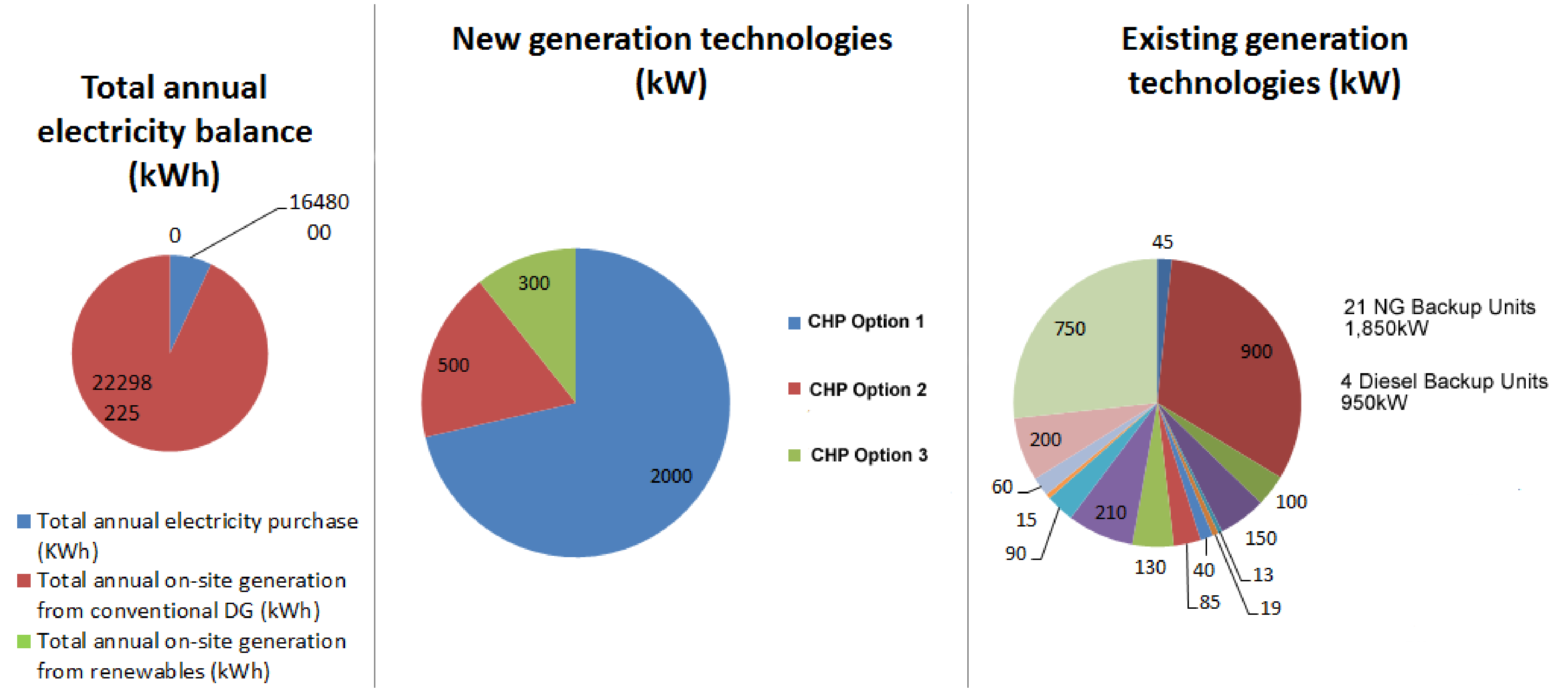


*Figure 16. DER-CAM investment results – Serving Total Load with island in Peak Load Hour*

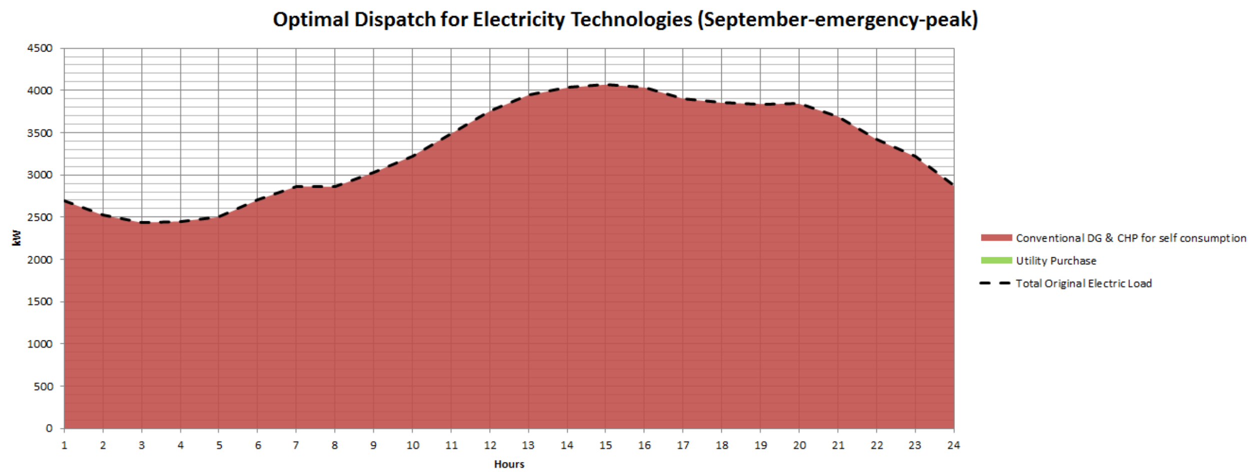


*Figure 17. Electrical Dispatch in Islanding Mode*

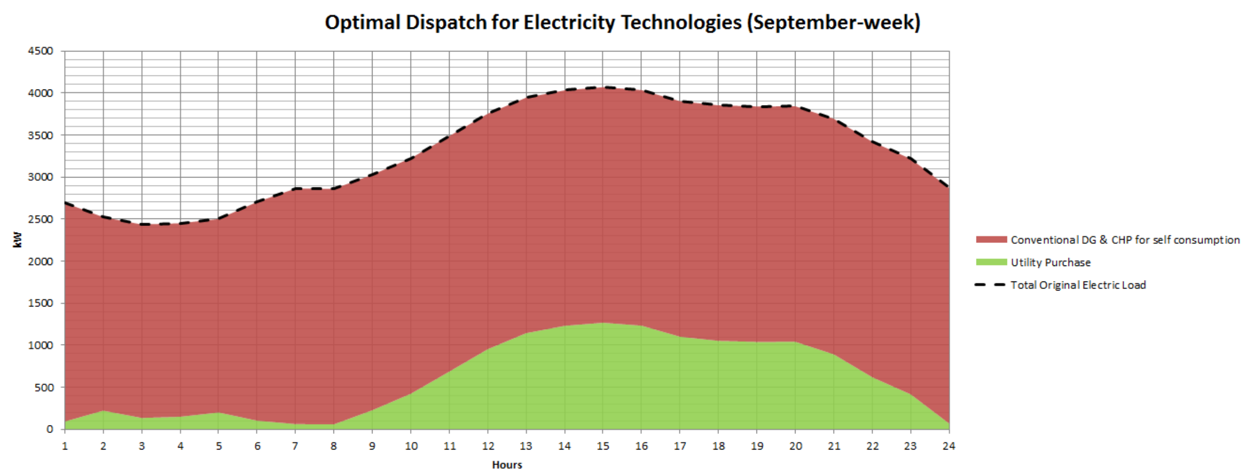


*Figure 18. Electrical Dispatch in Grid-Connected Mode*

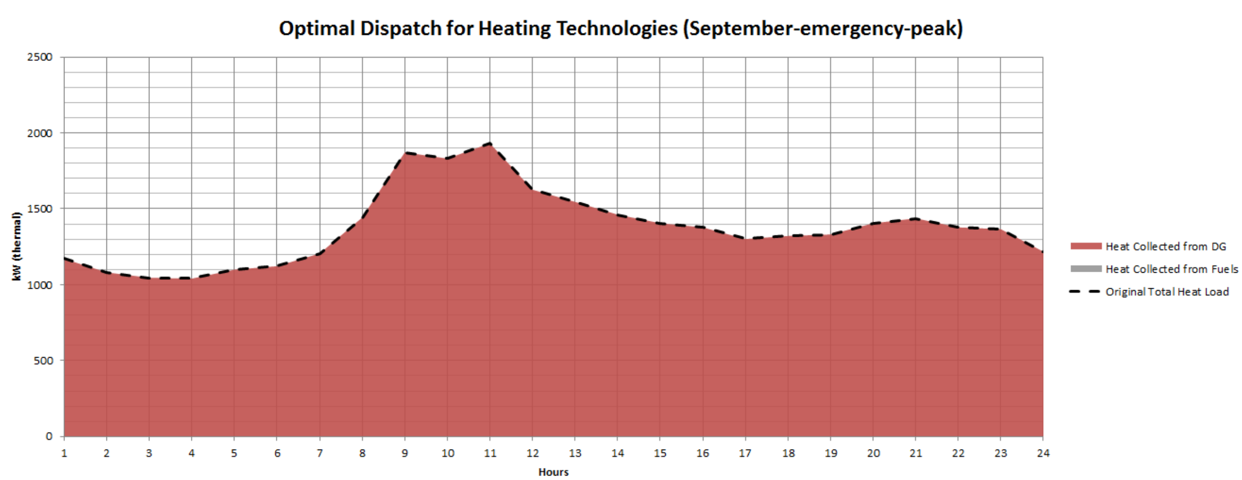


*Figure 19. Heat Dispatch in Grid-Connected Mode/Islanding Mode*

Resilience refers to the ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions, i.e., the ability to recover from a disturbance[1]. The electrical, thermal and communication infrastructure is vulnerable to many phenomena, such as hurricanes, earthquakes, drought, wildfire, flooding, and extreme temperatures. Some extreme weather events have become frequent and severe in recent years due to climate change. Snow storms and peak loads could cause damages or outages on the over-head system in the Village of Geneseo. Also heat waves in summer could affect distribution line conductor sags and any equipment that needs to be cooled off, such as, transformers, battery storage, etc. A wind gust could cause tower/pole and conductor faults due to trees falling. It would be also necessary to upgrade designs and focus more on emergency planning and restoration. For example, Hurricane Sandy occurred in 2012, which caused a widespread blackout of the power system in the eastern seaboard and left millions of homes in the dark for anywhere from a couple hours to a few weeks. Natural gas disruptions are less likely than electricity disruptions; however, it is relatively more difficult to recover from the outages than with electric systems because of the difficulty to locate and repair the underground leakages. The extreme weather would affect both individual equipment failure and system operations. The damage from such events can impose large costs on the distribution system as well as severe impacts on the local economies.

The proposed microgrid makes Geneseo's grid more resilient to:

- Energy resources disrupting events (discussed in this section)
- Distribution Network disrupting events [2](discussed in subtask 2.4)[3]
- Communication Network disruptive events1 (discussed in subtask 2.6)[4]

## Energy resource disrupting events

DER-CAM was used to analyze powering the critical loads with different islanding time periods, from one day to one week. Also, various load curtailment levels were taken into account. The proposed DER capacity and operational costs to serve all the critical loads (100% level/no curtailment) obtained from DER-CAM simulation is shown in figure 20. The proposed new capacity would depend on the peak critical load and doesn't change along with the islanding time period. The reason for this is that it is more economical for the proposed microgrid to mainly depend on local DERs for supplying power to its critical facilities instead of purchasing the power from grid, so the increase in islanding days doesn't trigger more CHP to be recommended. The operational costs are almost flat with the increase in islanding time in the 100% load level since most of the loads are served by local DERs and local DER operation cost is only dependent on natural gas price. Figure 21 shows the simulation results for serving 90%-60% of critical loads (10%-40% load curtailment), respectively. In figure 21, an extra 10% reduction

[1] Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure. Available online: http://energy.gov/sites/prod/files/2015/04/f22/QER%20ch2%20final_1.pdf

[2] Due to unavailability of Power System and Communication Network data further study is not provided at this phase. Some suggestion will be proposed in subtask 2.4.

[3] This item will be discussed later in subtask 2.4.

[4] Discussed later in subtask 2.6.

in peak load causes less CHP capacity (200 kW, 250 kW, 250 kW and 100 kW, respectively). It can be seen that lower investments would be needed as more load is curtailed, just as the operational costs are reduced, which indicates that higher resilience of critical loads can be achieved through either load management or adding new generation resources.

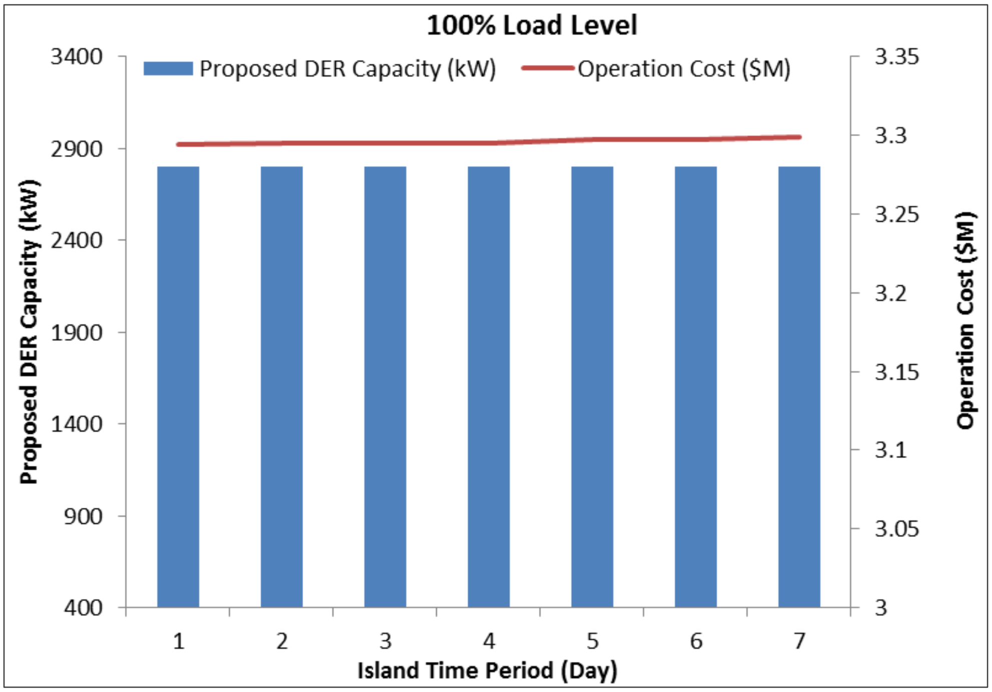


*Figure 20. Proposed DER Capacity and Operation Cost for Serving 100% of Critical Loads*

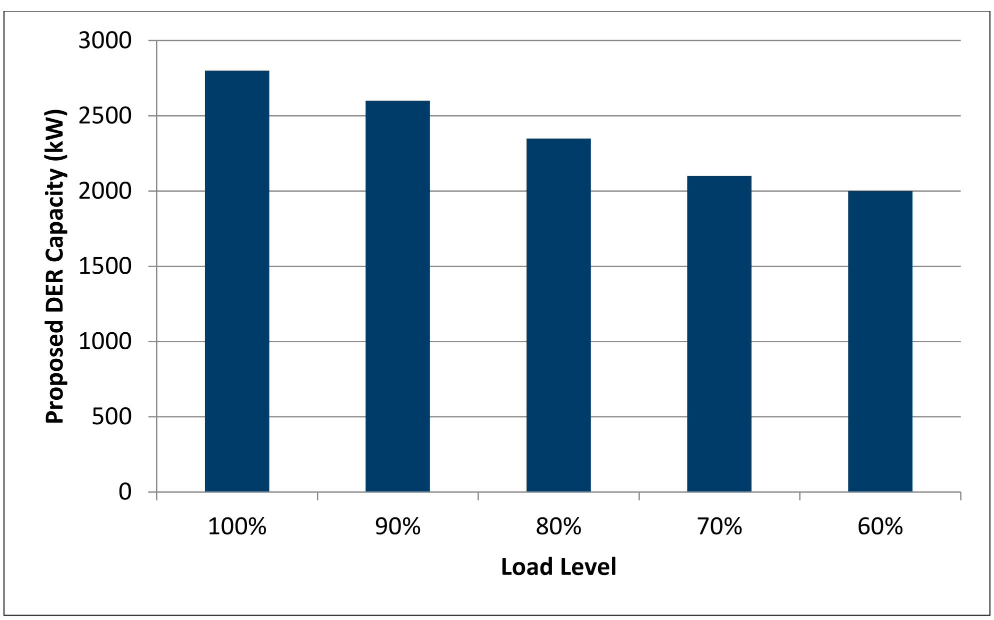


*Figure 21. Proposed DER Capacity and Operation Cost for Serving Critical Facilities*

The DER-CAM simulation results are also shown in table 15 and table 16. In these tables, having the capacity to serve critical loads without any disruption for seven days with no critical load curtailment is defined as 100% resiliency, and the capacity to serve 60% of the critical load for one day is defined as 10% resiliency.

*Table 15. The Annual Costs Savings by the Investment for Supplying Power for Critical Load with One Week Islanding in Peak Month (September)*

| Islanding Days | Load Curtailment | Resilience (%) | Proposed DER Capacity(kW) | Operation Cost ($) | Investment Cost ($) |
|---|---|---|---|---|---|
| 7 | 0 | 100% | 2,800 | 3,298,835 | 3,361,000 |
| | 10% | 97.35% | 2,600 | 3,112,894 | 3,121,000 |
| | 20% | 94.71% | 2,350 | 2,942,019 | 2,821,000 |
| | 30% | 92.06% | 2,100 | 2,775,489 | 2,521,000 |
| | 40% | 89.41% | 2,000 | 2,609,996 | 2,401,000 |
| 6 | 0 | 86.76% | 2,800 | 3,297,742 | 3,361,000 |
| | 10% | 84.12% | 2,600 | 3,112,860 | 3,121,000 |
| | 20% | 81.47% | 2,350 | 2,942,015 | 2,821,000 |
| | 30% | 78.82% | 2,100 | 2,775,471 | 2,521,000 |
| | 40% | 76.18% | 2,000 | 2,609,987 | 2,401,000 |
| 5 | 0 | 73.53% | 2,800 | 3,297,714 | 3,361,000 |
| | 10% | 70.88% | 2,600 | 3,112,846 | 3,121,000 |
| | 20% | 68.24% | 2,350 | 2,942,016 | 2,821,000 |
| | 30% | 65.59% | 2,100 | 2,775,453 | 2,521,000 |
| | 40% | 62.94% | 2,000 | 2,609,977 | 2,401,000 |
| 4 | 0 | 60.29% | 2,800 | 3,294,953 | 3,361,000 |
| | 10% | 57.65% | 2,600 | 3,112,821 | 3,121,000 |
| | 20% | 55.00% | 2,350 | 2,941,969 | 2,821,000 |
| | 30% | 52.35% | 2,100 | 2,775,435 | 2,521,000 |
| | 40% | 49.71% | 2,000 | 2,609,968 | 2,401,000 |
| 3 | 0 | 47.06% | 2,800 | 3,294,894 | 3,361,000 |
| | 10% | 44.41% | 2,600 | 3,112,760 | 3,121,000 |
| | 20% | 41.76% | 2,350 | 2,941,948 | 2,821,000 |
| | 30% | 39.12% | 2,100 | 2,775,417 | 2,521,000 |
| | 40% | 36.47% | 2,000 | 2,609,958 | 2,401,000 |
| 2 | 0 | 33.82% | 2,800 | 3,294,709 | 3,361,000 |
| | 10% | 31.18% | 2,600 | 3,112,750 | 3,121,000 |
| | 20% | 28.53% | 2,350 | 2,941,916 | 2,821,000 |
| | 30% | 25.88% | 2,100 | 2,775,399 | 2,521,000 |
| | 40% | 23.24% | 2,000 | 2,609,949 | 2,401,000 |
| 1 | 0 | 20.59% | 2,800 | 3,294,546 | 3,361,000 |
| | 10% | 17.94% | 2,600 | 3,112,638 | 3,121,000 |
| | 20% | 15.29% | 2,350 | 2,941,895 | 2,821,000 |
| | 30% | 12.65% | 2,100 | 2,775,381 | 2,521,000 |
| | 40% | 10.00% | 2,000 | 2,609,939 | 2,401,000 |

*Table 16. Serving Critical Loads with Islanding in Peak Month (September)*

| Islanding Days | Load Curtailment | Resilience Weight (%)[1] | Proposed DER | Operation Cost (K$) | Investment Cost (K$) |
|---|---|---|---|---|---|
| 7 | 0-40% | 100% - 89.41% | 2,800-2,000 | 3,298.8 – 2,610 | 3,361 - 2,401 |
| 6 | 0-40% | 86.76% -76.18% | 2,800-2,000 | 3,297.7 – 2,610 | 3,361 - 2,401 |
| 5 | 0-40% | 73.53% - 62.94% | 2,800-2,000 | 3,297.7 – 2,610 | 3,361 - 2,401 |
| 4 | 0-40% | 49.71% - 73.53% | 2,800-2,000 | 3,295 – 2610 | 3,361 - 2,401 |
| 3 | 0-40% | 47.06% - 36.47% | 2,800-2,000 | 3,295 – 2610 | 3,361 - 2,401 |
| 2 | 0-40% | 33.82% - 23.24% | 2,800-2,000 | 3,294.7 – 2,610 | 3,361 - 2,401 |
| 1 | 0-40% | 20.59% - 10% | 2,800-2,000 | 3,294.5 – 2,610 | 3,361 - 2,401 |

As natural gas-fed CHP is the most feasible option for the microgrid, the microgrid will rely heavily on natural gas pipelines to power the facilities. Pipelines are highly resilient to inclement weather, but do have the potential to break down or be damaged. This would have to be monitored closely by Geneseo to prevent any small issues from becoming major problems if there is an interruption in natural gas supply.

During emergency operating conditions, the microgrid would be able to provide uninterrupted power to critical loads, through the use of DERs and load shedding schemes that ensure safe and reliable operation of the buildings that matter most in emergency situations. Long term outages will be mitigated by large natural gas fed combined heat and power (CHP) plant, which will maintain a black-start capability in the event the outage occurs when the CHP facility is not active. The proposed CHP would have the black-start capability so the black start can be initiated by the master controller based on a pre-defined black start procedure, or the engines can be started with the use of a battery or backup diesel generator. Once up to speed, the microgrid controller must connect the system through a "generator breaker" to a load that allows it to supply power to the CHP parasitic loads (otherwise, the engines will overheat and shut down). The second step is to then engage the "tie breaker" that places the full load on the CHP system. To operate in this mode, the CHP system must be producing the electric power with a synchronous generator.

DERs with fast start-up time capability take 5 minutes from initial to start to full load. Multiple engines can be started in parallel in the proposed community. The short start-up time makes gas engine power plants an attractive solution for frequent start/stop operation and offers optimal load following capability. Reciprocating engines start quickly, follow load well, have good efficiencies even when operating at partial load, and generally have high reliabilities.

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[1] Resiliency weight is introduced based on the maximum number of days that critical load capacity is being responded in the grid outage duration and maximum level of critical load which can be served. We define that the capability of serving critical load with no curtailment for seven days (as customer's requirement) is 100% resiliency and the capability of serving 60% critical load for one day is 10% resiliency.

The microgrid master controller would determine the optimal and reliable operation of the microgrid through optimal generation dispatch and load signals. The generation dispatch signals are sent to dispatchable distributed energy resource (DER) units, and the load signals are sent to building controllers. An interactive grid-forming control would be used either in island or grid-connected mode. In island mode, DERs apply this control scheme to share the load while in the grid-connected mode. DERs apply this control scheme to regulate the power exchange between the microgrid and the utility grid. In the grid-connected mode, the DER unit with grid-following control follows the microgrid voltage and frequency, which is set by the utility grid in grid-connected mode and other DER units in island mode. Reactive Power and Voltage Control service corrects for reactive power and voltage fluctuations caused by customers' operations. This service helps maintain voltage within limits (interconnection standards) set by the National Electric Reliability Council (NERC) for the reliable operation of the system. Further details about these services and their implementation methodology are available in Subtask 2.5.

## Sub Task 2.4 Electrical and Thermal Infrastructure Characterization

Rochester Gas & Electric (RG&E) owns and operates the distribution system within the village to serve approximately 8,000 residents. Geneseo is fed off of one substation with total capacity of over 7 megawatts. The substation, seen in figures 22 and 24 is called substation 167. Substation 167 feeds the SUNY campus from feeders 1208 and 1210 and the wastewater treatment plant from feeder 1211. The circuits are all 4.16 kV radial path circuits. There is no distribution automation (DA) on any of the circuits.

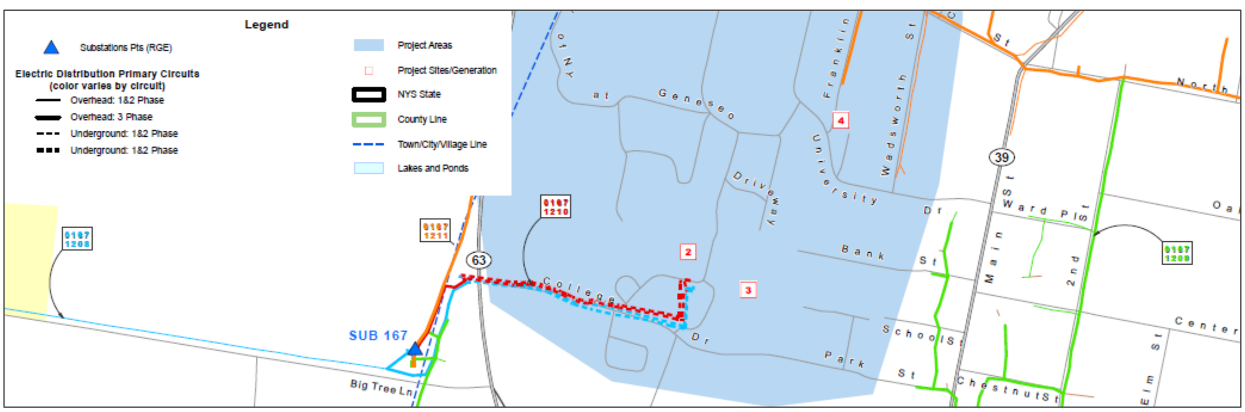



*Figure 22. Simplified Electrical Infrastructure Layout*

An intelligent distribution system consists of properly-sized cable and transformers capable of carrying the full expected load; feeder redundancy to offer an alternate power supply to buildings where power is interrupted; automated breakers and switches to execute the split second isolation of faults; automated restoration; and a communications system capable of orchestrating this split-second reconfiguration of the system.

Figure 23 provides a schematic diagram of a conceptual energy system for two critical buildings within the SUNY Geneseo microgrid. Power input to each building consists of two feeds from the substation. In

SUNY Building 1, feeders 1208 (primary) and 1210 (secondary) provide feeder redundancy through manual switches 176 and 177, respectively. A high pressure steam system supplies heating (red lines).

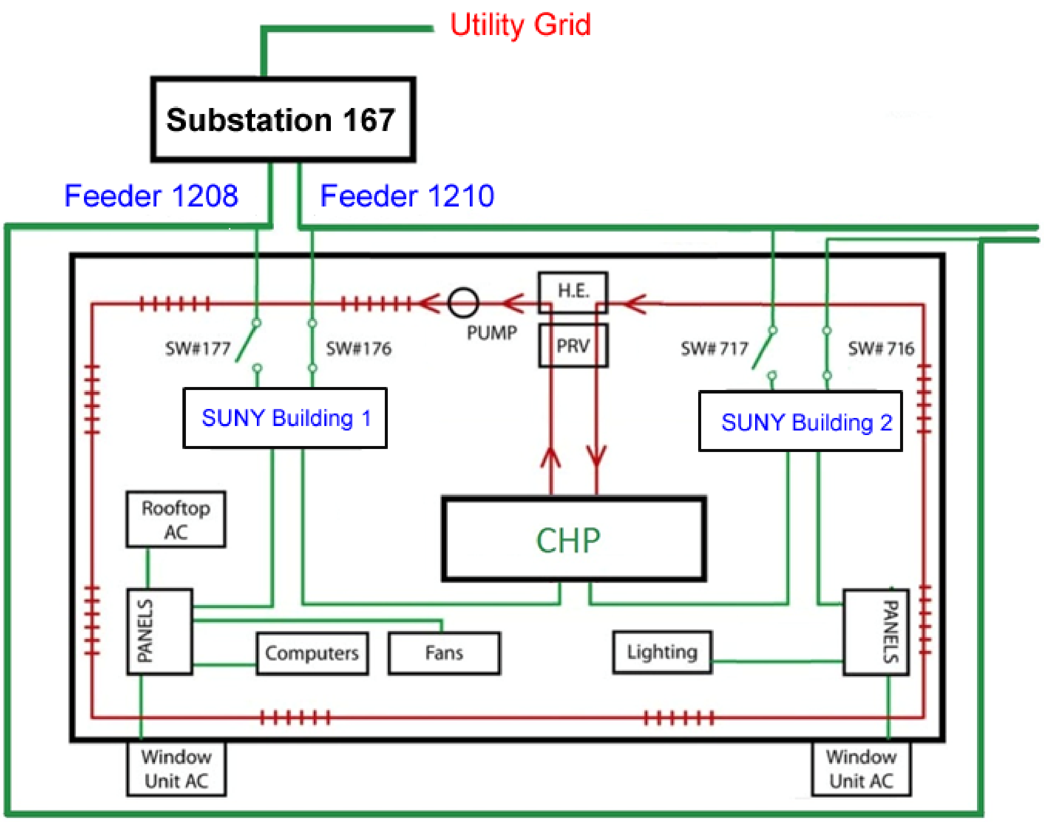



*Figure 23. Schematic Diagram of Conceptual Energy System for SUNY Geneseo*

The proposed microgrid makes Geneseo's grid more resilient to:

- Energy resources disrupting events (discussed in Subtask 2.3)[1]
- Distribution Network disrupting events [2](discussed in this subtask)
- Communication Network disruptive events[1] (discussed in Subtask 2.6)[3]

## Power System disrupting events

The proposed microgrid is equipped with self-sustaining electric[4] infrastructure, which is crucial for the success of the microgrid. The many factors that can negatively affect power supply must be mitigated automatically by the system if outages are to be avoided. Many self-sustaining elements need to work in

[1] Discussed in Subtask 2.3.
[2] Due to unavailability of Power System and Communication Network data further study is not provided at this phase.
[3] Discussed in Subtask 2.6.
[4] Perfect Power Protype, at"http://www.galvinpower.org/sites/default/files/documents/IIT_Perfect_Power_Prototype.pdf"

concert to achieve a true self-sustaining or self-healing electric infrastructure. Some of these elements are:

**Intelligent distribution system, high quality, properly sized cable and transformers -** An intelligent distribution system consists of properly-sized cable and transformers capable of carrying the full expected load; feeder redundancy to offer an alternate power supply to buildings where power is interrupted; automated breakers and switches to execute the split second isolation of faults; automated restoration; and a communications system capable of orchestrating this split- second reconfiguration of the system.

**Feeder redundancy** - Feeder redundancy will allow the re-routing of power to buildings in the event of a fault on a distribution feed. Used in concert with high-speed automated breakers and switches, redundant feeders allow for the instant reconfiguration of the system to keep power flowing to all buildings.

Normal operating conditions would see reliability improvements, through infrastructure reconfiguration, such as a High Reliability Distribution System (HRDS) which senses and clears faults with virtually no impact on building loads, to a self-healing and more fault tolerant grid, by reducing the number of single points of failure by adding redundancy to the electrical and communications networks, and by adding alternate sources of generation to serve critical and non-critical loads.

The HRDS leverages a continuously energized loop feeder concept, which provides a redundant electric supply to each campus building. Both feeds will be energized and supply electricity to the building, as well as being capable of carrying the entire building load. High-speed, intelligent automated switches will detect and isolate a fault without loss of power to the building.

Willdan proposes a loop-based community microgrid for Geneseo. It would be a HRDS, which can operate as loop or radial, though it would normally operate as radial (i.e., with no loop) so as to make the protection coordination easier (upstream to downstream) and to make the distribution design easier. Also, Vita Switch gears are proposed to be deployed within the community microgrid, which have the capability of network reconfiguration in case of an emergency or an outage. The conceptual design of Geneseo's and SUNY Geneseo's distribution network for supplying power to the critical facilities is shown in figure 24. Each square represents one of the three ways located in Vista switchgears, shown in figure 25. The DERs include the proposed CHP and the existing backup generators. Each Vista switch has three ways: Way 1 (inbound feeder), Way 2 (Outbound feeder), and Way 3 (Load). The electrical one-line diagram is not available at the time of report preparation, so the design is only a conceptual design.

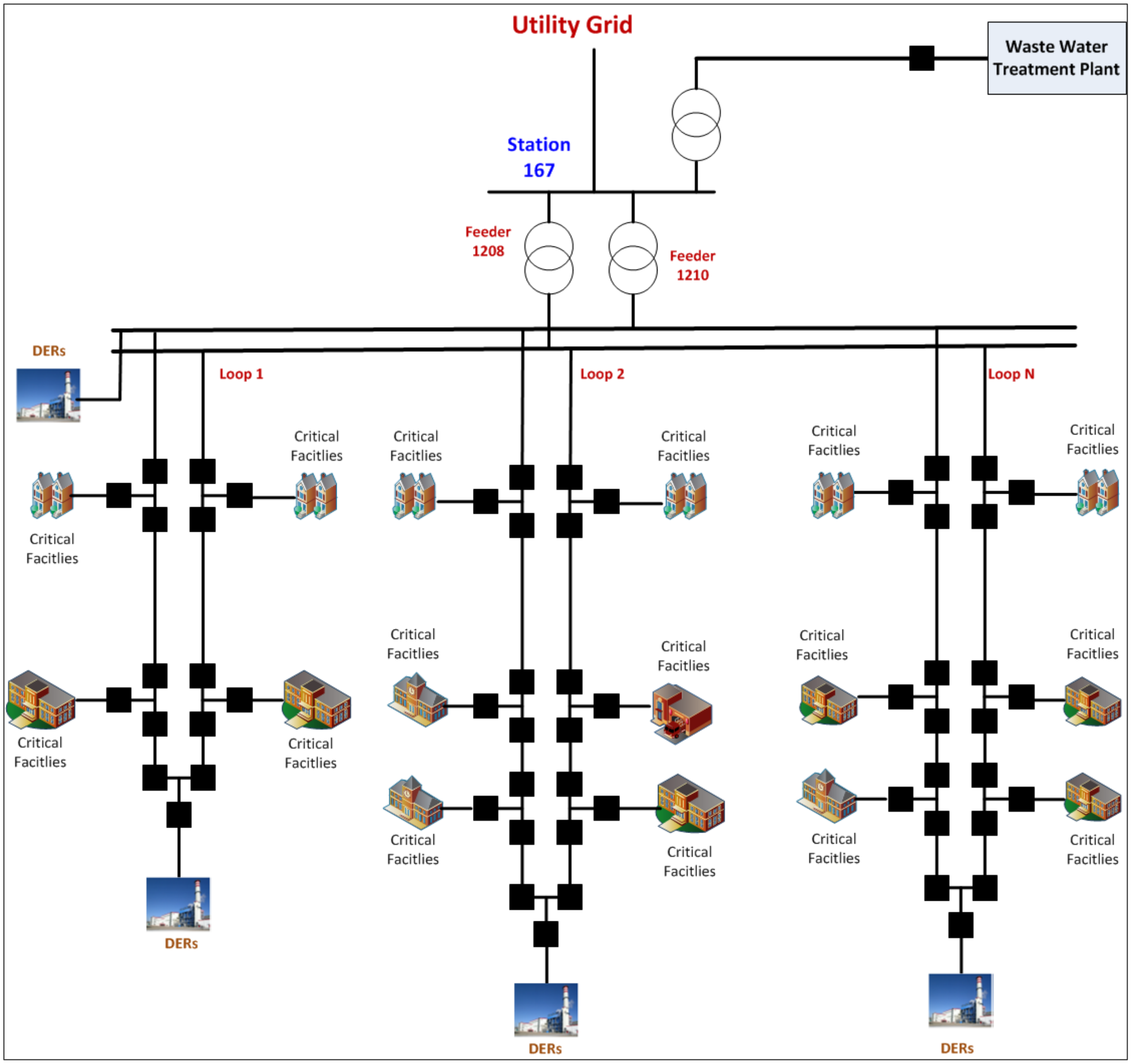



*Figure 24. Conceptual Design of Geneseo Community Microgrid*

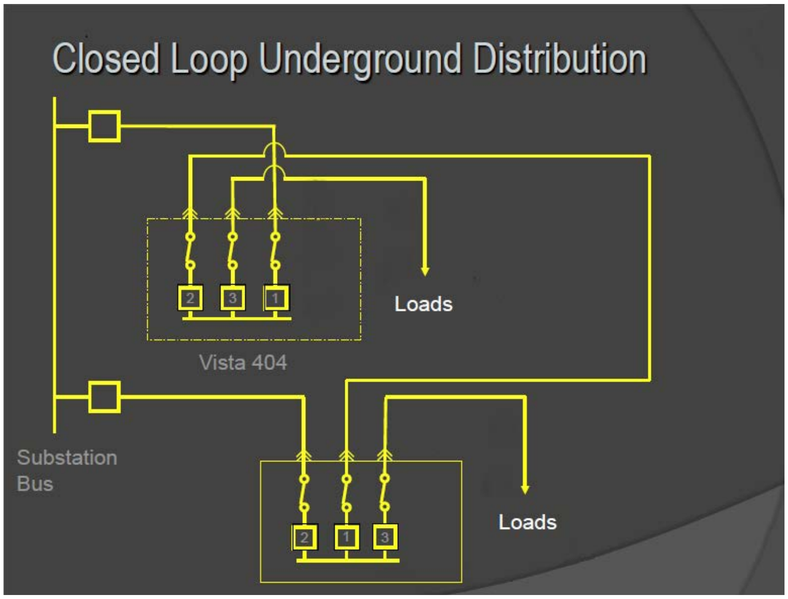



*Figure 25. Conceptual Design of Close Loop System Using Two Vista Switches*

The proposed HRDS design is reliable, versatile, upgradeable, and cost-efficient. The approach utilizes S&C VistaTM fault-clearing switchgear in a closed-loop system with SEL-351 directional over current protection relays. In the microgrid the following schemes will be implemented:

- A Permissive Over-reaching Transfer Trip (POTT) scheme will be used to protect the underground feeder cables. Using this scheme with the S&C Vista switch and SEL-351 relays results in the clearing of primary faults in less than 6 cycles. In addition, a Directional Comparison Blocking scheme is used as a back-up to the POTT scheme.
- Branch line faults will be cleared by the integral Vista Over-current Control, which can operate the fault interrupter to clear the fault in as little as 3 cycles.
- The system will use two substations in two closed-loop configurations to support load requirements as well as load equalization if a fault occurs on a feeder.
- To support new load growth, additional Vista units can be added anywhere along the loop system and will adhere to the system design without any changes in relay settings.
- Automated breakers and switches

Using HRDS the isolation of faults will be executed by automated breakers and switches that will sense fault conditions and open within 1/4 cycle, simultaneously isolating the fault and allowing power to flow along a secondary feeder route. This system of automated breakers and switches will employ:

- High speed, fault interrupting switchgear for the north and south main buses

- Automatic high speed transfer system – either at the individual building level, mid- distribution loop level, or substation level
- Multifunction directional over-current relays
- S&C Vista switches with vacuum fault interrupters

Finally the Geneseo distribution system serving critical loads is old and does not provide for redundancy. To compensate for this, the microgrid provides local generation and UPS/backup generation at key facilities to ensure that the microgrid can operate when grid power is lost and to provide ancillary services to the grid.

Substation 167 in Geneseo would be the Point of Common Coupling (PCC) where the microgrid could be isolated from the utility grid in order to operate in island mode in case of emergency, and resynchronize with the utility grid in order to operate in grid-connected mode.

A hierarchical protection configuration strategy is proposed for the microgrid protection that mainly contains four-level protection: load way, loop way, loop feeder way, and microgrid level. Each level is equipped with protection devices. Also, the four levels are coordinated. The protection devices and operational rules in each level are summarized in table 17. The load-shedding and other control schemes could also be implemented on the load-way protection level based on under/over-voltage and under/over-frequency functions of these relays. The hierarchical strategy aims at addressing the challenges in isolating various faults in time in loop-based microgrids. The performance of microgrid protection is summarized as follows:

- Detect and isolate faults both inside and outside the microgrid
- Detect and isolate faults inside the microgrid in both grid-connected and islanded mode
- Detect and immediately isolate load and DG faults,
- Prime protection and backup protection for protective device malfunction
- Compromise between selectivity and speed.

*Table 17. The Protection Devices and Operation Rules at Each Protection Level*[1]

| Protection Level | Protection Devices and Operation Rules in Grid-Connected and Island Modes |
|---|---|
| Load-way protection | Directional Overcurrent (DOC) digital relay with adaptive relay setting (responding to lower fault current in island mode):<br>—Operates only in load-way faults (DOC and auto reclosing). |
| Loop protection | DOC digital relay with adaptive relay setting:<br>—Operates in loop faults [primary and backup permissive overreach transfer trip (POTT)<br>Schemes<br>—Backup protection for load-way protection. |
| Loop-feeder protection | Non-direction Overcurrent (OC) relay:<br>—Operates to isolate the faulted loop only when the load-way and loop protections have failed within the loop. |
| Microgrid-level protection | OC relay and PCC switch:<br>*In grid-connected mode:*<br>—Unintentional islanding operation due to external fault or disturbance based on the signal from the MC<br>—OC relay (backup protection for the entire microgrid)<br>—Intentional islanding operation based on the islanding command from the MC.<br>*In island mode:*<br>—Resynchronization initiated by a command from the MC. |

[1] Adaptive Protection System for Microgrids: Protection practices of a functional microgrid system. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6774516

## Sub Task 2.5 Microgrid and Building Controls Characterization

Figure 26 shows the community microgrid elements, functions, and control tasks associated with each criterion. In particular, tertiary control is the upper level of the control system, which ensures the optimal operation of the microgrid by determining the set points of generation and load. In order to achieve the optimal economics, microgrids apply coordination with the utility grid and economic demand response in island mode. The short-term reliability at load points would consider microgrid islanding and resynchronization and apply emergency demand response and self-healing in the case of outages. Functionally, three control levels are applied to the microgrid:

1. Primary control, which is based on droop control for sharing the microgrid load among DER units.
2. Secondary control which performs corrective action to mitigate steady-state errors introduced by droop control and procures the optimal dispatch of DER units in the microgrid.
3. Tertiary control which manages the power flow between the microgrid and the utility grid for optimizing the grid-coordinated operation scheme.

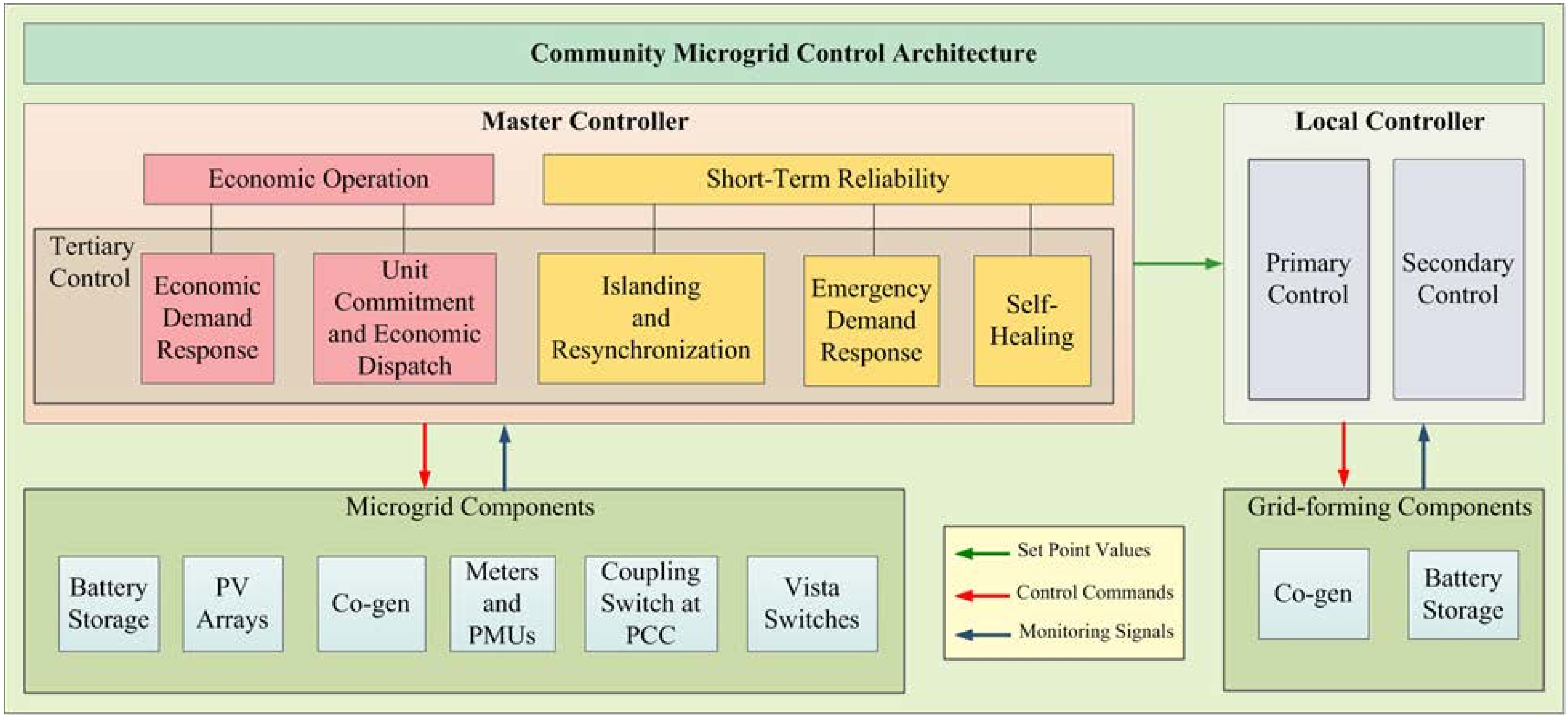
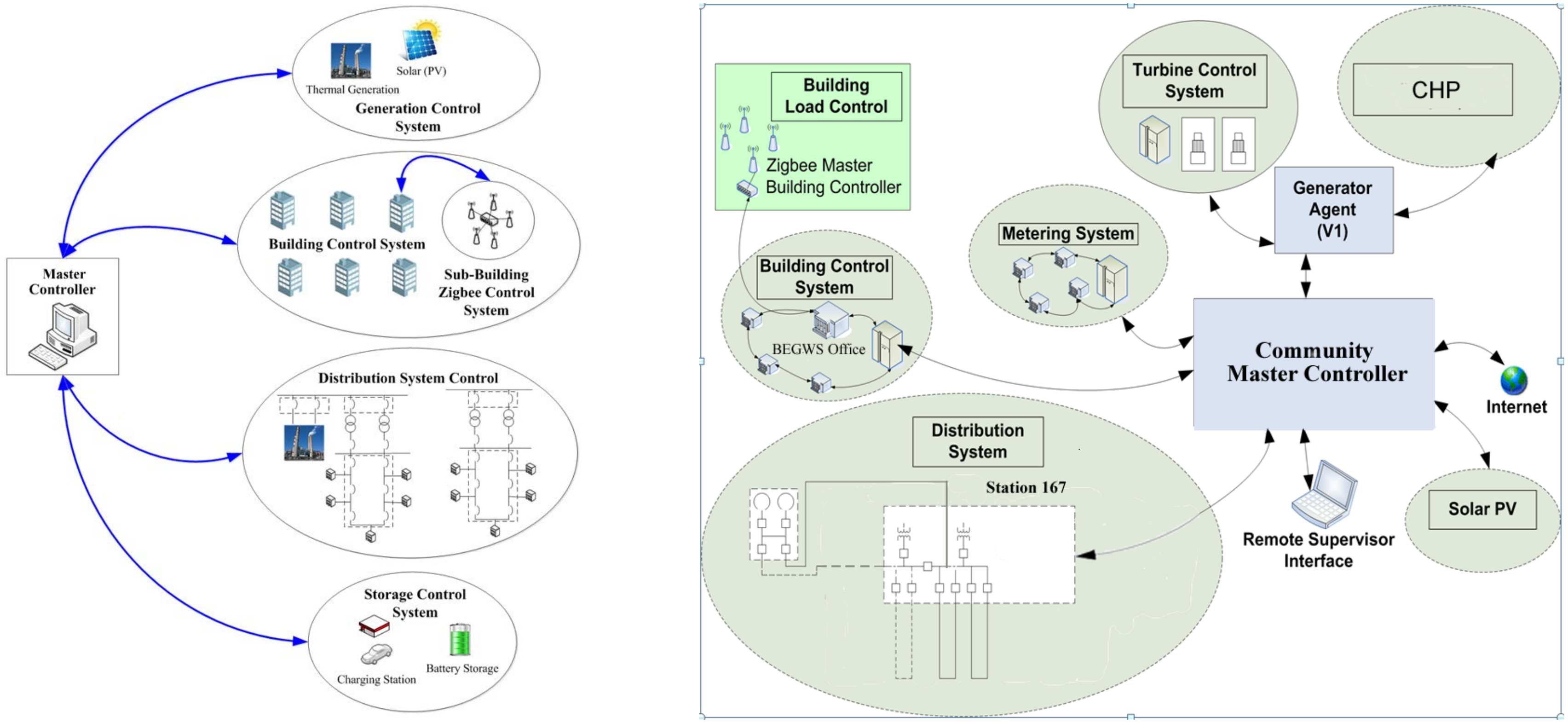



*Figure 26. Objectives and Functions for the Control and Operation of the Geneseo Community Microgrid*




(a) (b)

*Figure 27. Architecture of Master Controller for Geneseo Community Microgrid*

The hierarchical protection strategy aims to address the practical challenges of isolating faults swiftly in loop-based microgrids. The strategy decomposes the microgrid into four levels: load-way, loop-way, feeder, and microgrid. Each level considers DG characteristics and utilizes conventional protection schemes along with protection devices. The characteristics of plug-and-play and low voltage ride through (LVRT) are taken into consideration. The primary protection of each level is supplied by that level. The backup protection in the load-way level is located in the loop-way level, and the backup protection for the loop-way level is located in the feeder level. The backup protection of microgrid level can be provided by the utility.

A major element of the microgrid is its master controller. The master controller applies hierarchical control via supervisory control and data acquisition (SCADA) software to ensure reliable and economic operation of the microgrid. It also coordinates the operation of on-site generation, storage, and individual building controllers, shown in figure 28. Intelligent switching and advanced coordination technologies of the master controller through communication systems facilitate rapid fault assessments and isolation. The major functions of the master controller would include the following:

- Communications and errors management – detection and or safe shutdown
- P/Q control for generators
- Energy Storage System Management
- Point of Common Coupling (PCC) management - Power factor correction
- PCC management - Peak shaving/smoothing
- PCC management - Islanding and reconnection to grid
- Following active power command and voltage management
- Loss of communications safety
- Power limits, both kW and kVAR
- Loss of generation/storage asset management during grid-tied conditions
- Loss of generation/storage asset management during islanded conditions
- Unit commitment/availability
- Load shedding/Shifting
- Event logging

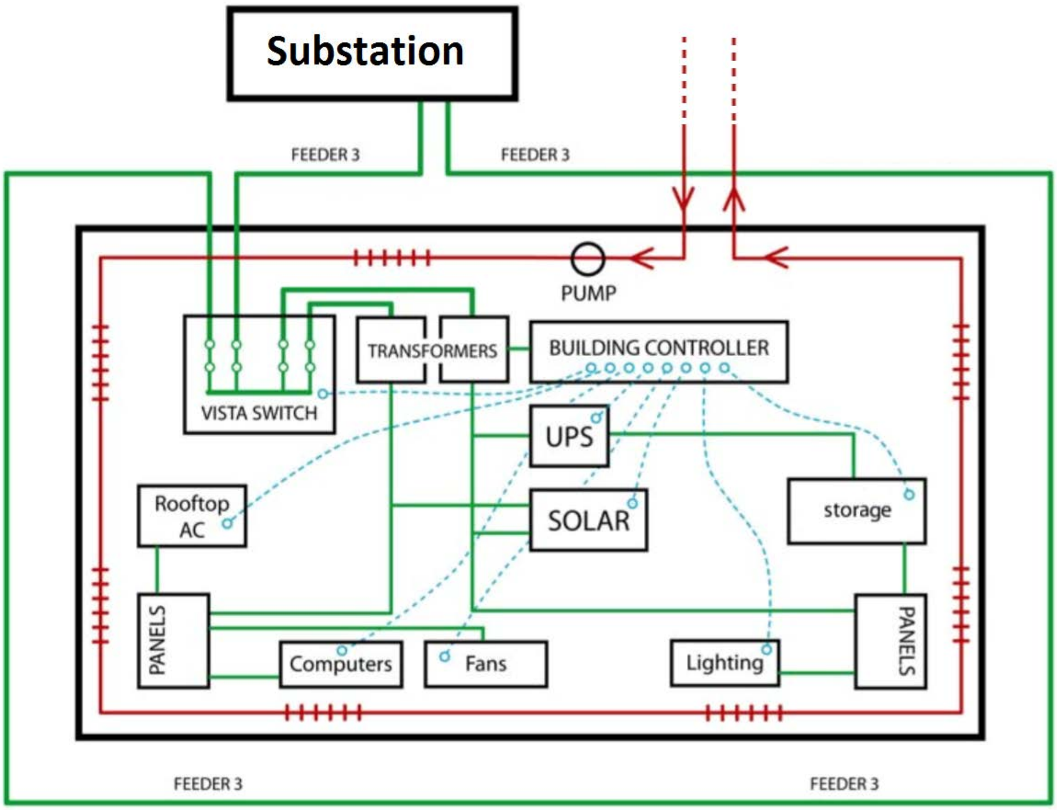



*Figure 28. Conceptual Architecture of Building Controller System*[1]

The hierarchical secondary control approach would receive information from loads and power supply entities as well as the information on the status of the distribution network and procure the optimal solution via an hourly unit commitment and real-time economic dispatch for serving the load in the normal operation mode and in contingency mode. Figure 25 shows the hierarchical framework of the master controller proposed for the microgrid. In figure 26, the monitoring signals provided to the master controller indicate the status of DER and distribution components, while the master controller signals provide set points for DER units and building controllers. Building controllers will communicate with sub-building controllers and monitoring systems to achieve device-level rapid load management.

The master controller would be deployed in Geneseo's central heating plant. With the master controller, the microgrid would be able to provide ancillary services to the grid including voltage support and frequency regulation, and distribution system restoration. The master controller would collect real-time and send out set-point information through SCADA. Most of the time, the master controller would operate in autonomous mode based on predefined rules while maintaining the reliability and economics

[1] IIT Perfect Power Prototype, Final Report October 15, 2007 available at http://www.galvinpower.org/sites/default/files/documents/IIT_Perfect_Power_Prototype.pdf

of the microgrid. In case of emergency, the controller would utilize the master controller to isolate the community from the utility grid and operate in island mode. Within the microgrid, the non-critical load could be curtailed or disconnected through smart meters or Vista switchgears, and the local distribution network could be reconfigured so the local DERs could supply power to the critical loads. Real-time data logging would be handled by OSIsoft's PI time series database.

Willdan proposes a loop-based network, which has the capability of supplying power to critical facilities from two feeders in order to improve the energy resilience of critical facilities. In cases of extreme weather events, if one feeder fails, the loads can transferred to another feeder and will still receive power feed. The microgrid would rely heavily on a robust fiber optic backbone and a 900 MHz mesh network for monitoring and control. This system remains extremely resilient in the face of inclement weather due to the fiber optic being underground and the mesh networked being formed by aboveground, but heavily redundant, mesh radios. Similar to the building controllers above, if one smart meter is unable to communicate, the rest of the meters would remain on the network and leverage each other to maintain a strong network connection.

The proposed microgrid would be operated locally in grid-connected and island modes and can provide black start operation, frequency and voltage support, active and reactive power control. However, ancillary services are not expected to play a large role in the microgrid. The microgrid would be able to sell energy back to the grid, which could be profitable through net metering. The master controller would optimize when it is profitable to do so. However, it is expected that almost all of the power produced by the microgrid DER would be consumed within the microgrid. The master controller would provide the following functions. During emergency operating conditions, the microgrid master controller would optimize generation and load to provide uninterrupted power to critical loads, through the use of DERs and load shedding schemes that ensure safe and reliable operation of the buildings that matter most in emergency situations. Long term outages will be mitigated by a natural gas-fed combined heat and power (CHP) plant, which will maintain a black-start capability in the event the outage occurs when the CHP facility is not active. This plant will rely on robust natural gas pipelines and produce enough power to serve all of the critical facilities, public street and security lighting, and some residential load. This added resiliency will keep emergency responders and residents safe and provide the microgrid with heat and power when it needs it most.

The islanding would follow the procedure shown in figure 29, resynchronization follows the procedure shown in figure 30, and self-healing follows the procedure in figure 31.

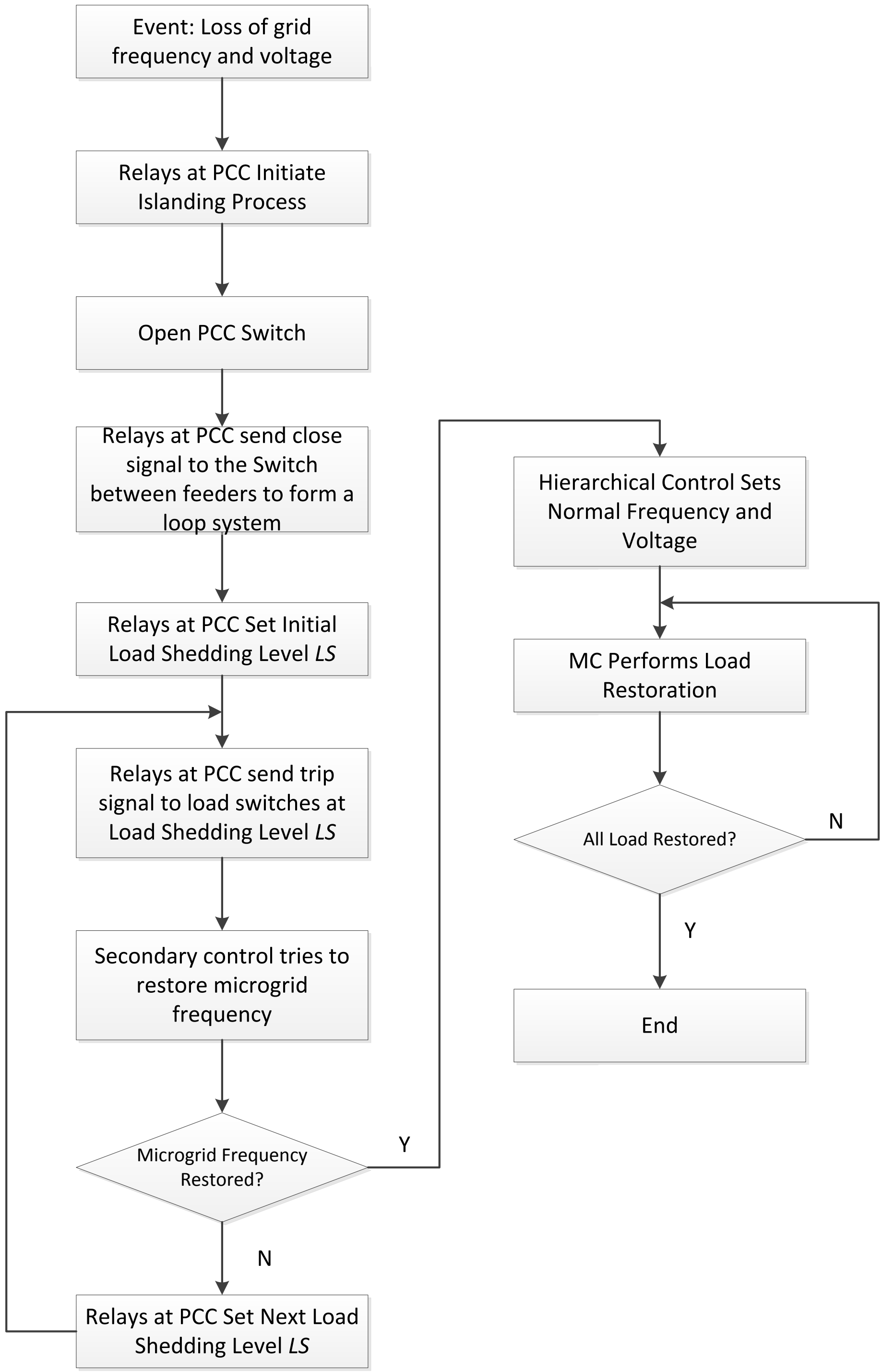



*Figure 29. Islanding Procedure*

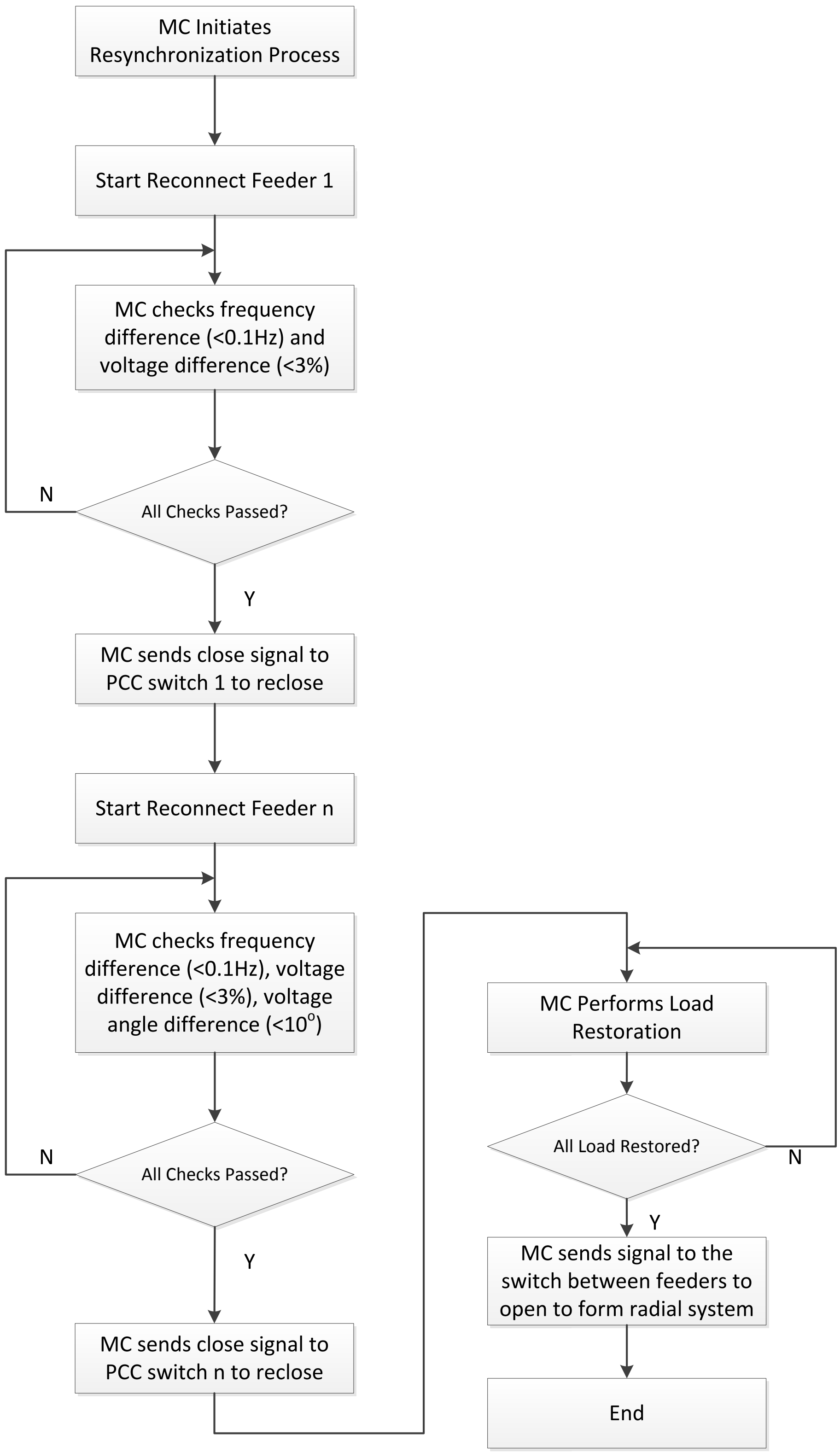



*Figure 30. Resynchronization Procedure*

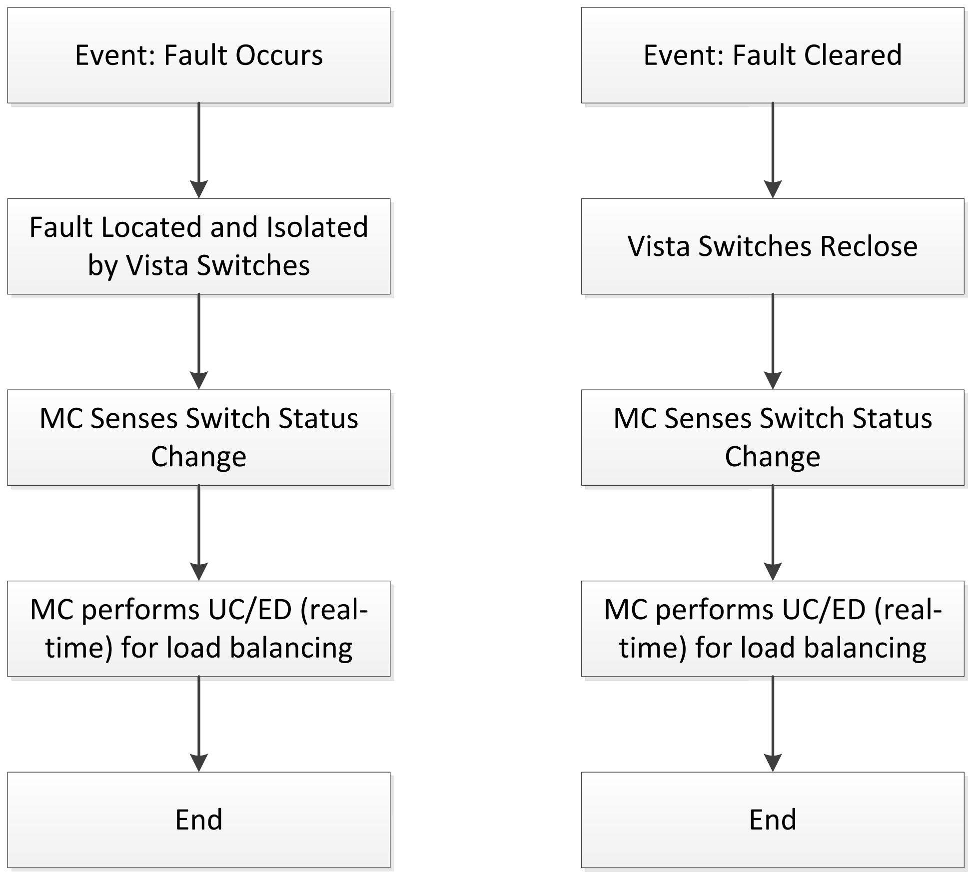



*Figure 31. Self-healing Procedure*[1]

The proximity of power generation to microgrid loads could result in improved power quality, lower power losses, better voltage stability, and higher reliability (fewer customer outages) by engaging fewer components, and eliminating additional transmission services. With the added DERs, ATS and other smart devices, the proposed community microgrid could significantly improve the reliability indices which include the System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI), Customer Average Interruption Frequency Index (CAIFI), Expected Energy Not Supplied (EENS), and Loss of Load Expectation (LOLE).

The main services and benefits which the proposed microgrid could provide are summarized as follows.

1. **Increase Reliability and Resiliency**. The microgrid will be able to automatically island the electric system, energize critical facilities, and allow a portion of the system to be energized in the event of a bulk system outage. A CHP-driven microgrid will also introduce additional redundancy into the existing Geneseo thermal system, which will improve the reliability and resiliency of the overall

[1] UC: unit commitment, ED: economic dispatch.

system. The reliability would be improved in normal operating conditions through infrastructure reconfiguration, such as a High Reliability Distribution System (HRDS) which senses and clears faults with virtually no impact on building loads, to a self-healing and more fault tolerant grid, by reducing the number of single points of failure by adding redundancy to the electrical and communications networks, and by adding alternate sources of generation to serve critical and non-critical loads.

During emergency operating conditions, the microgrid would be able to provide uninterrupted power to critical loads, through the use of DERs and load shedding schemes that ensure safe and reliable operation of the buildings that matter most in emergency situations. Long term outages will be mitigated by a natural gas-fed combined heat and power (CHP) plant, which will maintain a black-start capability in the event the outage occurs when the CHP facility is not active. These plant or plants will rely on robust natural gas pipelines and produce enough power to serve all of the critical facilities, public street and security lighting, and some residential load. This added resiliency will keep emergency responders and residents safe and provide the microgrid with heat and power when it needs it most.

2. **Reduce energy cost uncertainties and exposure to market fluctuations.** The microgrid would reap economic benefits in the form of added revenue streams from demand response, alternate generation sources, and energy efficiency measures to reduce overall energy costs, as well as participating in ancillary service markets such as fast regulation and operating reserve markets. Based on the price of electricity and availability of Distributed Energy Resources (DERs), the master controller will optimally dispatch the units to provide the cheapest, cleanest, and most reliable energy possible to the critical and non-critical microgrid facilities.
3. **Integrate distributed energy resources (DER) into system operations**. The existing backup generators would be integrated into the microgrid and able to provide services beyond simple backup.
4. **Capitalize on new value system.** The microgrid would enable Geneseo to have the capability of participating in the frequency regulation market by locating energy storage resources at critical points in the microgrid, and the potential for load curtailment, demand management, and demand response with all available resources. In the case of distributed energy storage resources, Geneseo will evaluate various ownership models to optimize the economic benefit to the system, including purchase, leasing and third-party ownership.

## Sub Task 2.6 Information Technology (IT)/Telecommunications Infrastructure Characterization


*Figure 32. Network Equipment Simplified Layout Diagram*

Any modern utility or system operator relies heavily on their communication infrastructure to monitor and control their grid assets. For a microgrid master controller and microgrid operators, this architecture enables real time control, rapid digestion of critical grid information, and historical data for analysis and reporting. As part of a feasible microgrid, assessment and upgrade of the equipment and protocols used in the microgrid area will be performed.

RG&E owns and operates two substations in the Geneseo service area and many miles of distribution lines, serving around 8,000 residents. A large majority of those customers are individually metered; however, these meters are read manually every month by a meter reader. RG&E has no known existing SCADA system and does not have smart switches or digital substations or any of the communications infrastructure associated with these resources.

A limited communications architecture can lead to increased frequency and duration of outages if problems must occur and be reported rather than having symptoms trigger notifications to grid operators of the location and scope of the issue. Limited information and delay in this information leads to man hours wasted and longer durations of customers without power, putting strain on residential customers and potentially costing commercial customers significant amounts of money. Systems could have telltale signs of issues for weeks, but operators may not discover these until they have caused damage and outages to the electric grid or substations, costing the utility money and potentially endangering employees and customers.

The proposed microgrid makes Geneseo's grid more resilient to:

- Energy resources disrupting events (discussed in Subtask 2.3)[1]
- Distribution Network disrupting events[2](discussed in this 2.5)[3]
- Communication Network disruptive events[1] (discussed in this subtask)

## Communication System disrupting events

Geneseo would benefit from an Advanced Metering Infrastructure (AMI) expansion, which would involve adding wireless communication infrastructure throughout the Village of Geneseo to allow for automatic and digital meter reads. The key advantage of this expansion would be the network addition, which often utilizes the 900 MHz ISM band and relies on communication between integrated Network Interface Cards (NICs) that form a mesh network, allowing signals to hop between any installed meters to reach their ultimate destination and increases the propagation range of the signal in proportion to the number and dispersion of integrated NIC Smart Meters. The integrated NICs are connected to a local Access Point (AP) that transmits the metering and control signals for the streetlights over a cellular wireless network back to the utility data center, where it can be fed into the SCADA platform for use in billing or monitoring the overall grid.

The microgrid would be connected efficiently and productively, through the use of modern communication architectures and equipment, enabling a master controller to optimize the microgrid control and giving operators the tools they need to perform their daily duties. Exact upgrades or additions to existing communications infrastructure will need to be determined in a Phase 2 design. This network would leverage the AMI network and seek to strengthen it through the use of connected LED

[1] Discussed in Subtask 2.3.
[2] Due to unavailability of network data further study is not available at this phase. Some suggestion will be proposed in Subtask 2.4.
[3] Discussed in Subtask 2.4.

streetlights, which require half the power of the existing High Pressure Sodium (HPS) fixtures and shorten the overall payback of a street lighting upgrade through the implementation of smart photocells or integrated NICs that individually meter and control each streetlight, seen in figure 33.

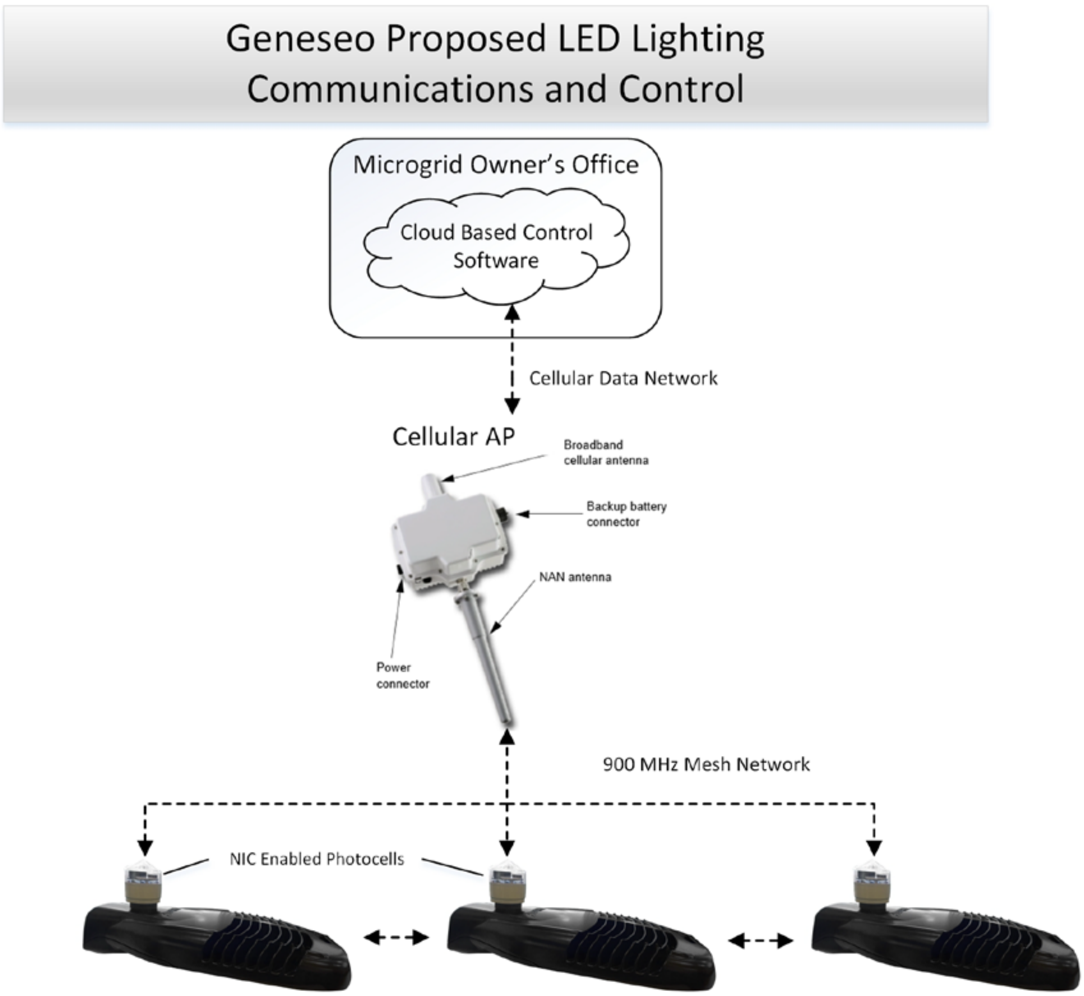



*Figure 33. Geneseo Proposed LED Lighting Communications and Control Diagram*

In addition to meters and streetlights, circuit breakers, relays, reclosers and other switchgear are vital to the control of the microgrid. While some distributed switchgear can utilize a similar wireless infrastructure, with data being fed through substations instead of through a cloud network, the control equipment is more vital to the safe operation of the microgrid and would ideally use a fiber optic backbone between the master controller location and the substations. The substation relays may have to be upgraded to communicate using the DNP3 protocol over TCP/IP, the de facto standard for modern utility communications, which will be used to monitor and control the proposed DER as well.

Once in the master controller location, the data will be fed into an upgraded or added SCADA system to allow operators to access, visualize, and control, all of the microgrid assets.

Utilizing a fully connected microgrid, with every vital piece of equipment monitored and controlled remotely, the master controller will be able to optimize load and generation automatically and in real time, the microgrid operators will be able to view the status, create reports, and plan future developments, and maintenance will be able to quickly assess and address any issues.

Further study of the communications and control equipment depends upon the provision of more detailed data about the existing communication and control equipment. This study would need to be performed to determine the exact quantity and specification of the upgrade. RF testing will need to be performed to determine the layout of the wireless network proposed. Training would have to be done on the SCADA system and the newly implemented relays, and personnel may need to be hired to maintain the network and communications equipment. A review of costs of the current system, including streetlight usage and maintenance data, current metering system costs, inaccuracies, and outage information will have to be obtained to determine exact cost savings of upgrading to the new system.

As SUNY Geneseo is the proposed owner/operator for the microgrid, the master controller would be located in a SUNY Geneseo data center that could house the SCADA system as well. While the master controller would automatically communicate with the SCADA system as well as with the field devices such as the building controllers (BCs) and automatic generation controllers (AGCs), microgrid operators would regulate access and control to the microgrid. This means that any loss in communications that disrupts the microgrid would need to be between building controllers and the master controller/ data center and that this loss would only prevent communication with one building, while the rest of the microgrid would maintain normal operation.

The proposed microgrid would rely heavily on the robust fiber optic backbone and the 900 MHz mesh network for monitoring and control. This system remains extremely resilient in the face of inclement weather due to the fiber optic being underground and the mesh networked being formed by above ground, but heavily redundant, mesh radios. Similar to the building controllers above, if one smart meter or streetlight is unable to communicate, the rest of the lights and meters would remain on the network and leverage each other to maintain a strong network connection.

## Recommendations

- To replace all the existing lighting with high efficient LED (Light Emitting Diode). By using the more efficient and safe LEDs for public street lighting and residential lighting and smart home appliances along with the proposed community microgrid, it can not only enable the capability of load shedding and load shifting, but also both the community and residential customers can reduce maintenance costs and electricity bills. Based on the microgrid's capability in exporting the power (back feeding) to the utility, the level of demand response capability varies. Figure 34 shows the amount of capacity available for demand response if the microgrid does not have capability of exporting the power to the grid through the PCC by either reducing the load (load curtailment or shifting) or dispatching the CHP or both. The amount of available capacity is equal to submission of Area1, Area2, and Area3. Area 1 is amount of power sold by the utility, and the microgrid will replace that with power generated by CHP.
- Participate in ISO/DSO Demand Response; see figures 34 and 35
- Area 2 in figure 35 shows the amount of capacity available for demand response (DR) at the PCC in the microgrid if the microgrid is not able to export power back to utility grid. Therefore, DR just reduces the load from the utility point of view either through load reduction or CHP power generation. So the maximum load seen would be equal to the base load level. The amount of available capacity is equal to the addition of Area 1 and Area 2.

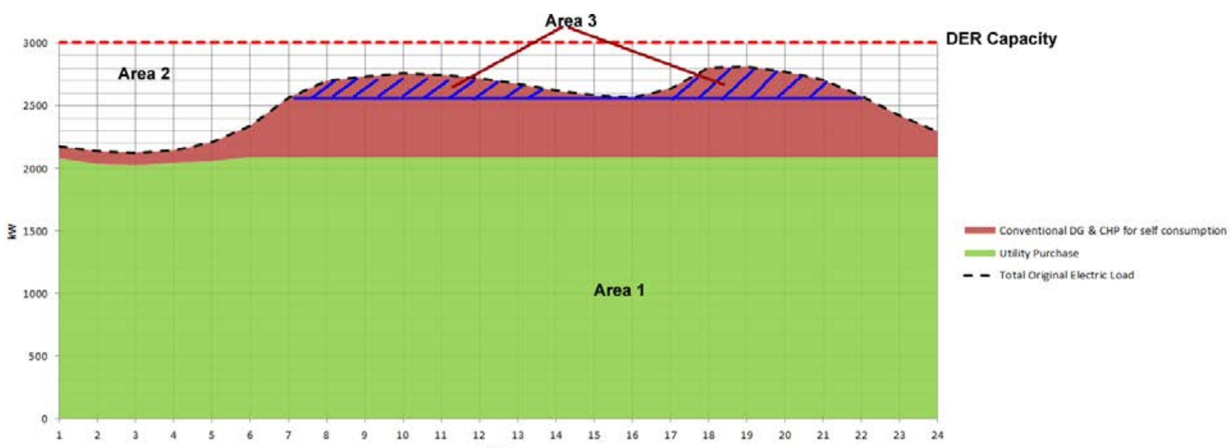



*Figure 34. Capacity Available for Demand Response Participation by Microgrid with Exporting Capability*

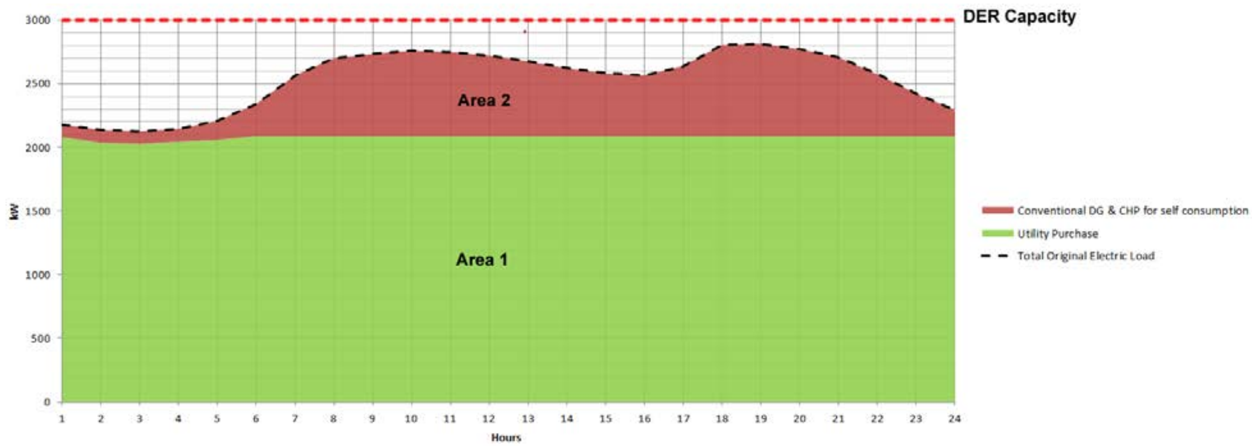



*Figure 35. Capacity Available for Demand Response Participation by Microgrid without Exporting Capability*

## DER-CAM

DER-CAM is a tool that was developed by Lawrence Berkeley National Laboratory (LBNL) to help optimize the selection and operation of distributed energy resources on a utility distribution system. The DER-CAM tool has application in the design of microgrids, and Willdan has used the tool extensively as a key component of the quantitative microgrid analysis.

The main objective of DER-CAM is to minimize either the annual costs or the CO2 emissions of providing energy services to the modeled site, including utility electricity and natural gas purchases, plus amortized capital and maintenance costs for any distributed generation (DG) investments. The key inputs into the model are the customer's end-use energy loads, energy tariff structures and fuel prices, and a list of user-preferred equipment investment options, with extensive unit cost and operation parameters, as shown in figure 36. Additional information is available on BNL's DER-CAM website[1].

[1] https://www.bnl.gov/SET/DER-CAM.php

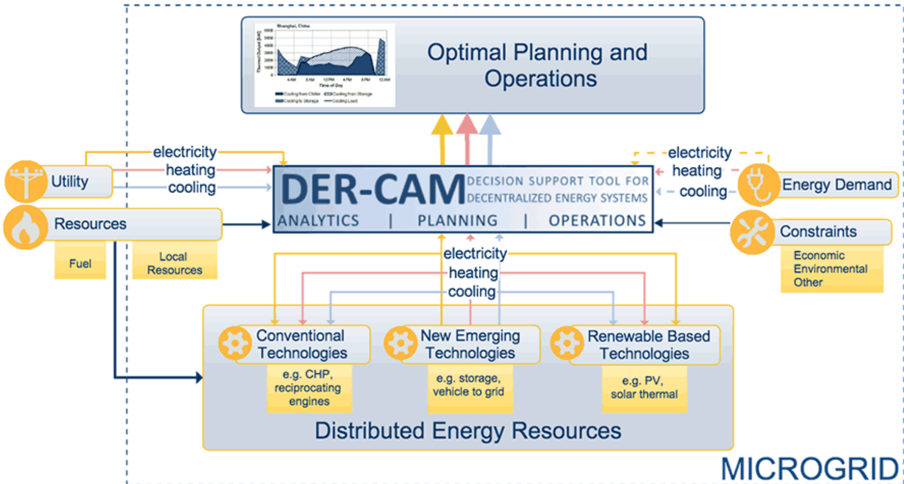



*Figure 36. Schematic of Information Flow in DER-CAM*

## DER-CAM Input Data

### *Load profile*

Accurate hourly load profiles are critical to DER-CAM simulations. The loads include electricity, space-heating, water-heating, cooling, refrigeration, natural gas only (e.g. for cooking). However, electricity and natural gas for space heating are the most important in terms of impact on the Geneseo community. A year of hourly electric load and natural gas usage data was available for the SUNY Geneseo Campus, but not for the WWTP, so the data for the campus was scaled to reflect the whole system.

### *Utility tariff*

The campus is under a Time of Use (TOU) pricing tariff. Four months of electric billing data was available and was extrapolated to cover a full year for an average yearly price of $0.0896/kWh[1].

The average gas price was $4.25/MMBtu.

### *Technologies investment*

Both Electric Storage and PV were considered for the microgrid; their investment parameters are seen in table 1. CHP was considered in step sizes of 500 kW, 250 kW, and 100 kW, to obtain precise simulation results. Costs were obtained from EIA[2] and from NREL[3-4].

[1] Hourly price for the same year in which community hourly load were provided is not available
[2] http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf
[3] http://www.nrel.gov/docs/fy11osti/48595.pdf
[4] http://www.nrel.gov/docs/fy13osti/56776.pdf

*Table 18. Continuous Investment Parameters*

| Technology | Fixed Cost ($) | Variable Cost ($/kW) | Lifetime (Years) | Fixed Maintenance ($/kW/Month) |
|---|---|---|---|---|
| Electric Storage | 0 | 400 | 15 | 0.069167 |
| PV | 0 | 3250 | 30 | 0.25 |

*Table 19. Discrete Investment Parameters*

| Technology | Max Power (kW) | Lifetime (Years) | Capital Cost ($/kW) | Om variable ($/kWh) | Fuel | Efficiency | Alpha (Heat to Power Ratio) |
|---|---|---|---|---|---|---|---|
| CHP Option 1 | 500 | 20 | 1200 | 0.011 | NG | 0.32 | 1.4 |
| CHP Option 2 | 250 | 20 | 1200 | 0.011 | NG | 0.32 | 1.4 |
| CHP Option 3 | 100 | 20 | 1200 | 0.011 | NG | 0.32 | 1.4 |

## Weather information

Hourly solar irradiance (Global Horizontal Irradiation (GHI)), hourly temperature, hourly wind speed were obtained from NREL's Solar Irradiance database[1]

## Global setting

For this analysis, a 10 year maximum payback period was used. Minimizing energy cost was selected to maximize the economic benefit.

## Simulations

For all of the NY Prize feasibility studies Willdan considered all of the scenarios a typical community microgrid could encounter. All of the analyses necessary to justify the integration of a community microgrid into the City of Geneseo were simulated as described by the following steps.

Step 1: A base case without any investment was simulated to obtain the reference cost. In this case the annual cost, as well as optimal heat and electricity dispatch, were calculated using DER-CAM, shown in section 2.2. The calculated annual operational cost was used for the following steps as a reference cost.

Step2: An investment case was simulated to see the economic and CO2 emissions benefits while allowing DER-CAM to choose the best DERs based on their operational cost and amortized

[1] https://maps.nrel.gov/nsrdb-viewer

capital cost. Results showed that the system should purchase all electricity and fuel for heat from PMLD or the local fuel provider. It should be noted that for the base case with investments, there were no DERs recommended for purely financial benefits. As a result of this, a number of the simulations described below returned the same zero value for suggested DER and were not included in the report, except as evidence for the recommendation that DER is not feasible for purely financial reasons.

Then a series of simulations were run to simulate a microgrid in both Grid Connected and Island mode operations. The goal of this step was to determine the optimal value of DER in both modes of operation.

## Grid Connected mode

In this mode, the optimal level of DERs was obtained to maximize reliability and economics.
Reliability simulations include:

1. Demand response at the point of common coupling (PCC) with different level (5%, 10%,15%,20%,25% of total load)
2. Direct Load Controlling (DLC) with different of load reduction (5%,10%,15%,20%,25% of total load)
3. Sensitivity analysis to electricity price increase, from $0.08/kWh to $0.13/kWh,
4. Sensitivity analysis to natural gas price increase, from $0.69/Therm to $3.5/Therm,
5. Sensitivity analysis to load increase, from 5% to 25%,

Economics simulations include:

All simulations were designed to account for possible changes over the 15-25 year life of the microgrid. The goal is to design a microgrid, which will be as tolerant as possible to electricity, natural gas and load fluctuations. In addition, the analysis informs the potential microgrid owner of risks in relying solely on the utility or any one type of DER.

## Island mode

In this mode the goal was to maximize load recovery at the time of an outage, planned or unplanned to account for likely and drastic outage scenarios and to see the effect on the PCM.

Load Recovery simulations include:

- Outage for a period of hours (summer and winter off and on Peak)
- Outage for a period of days (summer and winter off and on Peak)
- Outage for a period of a week (summer and winter off and on Peak)

## Results

The results of these simulations along with analysis of parameters outside of DER-CAM's array of options, such as Demand Response capacity credits, as well as qualitative additions to the microgrid, to be further analyzed during the cost benefit analysis stage of the study, were analyzed and compiled in the following report based on technical and preliminary financial feasibility.

# Task 3: Assessment of Commercial and Financial Feasibility

## Subtask 3.1 Commercial Viability – Customers

The Geneseo microgrid, as initially conceived, would serve the SUNY Geneseo campus, the village office building at 119 Main Street, and the village-owned wastewater treatment plant. The village office building houses the village offices, the police, and the court. It serves as a command center during emergencies and currently has no backup generation. The ability to maintain power to the campus during an outage would have direct benefits to the 5600 undergraduate students at the university as well as to several hundred more people when graduate students, faculty, and staff are taken into account. In addition, maintaining power to the village offices would have indirect benefits to both the university and to the surrounding Village of Geneseo with its 8,000 residents. These indirect benefits include increased public safety from being able to maintain government operations, including police operations, and to effectively direct public response during an emergency. In addition to the campus and the village offices, the village wastewater treatment plant, which serves both the campus and the surrounding village, was evaluated for participation in the microgrid. The plant currently shares a portable generator with the water plant. In the case of an outage, this generator takes four hours to hook up, and in the case of a widespread outage, the water plant takes priority, so the wastewater treatment plant is left without power.

As the feasibility study progressed, it was found that several barriers exist to including the village office building and the wastewater treatment plant in a microgrid. While the SUNY campus is served by two dedicated feeders that it owns, the wastewater treatment plant is on a third feeder, and the village offices are on a fourth feeder. Both of these other feeders are shared with a significant amount of residential and commercial load. Additionally, the wastewater treatment plant is 0.6 miles from campus and 1.3 miles from the substation, so running a dedicated express line, which would have to cross a road, would be expensive (possibly over $1M), particularly for an average load of only 26 kW. An express line run to the village offices would also need to cross a road and would incur a significant amount of expense for a small load (13.8 kW) at a facility that could more cost-effectively obtain the desired resiliency by installing a backup generator. In the case of the wastewater treatment plant, it was decided that it would be more economical to install a natural gas generator at the wastewater treatment plant. The natural gas generator would provide the needed resiliency at the plant and would be powered by biogas generated by the digester. This gas is currently flared. In addition, the gas production would be increased by adding to the digester food waste collected from the campus dining halls and from Wegmans supermarket as well as manure from area farms. This will produce environmental benefits by eliminating food from the waste stream, offsetting electrical consumption at the plant, and eliminating the flaring that is occurring at the plant. In the event of a prolonged outage affecting both the wastewater treatment plant and the water plant, there would be a cost savings from eliminating the need to rent a portable generator. There may be a financial benefit to the university by reducing tipping fees for the food waste, and there would be a financial benefit to the wastewater treatment plant from eliminating or reducing the need to purchase electricity from RG&E, the local utility. Additionally, there would be an indirect financial benefit to the university by improving its sustainability and therefore its attractiveness to potential students. Finally, there would be an indirect benefit to the community by reducing the risk of discharging pollution to the Genesee River in the event of a widespread and prolonged outage.

Due to the cost barriers to establishing a community microgrid, the currently proposed microgrid would be a campus microgrid, owned and operated by SUNY Geneseo, with no outside power purchasers. It would include CHP generation at the central heating plant as well as solar generation located on land adjacent to campus. The control system would be located in the central heating plant. The electricity and heat produced by the microgrid generation would offset electricity and gas purchased from RG&E. The microgrid could possibly provide services to NYISO through ancillary services, but RG&E does not currently have an ancillary services program, and for other reasons describe in Section 3.5, ancillary services are not likely to play a large part in the microgrid.

## Subtask 3.2 Commercial Viability – Value Proposition

In addition to providing financial benefits through cost savings, the proposed microgrid would provide added resiliency to the SUNY Geneseo campus. The campus currently has several buildings that serve important functions in an emergency but yet do not currently have backup power. These are the Lauderdale Health Center and Schrader Hall. Schrader Hall houses the campus police and also contains a gymnasium which is a designated community shelter in case of emergency. The addition of approximately 2 MW of Combined Heat and Power (CHP) generation, in combination with the 2.8 MW of existing backup generation, would allow the entire campus load to be served in the case of a grid outage (average demand is 2.6 MW and peak demand is 4.8 MW). The most common causes for prolonged grid outages in Geneseo are snow and ice storms. The two distribution feeders that serve the SUNY Geneseo campus are both underground and therefore very resilient to these types of storms. If the larger grid were to lose power in a storm, SUNY's feeders would be isolated in a microgrid and could be served indefinitely by the CHP plant, which would be fed by RG&E's gas lines. Some load curtailment may be necessary if the outage was to outlast the diesel supplies for the backup generators and if diesel delivery was not possible, but this scenario is unlikely. The proposed 2 MW solar array would also provide some added resiliency, although it could not be depended on to provide power throughout an entire outage.

Although the proposed microgrid would be a campus microgrid, it would still have value for the larger community. The ability to keep Shrader Hall, a designated community shelter, powered during an outage would provide valuable safety and security to the Village of Geneseo. In addition, the ability to keep SUNY Geneseo fully operational would be important to the stability of the larger community as the student population at Geneseo comprises over 40% of the community population, and SUNY Geneseo is the largest employer in the area.

Benefits to the utility are likely to be minimal as there are no current capacity constraints, nor are they anticipated in the near future. There may be some costs to the utility in order to integrate the microgrid into their distribution system.

Table 20 Summarizes the value proposition for the various stakeholders, and table 21 presents a SWOT analysis.

*Table 20. Stakeholder Value Proposition*

| Stakeholder | Value Proposition |
|---|---|
| SUNY Geneseo | The SUNY Geneseo microgrid will ensure that university operations can continue during a grid outage and that students, faculty, and staff will remain safe. The university will also realize cost savings from generating its own power using natural gas and from being able to use the waste heat. Depending on the negotiated PPA, they may also realize savings from the solar installation. The solar installation will help the university become more sustainable by reducing its greenhouse gas emissions. Additionally, the CHP installation is estimated to produce between a 24% and 36% reduction in greenhouse gas emissions, depending on the estimation method used. The wastewater treatment plant project would help the university eliminate food scraps from the waste stream and promote reduced fuel consumption and emissions at the WWTP. The solar generation and high-efficiency CHP will help them to meet their obligations under the New York Governor's Executive Order 88. Increased sustainability in general helps the university further part of its mission and makes it more attractive to potential students. |
| Village of Geneseo | The village will benefit from having the Shrader building powered in an emergency, as it is a designated emergency shelter. The village will also benefit from the stability provided by keeping the university fully powered in an outage since the university is the largest employer in the village and since the student population comprises over 40% of the overall population. Assuming that generation is installed at the WWTP, the village will benefit from the added resiliency and reduced risk of pollution events. |
| Wastewater Treatment Plant | Assuming generation is installed at the wastewater treatment plant, the plant will have added resiliency and reduced risk of pollution events. There may also be a cost savings from offsetting purchased electricity or gas. Emissions would be reduced by eliminating flaring. |
| NY State | The microgrid may make it easier and more profitable for SUNY Geneseo to participate in demand response markets, which would benefit the NYISO grid. |

| Parameter | Strengths | Weaknesses | Threats | Opportunities |
|---|---|---|---|---|
| **Technology** | State of the Art | Unproven-- Lack of performance history, in particular in emergency conditions | Disruptive next generation versions or replacements (rapid obsolescence) | Maximize operational efficiency |
| | Resilient | Expensive | Failure of microgrid DER or other components (potentially catastrophic) | Reduce environmental impacts |
| | Smart | Complicated | Deployment challenges & supporting infrastructure requirements | Leverage revenue and mitigate cost exposure to power purchases |
| | Efficient | Difficult to obtain private financing absent performance guarantee | Vendor attrition | Enhance security & resiliency |
| | New | Limited vendors, lack of standardization (married to technology choice) | | Economic benefits (enhanced revenue, rapid recovery, security, load shaping, etc.), support new technology development |
| **Regulatory** | Complies with REV | May not comply with market restructuring rules | Permitting hurdles, obstacles, and timing | Advance next-generation energy resources |
| | Environmental benefits | May not comply with permitting requirements | Ability to acquire land for solar installation | Increase efficiency, optimize loads, enhance resilience |
| | Enhances grid/energy security and ability to provide emergency services | Must go through aggregator to reach NYISO markets | Utility interconnection requirements | Enhanced compliance with civic obligations for safety and emergency services |
| **Financial** | Facilitates load management | Requires subsidy/guarantee from host/DOE/NYSERDA | Non-performance of vendor/technology | Cost reduction/peak shaving load shaping |
| | Creates new revenue streams | Revenue streams generally small and neither guaranteed nor predictable | Increased deployment may limit market opportunities and/or revenue stream values | Benefit grid and environment |
| | Fuel supply price (natural gas) gives CHP attractive payback | Fuel supply availability during winter peak can be constrained | Fuel supply price and availability subject to supply/demand competition | Enhancing alternative fuel penetration/markets |
| | Campus microgrid minimizes cost/benefit ratio | Campus microgrid not eligible for NY Prize Phase 2 funding | Variations in available incentives | Replacement of obsolete/ aging infrastructure |
| | No capital investment required for PPA | Limited capital funds available | Annual variations in SUNY capital budget | Serve as model for SUNY |
| **Construction/ Operation** | EPC turnkey with performance guarantees | Unproven technology/ lack of operating history | Performance shortfalls or failures | Dynamic system optimization |
| | Independent construction monitor/engineer | Reliance on third parties | Delays in completion and operation date | Enhancing/upgrading distribution infrastructure |

| | | | | |
|---|---|---|---|---|
| | Enhanced services during emergencies | Technology training and additional infrastructure | Fuel supply interruption | Enhanced load control |

*Table 21. SWOT Analysis*

Microgrids are still an emerging technology, and while SUNY Geneseo would not be the first university in the state to build a microgrid – Cornell and NYU both have them – it would be one of only a few. The biogas production and electricity generation at the wastewater treatment plant, while not technically part of the microgrid, would be a relatively unique piece of the project. The biogas generation, the solar installation, and the CHP installation would further the goals of NY REV in seeking to transform the state's energy distribution system toward cleaner and more local power. In addition, the project can serve as a model for microgrids throughout the 64-campus SUNY system.

## Subtask 3.3 Commercial Viability – Project Team

SUNY Geneseo would be the primary applicant, owner, and operator for the campus microgrid project. Microgrid development will be funded through feasibility by NYSERDA grants. Development and construction will be funded through available grants, private equity (where possible), and the SUNY capital budget. The solar installation will likely be funded through a Power Purchase Agreement (PPA). For other parts of the microgrid, an Engineering, Procurement, and Construction (EPC) contract will be used as a vehicle for performance through the commercial operation date (COD). Appropriate warranties will be obtained from technology providers and cover each key component of the microgrid. SUNY Geneseo and Willdan Energy Solutions currently comprise the project team, with Willdan providing the energy and engineering expertise. Additional team members would be added as needed to support the construction and financing of the project. Potential project team members in the design and build phase of the project may include an engineering and construction firm, technology vendors, a permitting consultant, financing partners, and legal and regulatory advisors. Construction firms would be selected through SUNY's defined bidding process. Consultants would be selected using SUNY's Request for Qualifications process. The village would be an integral part of the team for the wastewater treatment plant project. MRB Group, the firm that handles engineering at the plant for the village, would likely be involved.

SUNY Geneseo currently owns and operates its own electrical distribution feeders and switchgear in addition to the central steam heating plant and other HVAC equipment throughout its 50-plus buildings. Willdan is a 51-year-old company that provides energy and engineering expertise and professional services to thousands of municipalities across the country. Willdan has recently been awarded eight NY Prize awards and is a growing force in the microgrid market.

## Subtask 3.4 Commercial Viability – Creating and Delivering Value

Smart grid and microgrid technologies were screened to determine which ones would best support the requirements of a microgrid in Geneseo. CHP was chosen because it integrates well with the existing steam heating plant – it can feed its heat directly into the existing steam loop, and it was sized to match the existing heat load – and is able to provide continuous power in outage situations as well as having a strong resilience to weather events. It was determined, though, that it would not be economical to run the CHP during the summer as there is not a sufficient heat load at Geneseo. In addition, the central heating plant is shut down every summer for maintenance. Further design work would be needed to determine if the CHP could remain on standby during the summer months for use in an outage. CHP would also have environmental benefits, producing a net decrease in greenhouse gas emissions. The EPA emissions calculator shows that with a 2 MW CHP installation, there would be an emissions decrease of 6.4 tons/yr of $SO_2$, 1736 tons/yr of $CO_2$ and an increase of 6.5 tons/year of $NO_x$. Solar was chosen for its sustainability benefits and for the protection it provides from fuel cost increases. In grid-connected mode, the CHP and solar would produce maximum power. In islanded mode, the CHP output would be modulated to follow the load and to balance with the solar output. Communications and control technologies were chosen based on the team's experience with microgrids and its judgment of what would work best with the Geneseo infrastructure and proposed generation.

The addition of CHP and solar generation to the Geneseo campus will allow it to operate as a microgrid and take advantage of new revenue streams such as demand response and fast response regulation markets, increase resiliency through on-site generation, and realize ongoing savings compared to purchasing utility power due to the ability to utilize both electricity and heat. The installation of CHP may require the construction of an addition to the central heating plant, and it would require training and possibly the hiring of additional personnel to operate it. The installation of solar will depend on successful negotiations to acquire land and to sign a Power Purchase Agreement (PPA). Both systems will require ongoing maintenance.

SUNY Geneseo owns its two feeders, operating at 4.16 kV, which connect to RG&E's substation 167. Switchgear is housed in the Clark services building. Since the university owns its own feeders that do not carry any other load, these feeders can be isolated from the RG&E grid to form an islanded microgrid. The existing steam loop, which feeds many of the non-residential buildings in central campus, will provide a use for the heat from the CHP plant. The existing 2.8 MW of existing diesel and natural gas backup generation will continue to play a role in the microgrid. Many of the campus buildings are currently controlled by a Carrier Comfort Network building automation system, which will be useful to the control of the microgrid.

The cooperation of RG&E would be required for the construction of a campus microgrid in order to establish the PCC at the RG&E substation and to ensure that the proper protective gear is installed. RG&E field personnel would also need the necessary infrastructure information in order to be able to safely work on the distribution system.

The microgrid master controller would optimize the operation of the microgrid through generation dispatch and load schedule signals. The generation dispatch signals are sent to dispatchable distributed energy resource (DER) units, and the load schedule signals are sent to building controllers. An interactive grid-forming control would be used both in island and in grid-connected mode. In island mode, DERs apply this control scheme to share the load, while in the grid-connected mode, DERs apply this control scheme to regulate the power exchange between the microgrid and the utility grid. In grid-connected mode, the DER unit, with grid-following control, follows the microgrid voltage and frequency, which is set by the utility grid in grid-connected mode and by other DER units in island mode.

The general process for project development will proceed from feasibility assessment to design and construction in phases beginning with the solar and CHP installation, and concluding with the master controller installation and commissioning. Separately, the village will work with an engineering firm to modify the existing digester at the wastewater treatment plant to accept food waste and to install the necessary gas-cleaning and power generation equipment.

As the microgrid would be a campus microgrid, the community will not incur any costs but at the same time will only receive the indirect benefits of added resiliency at the university. All the operational decisions and responsibilities will lie with SUNY Geneseo.

## Subtask 3.5 Financial Viability

### Potential Revenue Streams

The primary financial benefit of the microgrid is likely to be cost savings resulting from the ability to generate power at a lower price than the utility's retail price, to reduce demand charges, and to utilize the generated heat to offset natural gas purchases. The power would be consumed entirely by SUNY Geneseo and not sold to other customers. Assuming the microgrid includes natural gas-fired CHP, potential revenue sources may include demand response-related revenues and ancillary services payments from NYISO. If biogas production enhancement and biogas-powered generation are implemented at the wastewater treatment plant, cost savings would accrue from offsetting electricity purchases. There is also the potential to clean the biogas and inject it into RG&E's lines at a negotiated price without installing any natural gas generation. The estimated volume of gas is approximately 10.9 million $ft^3$/year. Estimating a wholesale price of $0.39/ccf, the revenue would be $42,510. If this gas were used to generate power instead of being sold to RG&E, the estimated revenue from offsetting electricity purchases at $0.09/kWh would be about $57,767. However, there are significant capital costs associated with these options that would be difficult to offset with the expected revenue. Both options would require gas-cleaning equipment, some type of equipment to load food waste into the digester, and a gas pressure boosting system. These costs could easily exceed $500,000. In order to generate power, an engine would need to be purchased. In addition to capital costs, O&M costs would make a financial return difficult. O&M for the engine is estimated to be at least $0.04/kWh, and O&M for the gas cleaning equipment would also be significant. Another option would be to use the biogas to heat the digesters instead of purchasing natural gas to do so. However, a boiler to do this is estimated to cost $50,000-$100,000, and gas pressure boosting equipment would likely be required. Given that the plant in 2014 only purchased 3238 $ft^3$ of gas, the costs of doing this would likely outweigh the benefits.

Potential revenue streams and/or savings will be highly dependent upon the final configuration of the microgrid, factors affecting power prices in the New York Independent System Operator's (NYISO's) markets, and natural gas markets, among other items. Should the Geneseo microgrid proceed to the next round, detailed information on actual technology and detailed production cost modeling would be necessary to quantify expected revenue streams.

## Demand Response Revenues

Any behind-the-meter generation associated with the microgrid could potentially participate in the NYISO market through RG&E, a demand response service provider. Three possible programs exist – the CA$HBACK, CA$HBACK plus, and the Commercial System Relief Program. The CA$HBACK program is available to customers with at least 100 kW of curtailable load and is a voluntary program. Compensation rates are usually at least $0.45/kWh. CA$HBACK plus is a contract program that requires a 6-month contract (November-April or May-October). It's available to customers with at least 300 kW of curtailable load and requires at least a 4-hour curtailment per request. Customers using distributed generation to reduce load must meet Department of Environmental Conservation regulations and permitting. The Commercial System Relief Program provides up to 21 hours of advance notice of a curtailment event. Compensation rates are typically $0.15/kWh. There is a $50/month fee to subscribe to RG&E's Energy Profiler Online service. The program has both a voluntary option and a reservation payment option. Under the reservation payment option, in addition to the $0.15/kWh payment, there is a payment of $3.25/kW/month if there are four or fewer events and a payment of $3.50/kW/month if there are five or more events.

The proposed CHP installation at SUNY Geneseo would be most economical if it were run nearly constantly and at full load except for the summer months. Therefore, it would not be available to participate in a demand response program. It could potentially be started up during the summer in response to a demand response event, but the cost and benefits of doing this would need to be examined more closely. SUNY Geneseo has participated in demand response programs in the past and received a small amount of economic benefit, but the aggregators with whom they enrolled discontinued their demand response offerings, so the university no longer participates. If the university had a demand response program available to them, they would consider participating again, and automation provided by a microgrid control system may make the process easier and more cost-effective. However, demand response it not anticipated to be a major factor in the financial viability of the microgrid. Based on a very rough estimate of 400 kW of curtailable load curtailed four times per month during the summer months, it may be able to provide on the order of $10,000/year in revenue.

## Ancillary Services

Microgrid generation may potentially participate in other NYISO ancillary services markets, however the extent to which resources can take advantage of these potential revenue streams is not clear as RG&E does not currently have tariffs in place. For example, RG&E lacks a tariff for regulation service. To participate in the regulation market, microgrid generation resources would bid available capacity into the market, but may not be dispatched. A unit could only bid *available* capacity allowing for scheduled maintenance and forced outages and adjusting for reserve capacity. Typical availability factors range from 60% to 85% or more depending on technology and maintenance routines. Furthermore, when offering regulation service into the market, the portion so committed could not be used for generation.

The CHP unit may be able to participate in the NYISO Demand-Side Ancillary Services Program (DSASP) for which NYISO provides a minimum of $75/MWh. However, FERC is ruling on the eligibility of behind-the-meter generation (Docket #EL13-74-000) and, according to NYISO's recent semi-annual update, there has been no activity for the past several years.1 At this time revenue streams from this market seem marginal.

As with demand response, ancillary services revenue is likely to be minimal due to the fact that the CHP would be running at nearly full capacity except for the summer months when it would be shut down. Should the microgrid configuration ultimately include energy storage, additional revenue streams from sales of ancillary service may be possible. Again, such revenues would be predicated upon potential revisions to tariff structures.

## Purchased Power Savings

According to a CHP feasibility report produced by the DOE Technical Assistance Partnership program, a 1.98 MW CHP installation at the central heating plant could be expected to produce $563,159 in annual savings[2]:

*Table 22. Purchased Power Savings*

| | Baseline | 1.98 MW Reciprocating Engine CHP |
|---|---|---|
| Purchased electricity costs | $2,245,245 | $1,269,984 |
| Purchased CHP and boiler fuel costs | $628,952 | $653,685 |
| Incremental O&M costs | N/A | $199,033 |
| Annual operating costs | $2,661,129 | $2,097,969 |
| Annual operating savings | N/A | $563,159 |

## Energy Savings from Biogas

Assuming the project includes biogas production at the wastewater treatment plant, additional revenue or savings would be realized. Revenue would be received if the biogas were sold to RG&E, and cost savings from offsetting purchased electricity would be realized if biogas-powered generation was installed. Additional technical analysis would be required to quantify the level of savings.

## Funding

Microgrid development will depend on access to financing and cost of capital. As with any capital investment, the cost and availability of funding will reflect the risk profile of the venture. In the case of microgrids, the Willdan team expects first tier risks—that may drive financing terms, where available, or under certain circumstances prevent access to capital markets—to include technology risk, regulatory

[1] New York Independent System Operator, Semi-Annual Reports on New Generation Projects and Demand Response Programs (Docket Nos. ER03-647-000 and ER01-3001-000) dated June 1, 2015, Attachment II, page 1.

[2] CHP Feasibility Analysis for SUNY Geneseo, Northeast CHP TAP, January 29, 2016.

risk, lack of a proven track record, and market risk. The regulatory regime will affect the project with regards to potential revenue streams, emissions limits, operating restrictions, technology, and available incentives.

Obtaining funding from the SUNY capital budget will be difficult for SUNY Geneseo. The current budget allocated to Geneseo is just under $4M, and $1.2M is needed for the planned demolition of Blake Hall, $10M is needed for a project on Fraser Hall, and $19.6M is needed for Sturges Hall. The SUNY capital budget is currently done on an annual basis and typically grants each campus budget for their top priorities. Since the microgrid has not been promoted as a top priority in the past, it will be difficult to obtain funding for it.

## Incentives

The CHP project relies on NYSERDA incentives to make its return on investment more attractive. In particular, the proposed 1.98 MW of CHP would qualify for PON 2701, which covers systems larger than 1.3 MW. This program provides maximum incentives of $2M or 50% of the project cost, whichever is less. There are also three 10% bonus incentives available, including one 10% bonus for projects serving critical infrastructure, including facilities of refuge, for which SUNY Geneseo may qualify. This program is set to run through December 30, 2016.

## Project Guarantees/Financing Backstops

The microgrid may require additional guarantees to secure financing. The availability, cost, and timing of such guarantees may impact development. Microgrid technology is emerging and unproven. It offers great possibility and, under the correct circumstances, should be highly attractive to private equity. However, given the risks discussed above, any project's access to private capital will ultimately depend on the guarantor or backstop underpinning the project. Put another way, with unproven technology in an emerging market, private equity will seek to insulate investors from risk assuming a worst-case scenario to offer capital at a reasonable price. Funding sources will require adequate de-risking of the venture. If Geneseo decides to proceed with only CHP or solar, instead of a full-blown microgrid, there are be less technology risk, and financing may be easier to secure.

Classifying microgrid assets as Critical Infrastructure Protection assets under NERC or security assets under Homeland Security may open avenues to external funding from state and federal sources and/or facilitate use of these entities as backstops or ultimate guarantors. Additionally, on August 24, 2015, President Obama announced that the Department of Energy's Loan Programs Office issued guidance for Distributed Energy Projects, making microgrids potentially eligible for DOE's Loan Guarantees Program. Due to the fees and costs associated with such guarantees, this program is typically cost effective for projects of $25 M or more. The DOE would consider packaging projects together to create a cost-effective critical mass. It is currently unclear the feasibility of such an approach. Additional research is warranted in the next phase.

The anticipated cost categories and relative cost magnitudes for the microgrid's construction and operation are as follows, although depending on the ultimate configuration of the microgrid, additional costs may exist:

- CHP installation: $6 million
- Solar installation: $7-8 million
- Communication and control system installation: $1-2 million
- Incremental O&M: $400,000/year
- Incremental fuel: $200,000/year

Financial payback would come from electric and natural gas purchases offset by the CHP installation. The solar installation would likely involve purchasing electricity through a PPA, so any potential financial payback would depend on the terms of the negotiated PPA.

## Subtask 3.6 Legal Viability

SUNY Geneseo currently owns the site where the CHP would be installed at the central heating plant, and they would own the proposed CHP equipment. They are in negotiations with neighboring landowners to acquire land for the solar installation. The solar installation itself would likely be owned by a company with which SUNY Geneseo would have a PPA. Although permits will be required for installation of both the CHP and solar, as well as for the biogas project at the wastewater treatment plant, these permits are likely to be similar to what would be required for any project. There are no known significant legal obstacles to the proposed projects.

Legal and regulatory support will be sought both from subject experts within Willdan and from other industry professionals. Willdan's existing relationship with Brookhaven National Laboratories is expected to provide assistance in this area as well. Appropriate SMEs will be incorporated into the team as appropriate in the next rounds.

# Task 4: Develop Information for Benefit Cost Analysis

The results of the IEC Benefit Cost Analysis are presented in Appendices A (not including 119 Main Street) and B (including 119 Main Street).

## Sub Task 4.1 Facility and Customer Description

This section describes the facilities that were included in the benefit cost analysis. The SUNY Geneseo campus consists of over 50 buildings and belongs to the "large commercial/industrial" rate class (defined by NYSERDA as consuming > 50 MWh annually) in the "All other industries" economic sector. Its average annual electricity usage is 22909 MWh with a peak demand of 4.8 MW. It would require 24 hour electricity supply during an outage, and the proposed microgrid would be able to meet 100% of the average supply.

The wastewater treatment plant belongs to the "small commercial/industrial" rate class in the "All other industries" economic sector. Its average annual electricity usage is 24.7 MWh with a peak demand of 0.004 MW. It would require 24 hour electricity supply during an outage, and the proposed microgrid would be able to meet 100% of the average supply.

Finally, the 119 Main Street location, which was eliminated from the proposed microgrid design, belongs to the large commercial/industrial rate class in the "All other industries" economic sector. Its average annual electricity usage is 53.8 MWh with a peak demand of 0.02 MW. It would require 24 hour electricity supply during an outage, and the proposed microgrid would be able to meet 100% of the average supply.

## Sub Task 4.2 Characterization of Distributed Energy Resources

This section describes the DER that would be used in the proposed microgrid. The natural gas-fueled CHP generator would have a capacity of 2.4 MW and a fuel consumption rate of 9.3 MMBtu/MWh. During normal operations, it would produce 20,239 MWh, and during a major outage, it would produce 55.4 MWh/day. The solar installation would have a 2 MW capacity and on average would produce 2920 MWh/year. During an outage, it would on average produce 8 MWh/day, although the actual production would vary widely based on weather conditions.

The proposed DER, in combination with about 1/3 of the existing diesel backup generation (or less if the proposed solar were generating), would be able to power the campus in an outage. Due to insufficient uses for the heat and the fact that the central heating plant is shut down for maintenance during the summer, the CHP would not run during the summer months. However, it would still produce a positive economic return. An analysis by the DOE Technical Assistance Partnership Program, evaluating CHP independently of a microgrid, estimated that the CHP would have a 12 year payback period and 13% IRR before incentives. With incentives, the estimated payback period would drop to 6.8 years. The CHP would also result in a 33% reduction in $CO_2$ emissions (although the smaller NOx emissions would increase). This assumes that the CHP offsets fossil fuel generation with an emissions profile equal to the fossil fuel emissions average for upstate New York. Although there is a high percentage of hydro and nuclear generation in New York's generation portfolio, the EPA recommends that this be considered baseload generation.

The 2 MW solar installations would be financed through a PPA, for which SUNY Geneseo is currently soliciting proposals. Finally, biogas production and power generation at the wastewater treatment plant may be feasible but would require a pilot project to further clarify the potential.

## Sub Task 4.3 Capacity Impacts and Ancillary Services

The microgrid is not expected to have a significant impact on the capacity of the RG&E distribution system as they claim to have adequate capacity, although they did not provide data to demonstrate this. The Geneseo community is a small community and is not rapidly growing, so it is not expected that the microgrid would play a significant role in enabling the deferral of distribution or transmission system upgrades on the part of the utility.

Demand response is not anticipated to play a large role in the microgrid. As a rough estimate, there may be 400 kW of load that could participate in a DR program. The microgrid generation is expected to normally run at full or nearly full capacity, so it would not be available for demand response. SUNY Geneseo has participated in DR programs in the past, but the providers discontinued their programs. If DR programs were available, the university would consider participating again and enrolling curtailable load, but the amount of revenue was never large. RG&E does not currently offer any ancillary service programs such as reactive power support, so ancillary services are not expected to be part of the microgrid.

A CHP system at SUNY Geneseo would augment the capacity of the current heating system. A 1.98 MW CHP system is estimated by the DOE to produce 17,877 MMBtu of heat, which would supply an estimated 31% of the facility's thermal demand. The CHP system is estimated to produce 990 lb/MWh of $CO_2$, 2.07 lb/MWh of $NO_x$, and 0.005 lb/MWh of SO.

## Sub Task 4.4 Project Costs

This section provides information about the costs of the proposed generators and other microgrid assets. The estimates came from the DER-CAM library and information from the DOE TAP. Information on costs for the wastewater treatment plan was obtained from ClearCove and MRB Group. All the numbers are very rough estimates, +/- 30%, and more precise numbers would need to be obtained for any implementation work.

*Table 23. Capital Components Cost and Lifespan*

| Capital Component | Installed Cost ($) | Component Lifespan (round to nearest year) |
|---|---|---|
| CHP | 7,295,878 | 20 |
| Solar | 6,500,000 | 30 |
| Distribution lines - Underground | 4,356,000 | 40 |
| Transformer | 53,000 | 20 |
| S&C PME Switch | 18,500 | 20 |
| Smart Switch | 18,000 | 20 |
| Automatic Transfer Switch | 685 | 20 |
| 35kV breaker | 40,000 | 20 |
| 12.47kV breaker | 15,000 | 20 |
| 1500A Panelboard (208V) | 18,000 | 20 |
| Manhole | 3,750 | 40 |
| Building Controller | 700 | 15 |
| Wired Communication in Buildings | 80,000 | 15 |
| Master Controller | 100,000 | 25 |
| Smart Meters | 1,000 | 15 |
| E Bridge/Repeater | 350 | 15 |
| Access Point | 1,500 | 15 |
| Fiber Optic | 100,000 | 15 |
| Relay | 3,000 | 20 |
| Automatic Generation Controller | 2,508 | 20 |
| SCADA Software | 100,000 | 25 |
| OSIsoft Data Historian (PI) Full (50,000 tags) | 537,500 | 25 |
| OSIsoft Data Historian (PI) Full (50,000 tags) + training | 690,625 | 25 |

Initial planning and design costs are estimated to be approximately $3 million, or 15% of the installed cost.  Fixed O&M costs are estimated at $290,000, and variable O&M costs, excluding fuel costs, are estimated at $12.47/MWh.

## Sub Task 4.5 Costs to Maintain Service During a Power Outage

Table 24 outlines the existing backup capabilities at SUNY Geneseo and at the wastewater treatment plant.  The wastewater treatment plant's generator is a portable generator shared with the water plant. If one of those facilities experiences an outage, the generator must be moved to the appropriate location and then hooked up by technicians.  The process takes approximately four hours.

*Table 24. Existing Backup Capabilities*

| Facility Name | Generator ID | Energy Source | Nameplate Capacity (MW) | Standard Operating Capacity (%) | Avg. Daily Production During Power Outage (MWh/Day) | Fuel Consumption per Day | | One Time Operating Costs ($) | Ongoing Operating Costs ($/Day) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Quantity | Unit | | |
| SUNY Geneseo | Bailey | Diesel | 0.250 | 100 | 5.4 | 480 | Gallons | 100 | |
| SUNY Geneseo | College Union | Natural Gas | 0.045 | 100 | 0.972 | 680 | cf/h | 100 | |
| SUNY Geneseo | DOTY | Natural Gas | 0.45 | 100 | 9.72 | 5890 | cf/h | 100 | |
| SUNY Geneseo | Erwin | Natural Gas | 0.1 | 100 | 2.16 | 1276 | cf/h | 100 | |
| SUNY Geneseo | Heating Plant | Natural Gas | 0.15 | 100 | 3.24 | 8 | Ft3/mo (test mode) | 100 | |
| SUNY Geneseo | ISC | Natural Gas | 0.45 | 100 | 9.72 | 5551 | cf/h | 100 | 100 |
| SUNY Geneseo | Letchworth Dining Hall | Diesel | 0.2 | 100 | 4.32 | 384 | Gallons | 100 | 100 |
| SUNY Geneseo | Milne Library | Natural Gas | 0.0125 | 100 | 0.27 | 277 | cf/h | 100 | 100 |
| SUNY Geneseo | Red Jacket | Natural Gas | 0.085 | 100 | 1.836 | 1,190,595 | Btu/h | 100 | 100 |
| SUNY Geneseo | Saratoga Heating Plant | Diesel | 0.250 | 100 | 5.4 | 480 | Gallons | 100 | 100 |
| SUNY Geneseo | South Hall | Natural Gas | 0.130 | 100 | 2.808 | 1420 | cf/h | 100 | 100 |
| SUNY Geneseo | Welles | Natural Gas | 0.0185 | 100 | 0.3996 | 277 | cf/h | 100 | 100 |
| SUNY Geneseo | Erie | Natural Gas | 0.04 | 100 | 0.864 | 584 | cf/h | 100 | 100 |
| SUNY Geneseo | Genesee | Natural Gas | 0.035 | 100 | 0.756 | 585 | cf/h | 100 | 100 |
| SUNY Geneseo | Jones | Natural Gas | 0.03 | 100 | 0.648 | 572 | cf/h | 100 | 100 |
| SUNY Geneseo | Jones (cogen) | Natural Gas | 0.03 | 100 | 0.648 | 430 | cf/h | 100 | 100 |
| SUNY Geneseo | Livingston (cogen) | Natural Gas | 0.03 | 100 | 0.648 | 535,819 | Btu/h | 100 | 100 |

*Table 24. Existing Backup Capabilities (continued)*

| Facility Name | Generator ID | Energy Source | Nameplate Capacity (MW) | Standard Operating Capacity (%) | Avg. Daily Production During Power Outage (MWh/Day) | Fuel Consumption per Day | | One Time Operating Costs ($) | Ongoing Operating Costs ($/Day) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Quantity | Unit | | |
| SUNY Geneseo | Livingston (cogen) | Natural Gas | 0.03 | 100 | 0.648 | 535,819 | Btu/h | 100 | 100 |
| SUNY Geneseo | Livingston (cogen) | Natural Gas | 0.03 | 100 | 0.648 | 535,819 | Btu/h | 100 | 100 |
| SUNY Geneseo | Nassau | Natural Gas | 0.035 | 100 | 0.756 | 535,819 | Btu/h | 100 | 100 |
| SUNY Geneseo | Niagara | Natural Gas | 0.035 | 100 | 0.756 | 873,915 | Btu/h | 100 | 100 |
| SUNY Geneseo | Onondaga | Natural Gas | 0.06 | 100 | 1.296 | 585 | cf/h | 100 | 100 |
| SUNY Geneseo | Putnam | Diesel | 0.035 | 100 | 0.756 | 67.2 | Gallons | 100 | 100 |
| SUNY Geneseo | Seneca | Natural Gas | 0.25 | 100 | 5.4 | 277 | cf/h | 100 | 100 |
| SUNY Geneseo | Steuben | Natural Gas | 0.015 | 100 | 0.324 | 535,819 | Btu/h | 100 | 100 |
| SUNY Geneseo | Suffolk | Natural Gas | 0.035 | 100 | 0.756 | 535,819 | Btu/h | 100 | 100 |
| SUNY Geneseo | Wayne | Diesel | 0.035 | 100 | 0.756 | 67.2 | Gallons | 100 | 100 |
| Geneseo Wastewater Treatment Plant | Unit 1 | Diesel | 0.30 | 85 | 6.12 | 27.0 | MMBtu/hr | 1000 | 900 |

It is estimated that it costs SUNY Geneseo approximately $1000/day to maintain and run the backup generation during an outage, although this is a difficult cost to estimate. Table 25 details cost estimates for the facilities to maintain service when backup generation is not available.

*Table 25. Cost of Service Maintenance*

| Facility Name | Type of Measure (One-Time or Ongoing) | Description | Costs | Units | When would these measures be required? |
|---|---|---|---|---|---|
| Geneseo Wastewater plant | One-Time Measures | Hooking up additional portable generator | 2500 | $ | Year-round |
| Geneseo Wastewater plant | Ongoing Measures | Renting additional portable generator | 1,000 | $/day | Year-round |
| Village offices | Ongoing Measures | Renting portable generator | $150/ day | | Year round, 7 days/week |
| Village offices | Ongoing Measures | Fuel for generator | 77 | $/day | Year-round |
| SUNY Geneseo | Ongoing Measures | Renting portable generator | 3,000 | $/day | Year-round |
| SUNY Geneseo | One-Time Measures | Hooking up portable generator | 7500 | $ | Year-round |
| SUNY Geneseo | Ongoing Measures | Staff to oversee safety and logistics | 5000 | $/day | Year-round |
| SUNY Geneseo | Ongoing Measures | Fuel for generator | 3456 | $/day | Year-round |

## Sub Task 4.6 Services Supported by the Microgrid

When running on backup power, SUNY Geneseo currently loses approximately 40% of its ability to provide services. This percentage would be near zero with the construction of a microgrid. The wastewater treatment plant loses 5% of its function while on backup power. Without backup power, both the university and the treatment plant lose approximately 90% of their function. The village building at 119 Main Street loses approximately 70%. Without backup power, approximately 3400 university residents are left without power.

The wastewater treatment plant serves over 10,400 residents, and the village offices serve 8000 people. The university serves a population of about 6000. The university maintains a police force of about 15, and the village has a force of 2-3. The police forces are estimated to lose 30% of their effectiveness during an outage.

# Task 5: Conclusions and Recommendations

The recommendations considered as part of this project were 1) design and build a community microgrid, 2) design and build a campus microgrid, 3) install CHP and solar at the university without creating a microgrid. While the first option was the focus at the outset of the project, it was determined the cost to include other community facilities in the microgrid would not be economically justified. The wastewater treatment plant is over a mile from the substation, and shares a feeder with other residential and commercial load. The cost to tie this facility into the microgrid and run lines across roads could easily reach the high six figures. The village office building, while closer to campus, also shares a feeder with other load and would need to be tied into the microgrid by crossing a road. The building also has a small load (13.8 kW) and could easily enhance its reliability by installing a diesel backup generator. Other critical village facilities are farther from campus. Therefore, the Willdan team concluded that a Geneseo Community microgrid would be technically feasible but financially infeasible. Since the inclusion of the wastewater treatment plant and the village offices in the microgrid would add significant cost and complexity for limited benefit, Willdan recommends that a campus-style microgrid would be more appropriate for SUNY Geneseo. Since a campus style microgrid would make the project ineligible for further NY Prize funding, financing the microgrid construction would be difficult for the university, having a limited capital budget which is controlled at the state level. If this is indeed the case, Willdan recommends that SUNY Geneseo consider installing CHP and solar DER now and possibly tying them together into a microgrid in the future. The DOE CHP Technical Assistance Partnership program estimated that a 1.98 MW CHP installation (independent of a microgrid) in the university central heating plant would have a 12.5 year payback period and 14.3% IRR. The payback period could be shortened to 6.3 years with currently available incentives. A solar installation could be financed completely through a Power Purchase Agreement (PPA). After these DER were installed and accrued some financial benefit to the university, the university could consider tying them together into a microgrid if appropriate financing could be obtained. Even without a microgrid, this DER would provide some reliability, financial, and environmental benefits to the university.

A CHP installation at the university central heating plant would be tied into the existing steam loop that serves the central part of campus. The recommended 1.98 MW size was selected to match the heat load to the heat generated and to allow for continual operation of the CHP. As proposed, the CHP would provide 31% of the heating plant's current heat demand. It was found that there was not sufficient summer heat load to justify summer operation of the CHP. Absorption chilling was considered but determined to not be economical. In addition, there would be significant operational expense to keep the CHP running during the summer as the central heating plant is currently shut down during these months for extensive maintenance and overhaul.

A CHP installation would have environmental benefits and produce a reduction in greenhouse gases. Compared to the upstate New York average for fossil fuel generation (hydro and nuclear generation are considered baseload generation, not offset by the CHP), the CHP installation would produce a reduction of 6.4 tons/yr of $SO_2$, 1736 tons/yr of $CO_2$ and an increase of 6.5 tons/year of $NO_x$. The $CO_2$ reduction represents a 33% decrease in current emissions.

A 2 MW solar installation would be located on land adjacent to campus. SUNY Geneseo is currently in negotiation with the landowner.

Collecting food waste from the campus dining halls to augment biogas production and enable power generation at the village's wastewater treatment plant, was an idea the created the impetus for this study. After discussions with the wastewater treatment plant and various subject matter experts at the plant, MRB Group, ClearCove, and NYSERDA, the financial feasibility of such a project seems doubtful. Costs are estimated between $600k and $1M for approximately $57k worth of annual energy production. The power production could likely be doubled if the holding tank at the plant were converted to a second digester, but this would incur another $1-2M in cost. The amount of food waste available from the dining halls is estimated by Campus Auxiliary Services to be 1 ton/week, possibly somewhat higher. Wegmans Food Markets has said they could provide 3-4 tons/week of food. The digester is estimated to be able accept one ton of food per day, so in order to maximize the generation, waste would need to be collected from another source. Geneseo is in a rural agricultural area, so there are many area farms that could provide waste. However, collecting waste from multiple sources would lead to increased costs, and the composition of the waste stream may affect the design of the digester. The food waste from Wegmans is currently being diverted to the Noblehurst digester, so the environmental benefits of diverting it to the Geneseo wastewater treatment plant would be limited to reduced emissions from a reduction in shipping distance. A process would need to be put in place to ensure that waste from the Geneseo dining halls was clean and free of plastic and other items that could clog pumps at the plant. The cost of such a process was not accounted for in this study.

The average daily flow at the wastewater treatment plant is 0.78 MGD, with a maximum month average daily flow of 1.33 MGD, and a peak hourly flow of 3.66 MGD. There was general agreement among the experts consulted that power generation at a small plant such as this is generally not economically beneficial. The most economical option may be to use the biogas to heat the digesters instead of flaring the biogas and purchasing natural gas, as is done now. This option was considered during a previous upgrade of the digesters, but the village decided against it. Even if the heat were utilized, the plant's 2014 natural gas consumption was only 3238 ccf, so there would not be large cost savings produced.

Due to the myriad of options surrounding the design of a digestion and power generation system at the plant, Willdan recommends that if SUNY Geneseo or the Village of Geneseo would like to proceed with such a project, they work with an engineering firm to design a pilot project to test the technical and economic feasibility under real-world conditions. Such a project would implement food digestion and gas production on a small scale and would help clarify some of the unknown questions including exactly how much gas could be produced from a given waste stream, how much waste the digester could process, how much cleaning would the gas need, how much power could be generated, and how the logistics of the process would work from collecting and loading the waste to drying and disposing of the sludge. If the pilot project proved feasible, then it could be scaled up to a full implementation.

There was strong support for this project from both SUNY Geneseo and the Village of Geneseo. SUNY Geneseo has a Director of Sustainability, who spearheaded the initiation of this project, so they are interested in it from both an environmental and economic perspective. The village was very willing to explore ways in which it could work together with the university. RG&E, the local investor-owned utility, was willing to work with the project team and support the project, although there were initial delays in obtaining the required data, which led to overall project delays.

# Disclaimer

The intent of this analysis report is to assess the technical, legal, and financial feasibility of community microgrid and estimate energy savings and additional revenue generation associated with the recommended upgrades to your facilities. Appropriate detail is included to help you make decisions about building community microgrid. However, this report is not intended to serve as a detailed engineering design document, as the improvement descriptions are diagrammatic in nature only, in order to document the basis of cost estimates and savings and to demonstrate the feasibility of constructing the improvements. Detailed design efforts may be required to fully understand the benefits and challenges you may encounter and to implement several of the improvements evaluated as part of this analysis.

While the recommendations in this report have been reviewed for technical accuracy, and we believe they are reasonable and accurate, the findings are estimates and actual results may differ. As a result, Willdan Energy Solutions is not liable if projected, estimated savings or economies are not actually achieved. All savings and cost estimates in the report are for informational purposes and are not to be construed as design documents or guarantees.

In no event will Willdan Energy Solutions be liable for the failure of the customer to achieve a specified amount of savings, for the operation of customer's facilities, or for any incidental or consequential damages of any kind in connection with this report or the installation of the recommended measures.

# Acknowledgement

This project is financially supported by the New York State Energy Research and Development Authority. On behalf of the members of this project, Willdan would like to thank Stephen Hoyt, NYSERDA Project Manager, for making this work possible. Willdan would also like to thank the SUNY Geneseo project sponsors and staff that supported this project; the Village of Geneseo, and the staff at the Geneseo wastewater treatment plant.  The cost benefit analysis portion of the project was completed by Industrial Economics Inc.

# Appendix A

## Benefit-Cost Analysis Summary Report – SUNY Campus and WWTP Only - Site 77 – Village of Geneseo (SUNY)

### Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the Village of Geneseo has proposed development of a microgrid that would that would enhance the resiliency of electric service for three facilities in this Livingston County community:

- The State University of New York (SUNY) Geneseo campus, which encompasses more than 50 individual buildings; and
- The Village of Geneseo wastewater treatment plant

The microgrid would be powered by a new 2.4 MW natural gas-fired combined heat and power (CHP) generator, which would be located at the SUNY Central Heating Plant, and a new 2 MW solar photovoltaic array, located adjacent to the SUNY campus. Both of these resources would produce electricity for the grid during periods of normal operation, as well as in islanded mode during power outages. The system as designed would have sufficient generating capacity to meet average demand for electricity from all included facilities during a major outage. Project consultants also indicate that the system would be capable of providing frequency regulation and reactive power support to the grid.

Concurrently with development of the microgrid, the project team will invest in upgrades to an existing, under-utilized anaerobic digester located at the wastewater treatment plant. The primary goal of these upgrades is to divert food waste from the SUNY Geneseo dining halls. Currently, the digester flares the gas produced at the wastewater treatment plant. Following the upgrades, the digester will produce additional methane gas and will sell the total amount (approximately 6.8 million cubic feet per year) to the local utility. Because the methane will not be used for onsite electricity generation, the project team does not consider the digester to be one of the microgrid's distributed energy resources. Nonetheless, the increase in the digester's output is a key ancillary benefit of the microgrid project, one that is both an important source of revenue and a factor that should be included in quantifying its social benefits.

To assist with completion of the project's NY Prize Stage 1 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.

### 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 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.[1] 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 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).

[1] 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.]

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.[1]

## Results

Table 26 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 1.5 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

*Table 26. BCA Results (Assuming 7 Percent Discount Rate)*

| Economic Measure | Assumed Average Duration of Major Power Outages | |
|---|---|---|
| | Scenario 1: 0 Days/Year | Scenario 2: 3.2 Days/Year |
| Net Benefits - Present Value | -$4,100,000 | $158,000 |
| Benefit-Cost Ratio | 0.9 | 1.0 |
| Internal Rate of Return | 1.6% | 4.7% |

## Scenario 1

Figure 37 and table 27 present the detailed results of the Scenario 1 analysis.

[1] 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.

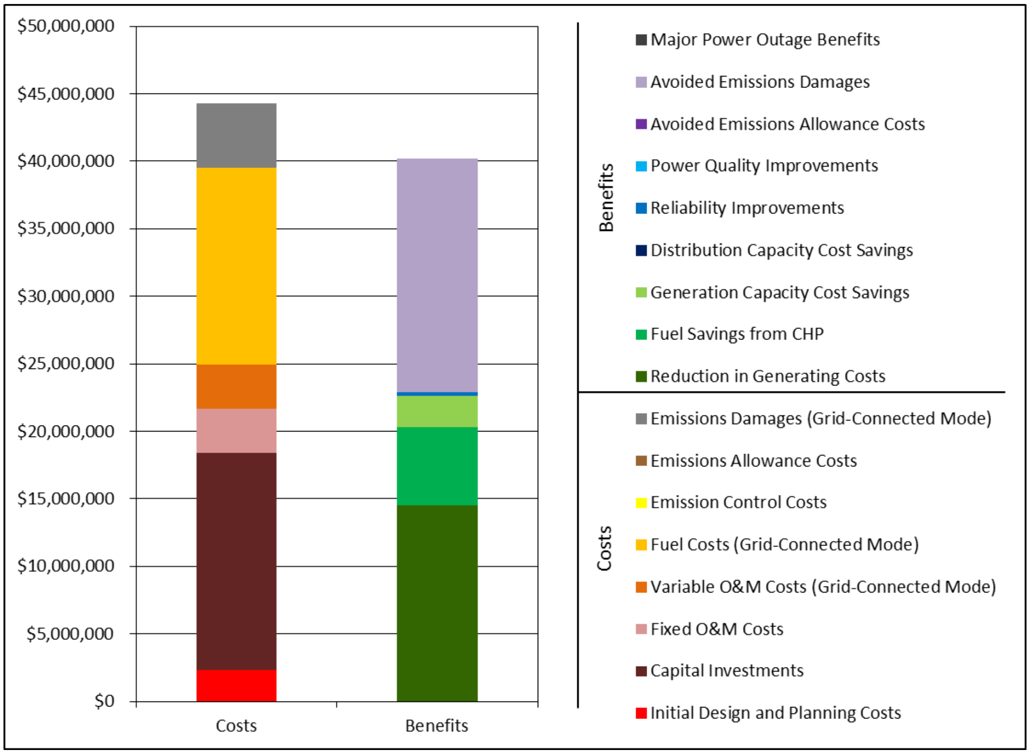



*Figure 37. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)*

*Table 27. 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 | $2,330,000 | $205,000 |
| Capital Investments | $16,000,000 | $1,320,000 |
| Fixed O&M | $3,270,000 | $289,000 |
| Variable O&M (Grid-Connected Mode) | $3,270,000 | $289,00 |
| Fuel (Grid-Connected Mode) | $14,600,000 | $1,290,000 |
| Emission Control | $0 | $0 |
| Emissions Allowances | $0 | $0 |
| Emissions Damages (Grid-Connected Mode) | $4,820,000 | $315,000 |
| **Total Costs** | **$44,300,000** | |
| **Benefits** | | |
| Reduction in Generating Costs | $14,500,000 | $1,280,000 |
| Fuel Savings from CHP | $5,780,000 | $510,000 |
| Generation Capacity Cost Savings | $2,320,000 | $205,000 |
| Distribution Capacity Cost Savings | $0 | $0 |
| Reliability Improvements | $281,000 | $24,800 |
| Power Quality Improvements | $0 | $0 |
| Avoided Emissions Allowance Costs | $8,390 | $740 |
| Avoided Emissions Damages | $17,300,000 | $1,130,000 |
| Major Power Outage Benefits | $0 | $0 |
| **Total Benefits** | **$40,200,000** | |
| **Net Benefits** | **-$4,100,000** | |
| **Benefit/Cost Ratio** | **0.9** | |
| **Internal Rate of Return** | **1.6%** | |

### *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 $3.0 million, based on a standard estimate of 15 percent of the total installed cost. The present value of the project's capital costs is estimated at approximately $16.0 million, including costs associated with the new 2.4 MW combined heat and power (CHP) system; new 2 MW photovoltaic array; upgrades to the existing anaerobic digester; underground distribution lines; smart meters; and other system controls. The present value of the microgrid's fixed operations and maintenance (O&M) costs (i.e., O&M costs that do not vary with the amount of energy produced) is estimated at approximately $3.27 million, or $289,000 annually.

### *Variable Costs*

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's CHP generator. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the project team and projections of fuel costs from New York's 2015 State Energy Plan (SEP), adjusted to reflect recent market prices.[1] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $14.6 million.

The BCA also considers the project team's best estimate of the microgrid's variable O&M costs (i.e., O&M costs that vary with the amount of energy produced). The present value of these costs is estimated at approximately $3.27 million, or $12.47 per MWh.

In addition, the analysis of variable costs 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 microgrid's natural gas generator are estimated at approximately $315,000 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 $4.82 million.

### *Avoided Costs*

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. These include generating cost savings resulting from a reduction in demand for electricity from bulk energy suppliers. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $14.5 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. Additional benefits would result from fuel savings due to the new CHP system and the production of methane gas by the anaerobic digester; the BCA estimates the present value of fuel savings over the 20-year operating period to be approximately $5.78 million. The reduction in demand for electricity from bulk energy suppliers and 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 $8,390 and avoided emissions damages with a present value of approximately $17.3 million.[2]

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[1] 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.

[2] 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.

In addition to the savings noted above, development of a microgrid could yield cost savings by avoiding or deferring the need to invest in expansion of the conventional grid's energy generation or distribution capacity.[1] The new CHP generator and photovoltaic array may reduce the conventional grid's demand for generating capacity by providing up to 2.73 MW of peak load support, based on standard capacity factors for each resource. The BCA estimates the present value of the project's generating capacity benefits to be approximately $2.32 million over a 20-year operating period. The project team took a conservative approach with respect to distribution capacity benefits, projecting no impact on local distribution capacity requirements. We note, however, that the project would entail a substantial investment in new distribution infrastructure (e.g., underground distribution lines, smart meters); these investments may yield benefits not accounted for in this analysis.

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

### *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 $24,800 per year, with a present value of $281,000 over a 20-year operating period. This estimate is developed 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:[2]

System Average Interruption Frequency Index (SAIFI) – 0.76 events per year.

Customer Average Interruption Duration Index (CAIDI) – 104.4 minutes.[3]

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

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

[2] www.icecalculator.com.

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

analysis assumes a 15 percent failure rate for backup generators.[1] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

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

### *Summary*

The analysis of Scenario 1 yields a benefit/cost ratio of 0.9; i.e., the estimate of project benefits is approximately 90 percent that of project costs. Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

## Scenario 2

### *Benefits in the Event of a Major Power Outage*

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[2,3]

As noted above, the Village of Geneseo's microgrid project would serve the SUNY Geneseo campus and a wastewater treatment plant during an extended outage. The project's consultants indicate that at present, both the campus and the wastewater treatment plant are equipped with backup generators. These include 25 separate natural gas and diesel backup generators on the SUNY Geneseo campus, which can support approximately 60 percent of the campus's ordinary level of service, and one diesel backup generator that can support approximately 95 percent of the ordinary level of service at the wastewater treatment plant. Operation of the 25 SUNY Geneseo generators would entail a combined one-time cost of $2,500 and additional costs of $8,200 per day, including fuel costs. The campus would also incur a cost of $1,000 per day to provide staff to oversee safety and logistics for the duration of the

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

[2] 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.

[3] 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.

outage. Operation of the generator at the wastewater treatment plant would entail a one-time cost of $1,000 and additional costs of $8,600 per day, including fuel costs.

Should these existing units fail, the team indicates that all three facilities could maintain operations by bringing in portable generators. The operation of the portable units would cost approximately $11,500 per day at the SUNY Geneseo campus, $2,200 at the wastewater treatment plant, plus one-time costs of $7,500 at SUNY Geneseo and $2,500 at the wastewater treatment plant. In the absence of backup power – i.e., if the backup generators failed and no replacements were available – SUNY Geneseo and the wastewater treatment plant would each experience a 90 percent loss in service capabilities, and the village offices would experience a 70 percent loss in service capabilities.

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

The SUNY Geneseo campus would rely on its existing backup generators, experiencing a 40 percent loss in service capabilities while the generators operate. If the backup generators fail, the campus would experience a 90 percent loss of service.

The wastewater treatment plant would rely on its existing backup generator, experiencing a five percent loss in service capabilities while the generator operates. If the backup generator fails, the facility would experience a 90 percent loss of service.

In all cases, the supply of fuel necessary to operate the backup generators would be maintained indefinitely.

In all cases, there is a 15 percent chance that the backup generator would fail.

The consequences of a major power outage also depend on the economic costs of a sustained interruption of service at the facilities of interest. The analysis calculates the impact of a loss in service at each facility based on the following value of service estimates:

- For the SUNY Geneseo campus, a value of approximately $356,000 per day. This figure is estimated using the ICE Calculator, assuming 24 hours of microgrid demand per day during an outage.[1]
- For the wastewater treatment plant, a value of $81,200 per day. This value is calculated using FEMA's national average estimates of the per-capita impact of a loss of wastewater service on economic activity and residential customers.

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the six facilities is approximately $256,000 per day.

[1] http://icecalculator.com/

*Summary*

Figure 38 and table 28 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 1.5 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

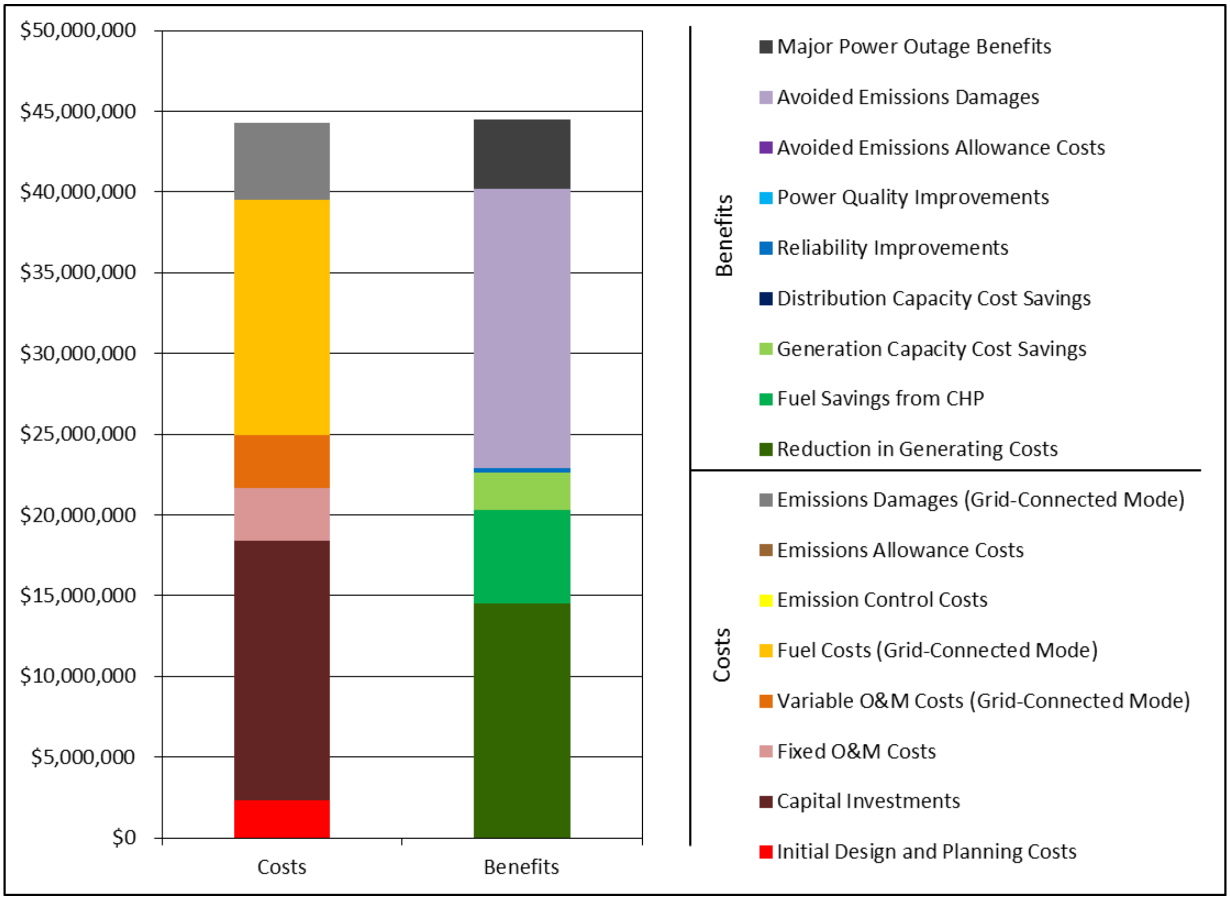


*Figure 38. Present Value Results, Scenario 2 (Major Power Outages Averaging 1.5 Days/Year; 7 Percent Discount Rate)*

*Table 28. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 3.2 Days/Year; 7 Percent Discount Rate)*

| Cost Or Benefit Category | Present Value Over 20 Years (2014$) | Annualized Value (2014$) |
|---|---|---|
| **Costs** | | |
| Initial Design and Planning | $2,330,000 | $205,000 |
| Capital Investments | $16,000,000 | $1,320,000 |
| Fixed O&M | $3,270,000 | $289,000 |
| Variable O&M (Grid-Connected Mode) | $3,270,000 | $289,000 |
| Fuel (Grid-Connected Mode) | $14,600,000 | $1,290,000 |
| Emission Control | $0 | $0 |
| Emissions Allowances | $0 | $0 |
| Emissions Damages (Grid-Connected Mode) | $4,820,000 | $315,000 |
| **Total Costs** | **$44,300,000** | |
| **Benefits** | | |
| Reduction in Generating Costs | $14,500,000 | $1,280,000 |
| Fuel Savings from CHP | $5,780,000 | $510,000 |
| Generation Capacity Cost Savings | $2,320,000 | $205,000 |
| Distribution Capacity Cost Savings | $0 | $0 |
| Reliability Improvements | $281,000 | $24,800 |
| Power Quality Improvements | $0 | $0 |
| Avoided Emissions Allowance Costs | $8,390 | $740 |
| Avoided Emissions Damages | $17,300,000 | $1,130,000 |
| Major Power Outage Benefits | $4,260,000 | $376,000 |
| **Total Benefits** | **$44,500,000** | |
| **Net Benefits** | **$158,000** | |
| **Benefit/Cost Ratio** | **1.0** | |
| **Internal Rate of Return** | **4.7%** | |

# Appendix B

## Benefit-Cost Analysis Summary Report – SUNY Campus, WWTP, and 119 Main Street - Site 77 – Village of Geneseo (SUNY)

### Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the Village of Geneseo has proposed development of a microgrid that would enhance the resiliency of electric service for two facilities in this Livingston County community:

- The State University of New York (SUNY) Geneseo campus, which encompasses more than 50 individual buildings; and
- The Village of Geneseo wastewater treatment plant.

The microgrid would be powered by a new 2.4 MW natural gas-fired combined heat and power (CHP) generator, which would be located at the SUNY Central Heating Plant, and a new 2 MW solar photovoltaic array, located adjacent to the SUNY campus. Both of these resources would produce electricity for the grid during periods of normal operation, as well as in islanded mode during power outages. The system as designed would have sufficient generating capacity to meet average demand for electricity from all included facilities during a major outage. Project consultants also indicate that the system would be capable of providing frequency regulation and reactive power support to the grid.

Concurrently with development of the microgrid, the project team will invest in upgrades to an existing, under-utilized anaerobic digester located at the wastewater treatment plant. The primary goal of these upgrades is to divert food waste from the SUNY Geneseo dining halls. Currently, the digester flares the gas produced at the wastewater treatment plant. Following the upgrades, the digester will produce additional methane gas and will sell the total amount (approximately 6.8 million cubic feet per year) to the local utility. Because the methane will not be used for onsite electricity generation, the project team does not consider the digester to be one of the microgrid's distributed energy resources. Nonetheless, the increase in the digester's output is a key ancillary benefit of the microgrid project, one that is both an important source of revenue and a factor that should be included in quantifying its social benefits.

To assist with completion of the project's NY Prize Stage 1 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.

## 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 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.[1] 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 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).

[1] 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.]

- 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.[1]

## Results

Table 29 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 1.5 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

*Table 29. BCA Results (Assuming 7 Percent Discount Rate)*

| Economic Measure | Assumed Average Duration of Major Power Outages | |
|---|---|---|
| | Scenario 1: 0 Days/Year | Scenario 2: 1.5 Days/Year |
| Net Benefits - Present Value | -$4,100,000 | $158,000 |
| Benefit-Cost Ratio | 0.9 | 1.0 |
| Internal Rate of Return | 1.6% | 4.7% |

### Scenario 1

Figure 39 and table 30 present the detailed results of the Scenario 1 analysis.

[1] 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.

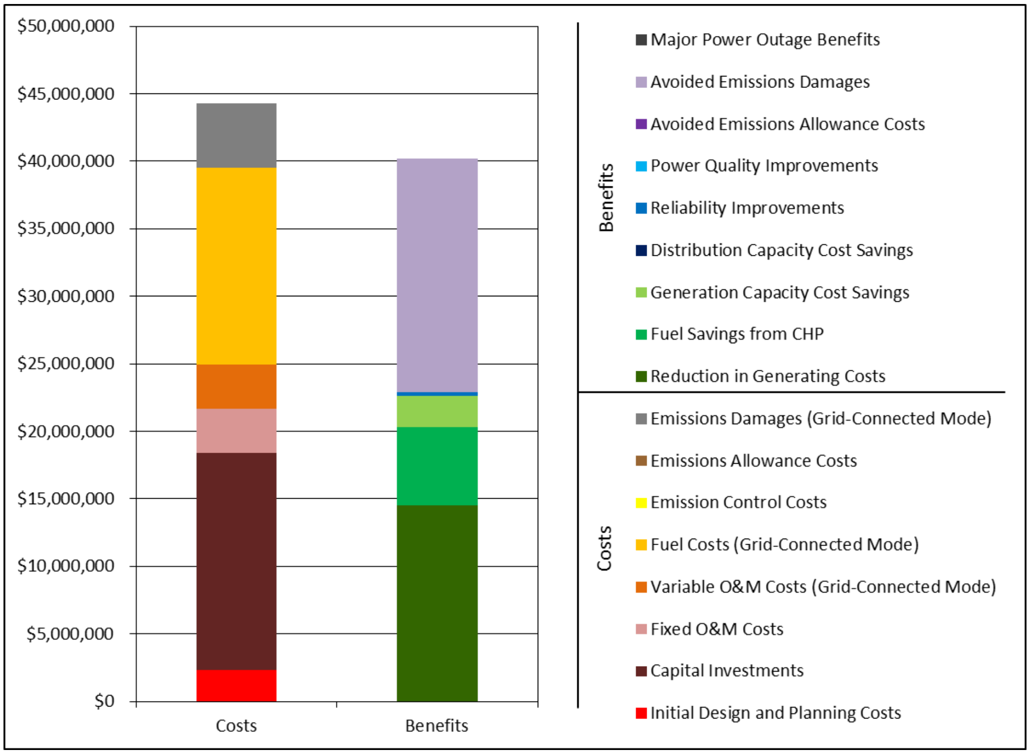


*Figure 39. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)*

*Table 30. 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 | $2,330,000 | $205,000 |
| Capital Investments | $16,000,000 | $1,320,000 |
| Fixed O&M | $3,270,000 | $289,000 |
| Variable O&M (Grid-Connected Mode) | $3,270,000 | $289,000 |
| Fuel (Grid-Connected Mode) | $14,600,000 | $1,290,000 |
| Emission Control | $0 | $0 |
| Emissions Allowances | $0 | $0 |
| Emissions Damages (Grid-Connected Mode) | $4,820,000 | $315,000 |
| Total Costs | **$44,300,000** | |
| Benefits | | |
| Reduction in Generating Costs | $14,500,000 | $1,280,000 |
| Fuel Savings from CHP | $5,780,000 | $510,000 |
| Generation Capacity Cost Savings | $2,320,000 | $205,000 |
| Distribution Capacity Cost Savings | $0 | $0 |
| Reliability Improvements | $281,000 | $24,800 |
| Power Quality Improvements | $0 | $0 |
| Avoided Emissions Allowance Costs | $8,390 | $740 |
| Avoided Emissions Damages | $17,300,000 | $1,130,000 |
| Major Power Outage Benefits | $0 | $0 |
| **Total Benefits** | **$40,200,000** | |
| **Net Benefits** | **-$4,100,000** | |
| **Benefit/Cost Ratio** | **0.9** | |
| **Internal Rate of Return** | **1.6%** | |

### *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 $2.33 million, based on a standard estimate of 15 percent of the total installed cost. The present value of the project's capital costs is estimated at approximately $16.0 million, including costs associated with the new 2.4 MW combined heat and power (CHP) system; new 2 MW photovoltaic array; upgrades to the existing anaerobic digester; smart meters; and other system controls. The present value of the microgrid's fixed operations and maintenance (O&M) costs (i.e., O&M costs that do not vary with the amount of energy produced) is estimated at approximately $3.27 million, or $289,000 annually.

### *Variable Costs*

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's CHP generator. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the project team and projections of fuel costs from New York's 2015 State Energy Plan (SEP), adjusted to reflect recent market prices.[1] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $14.6 million.

The BCA also considers the project team's best estimate of the microgrid's variable O&M costs (i.e., O&M costs that vary with the amount of energy produced). The present value of these costs is estimated at approximately $3.27 million, or $12.47 per MWh.

In addition, the analysis of variable costs 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 microgrid's natural gas generator are estimated at approximately $315,000 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 $4.82 million.

### *Avoided Costs*

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. These include generating cost savings resulting from a reduction in demand for electricity from bulk energy suppliers. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $14.5 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. Additional benefits would result from fuel savings due to the new CHP system and the production of methane gas by the anaerobic digester; the BCA estimates the present value of fuel savings over the 20-year operating period to be approximately $5.78 million. The reduction in demand for electricity from bulk energy suppliers and 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 $8,390 and avoided emissions damages with a present value of approximately $17.3 million.[2]

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[1] 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.

[2] Following the New York Public Service Commission's (PSC) guidance for benefit-cost analysis, the model values emissions of CO2 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 SO2 and NOx from bulk energy suppliers are capped and subject to emissions allowance requirements in New York, the model values these emissions based on projected allowance prices for each pollutant.

In addition to the savings noted above, development of a microgrid could yield cost savings by avoiding or deferring the need to invest in expansion of the conventional grid's energy generation or distribution capacity.[1] The new CHP generator and photovoltaic array may reduce the conventional grid's demand for generating capacity by providing up to 2.73 MW of peak load support, based on standard capacity factors for each resource. The BCA estimates the present value of the project's generating capacity benefits to be approximately $2.32 million over a 20-year operating period. The project team took a conservative approach with respect to distribution capacity benefits, projecting no impact on local distribution capacity requirements. We note, however, that the project would entail investments in new distribution infrastructure (e.g., smart meters); these investments may yield benefits not accounted for in this analysis.

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

### *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 $24,800 per year, with a present value of $281,000 over a 20-year operating period. This estimate is developed 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:[2]

- System Average Interruption Frequency Index (SAIFI) – 0.76 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 104.4 minutes.[3]

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

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[1] Impacts to transmission capacity are implicitly incorporated into the model's estimates of avoided generation costs and generation capacity cost savings. As estimated by NYISO, generation costs and generating capacity costs vary by location to reflect costs imposed by location-specific transmission constraints.
[2] www.icecalculator.com.
[3] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for Rochester Gas & Electric.

analysis assumes a 15 percent failure rate for backup generators.[1] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

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

### *Summary*

The analysis of Scenario 1 yields a benefit/cost ratio of 0.9; i.e., the estimate of project benefits is approximately 90 percent that of project costs. Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

## Scenario 2

### *Benefits in the Event of a Major Power Outage*

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[2,3]

As noted above, the Village of Geneseo's microgrid project would serve the SUNY Geneseo campus and a wastewater treatment plant during an extended outage. The project's consultants indicate that at present, both the campus and the wastewater treatment plant are equipped with backup generators. These include 25 separate natural gas and diesel backup generators on the SUNY Geneseo campus, which can support approximately 60 percent of the campus's ordinary level of service, and one diesel backup generator that can support approximately 95 percent of the ordinary level of service at the wastewater treatment plant. Operation of the 25 SUNY Geneseo generators would entail a combined one-time cost of $2,500 and additional costs of $8,200 per day, including fuel costs. The campus would also incur a cost of $1,000 per day to provide staff to oversee safety and logistics for the duration of the

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

[2] 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.

[3] 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.

outage. Operation of the generator at the wastewater treatment plant would entail a one-time cost of $1,000 and additional costs of $8,600 per day, including fuel costs.

Should these existing units fail, the team indicates that both facilities could maintain operations by bringing in portable generators. The operation of the portable units would cost approximately $11,500 per day at the SUNY Geneseo campus and $2,200 per day at the wastewater treatment plant, plus one-time costs of $7,500 at SUNY Geneseo and $2,500 at the wastewater treatment plant. In the absence of backup power – i.e., if the backup generators failed and no replacements were available – SUNY Geneseo and the wastewater treatment plant would each experience a 90 percent loss in service capabilities.

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

- The SUNY Geneseo campus would rely on its existing backup generators, experiencing a 40 percent loss in service capabilities while the generators operate. If the backup generators fail, the campus would experience a 90 percent loss of service.
- The wastewater treatment plant would rely on its existing backup generator, experiencing a five percent loss in service capabilities while the generator operates. If the backup generator fails, the facility would experience a 90 percent loss of service.
- In all cases, the supply of fuel necessary to operate the backup generators would be maintained indefinitely.
- In all cases, there is a 15 percent chance that the backup generator would fail.

The consequences of a major power outage also depend on the economic costs of a sustained interruption of service at the facilities of interest. The analysis calculates the impact of a loss in service at each facility based on the following value of service estimates:

- For the SUNY Geneseo campus, a value of approximately $356,000 per day. This figure is estimated using the ICE Calculator, assuming 24 hours of microgrid demand per day during an outage.[1]
- For the wastewater treatment plant, a value of $81,200 per day. This value is calculated using FEMA's national average estimates of the per-capita impact of a loss of wastewater service on economic activity and residential customers.

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the six facilities is approximately $252,000 per day.

[1] http://icecalculator.com/

### *Summary*

Figure 40 and table 31 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 1.5 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

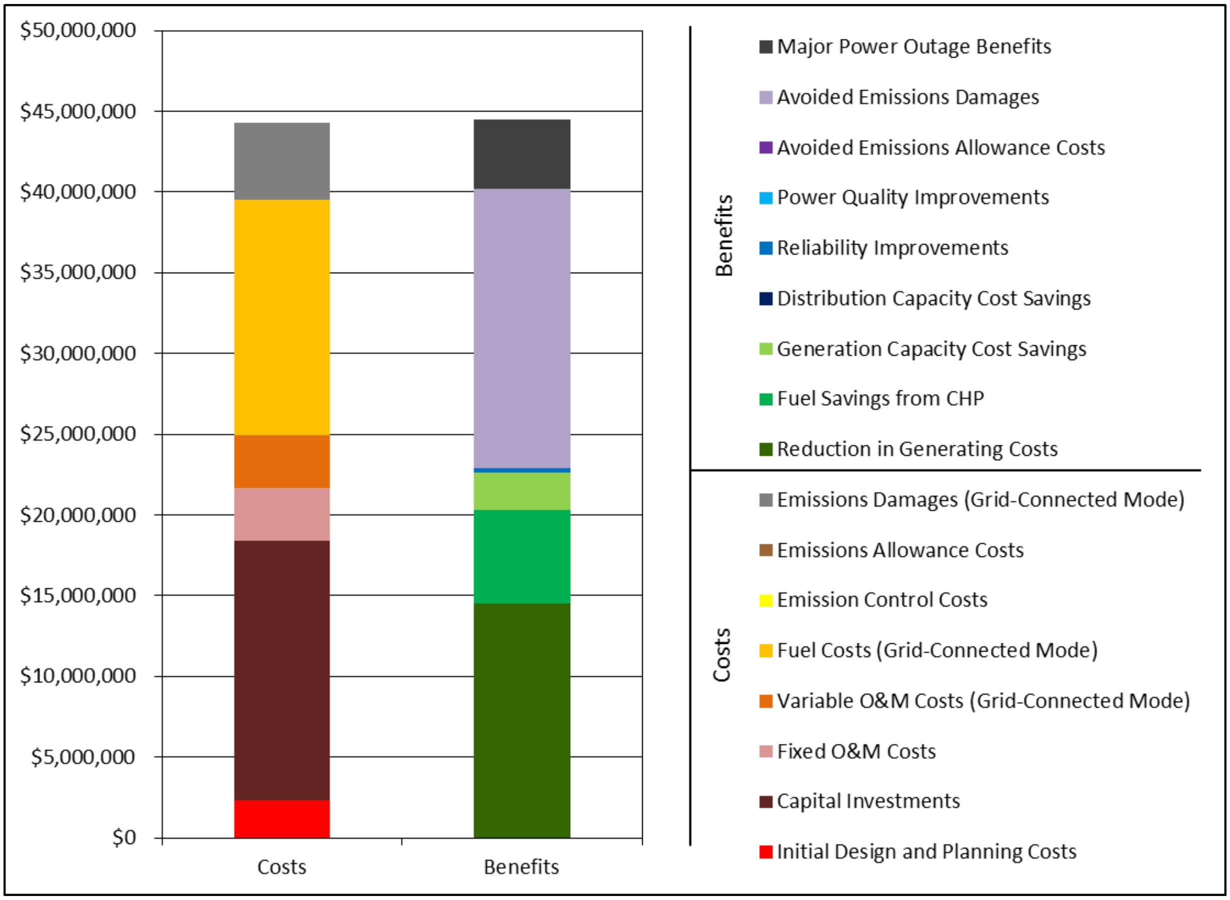


*Figure 40. Present Value Results, Scenario 2 (Major Power Outages Averaging 1.5 Days/Year; 7 Percent Discount Rate)*

*Table 31. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 1.5 Days/Year; 7 Percent Discount Rate)*

| Cost Or Benefit Category | Present Value Over 20 Years (2014$) | Annualized Value (2014$) |
|---|---|---|
| Costs | | |
| Initial Design and Planning | $2,330,000 | $205,000 |
| Capital Investments | $16,000,000 | $1,320,000 |
| Fixed O&M | $3,270,000 | $289,000 |
| Variable O&M (Grid-Connected Mode) | $3,270,000 | $289,000 |
| Fuel (Grid-Connected Mode) | $14,600,000 | $1,290,000 |
| Emission Control | $0 | $0 |
| Emissions Allowances | $0 | $0 |
| Emissions Damages (Grid-Connected Mode) | $4,820,000 | $315,000 |
| Total Costs | **$44,300,000** | |
| Benefits | | |
| Reduction in Generating Costs | $14,500,000 | $1,280,000 |
| Fuel Savings from CHP | $5,780,000 | $510,000 |
| Generation Capacity Cost Savings | $2,320,000 | $205,000 |
| Distribution Capacity Cost Savings | $0 | $0 |
| Reliability Improvements | $281,000 | $24,800 |
| Power Quality Improvements | $0 | $0 |
| Avoided Emissions Allowance Costs | $8,390 | $740 |
| Avoided Emissions Damages | $17,300,000 | $1,130,000 |
| Major Power Outage Benefits | $4,260,000 | $376,000 |
| **Total Benefits** | **$44,500,000** | |
| **Net Benefits** | **$158,000** | |
| **Benefit/Cost Ratio** | **1.0** | |
| **Internal Rate of Return** | **4.7%** | |

# Appendix C

## NY Prize Benefit-Cost Analysis: Microgrid Questionnaire

This questionnaire solicits information on the community microgrid you are proposing for the NY Prize competition. The information in this questionnaire will be used to develop a preliminary benefit-cost analysis of the proposed microgrid. Please provide as much detail as possible. The questionnaire is organized into the following sections:



If you have any questions regarding the information requested, please contact Industrial Economics, Incorporated, either by email (NYPrize@indecon.com) or phone (929-445-7641).

Microgrid site: Choose an item.

Point of contact for this questionnaire:


Name: Steve Heinzelman

Address: 807 Ridge Road, Suite 210B | Webster, NY 14580

Telephone: 585-750-7728

Email: sheinzelman@willdan.com


### *A. Project Overview, Energy Production, and Fuel Use*

1. The table below is designed to gather background information on the facilities your microgrid would serve. It includes two examples: one for Main Street Apartments, a residential facility with multiple utility customers; and another for Main Street Grocery, a commercial facility. Please follow these examples in providing the information specified for each facility. Additional guidance is provided below.

- **Facility name:** Please enter the name of each facility the microgrid would serve. Note that a single **facility** may include multiple **customers** (e.g., individually-metered apartments within a multi-family apartment building). When this is the case, you do not need to list each customer individually; simply identify the facility as a whole (see Table 1, "Main Street Apartments," for an example).
- **Rate class:** Select the appropriate rate class for the facility from the dropdown list. Rate class options are residential, small commercial/industrial (defined as a facility using less than 50 MWh of electricity per year), or large commercial/industrial (defined as a facility using 50 or more MWh of electricity per year).
- **Facility/customer description:** Provide a brief description of the facility, including the number of individual customers at the facility if it includes more than one (e.g., individually-metered apartments within a multi-family apartment building). For commercial and industrial facilities, please describe the type of commercial/industrial activity conducted at the facility.
- **Economic sector:** Select the appropriate economic sector for the facility from the dropdown list.
- **Average annual usage:** Specify the average annual electricity usage (in MWh) **per customer**. Note that in the case of facilities with multiple, similar customers, such as multi-family apartment buildings, this value will be different from average annual usage for the facility as a whole.
- **Peak demand:** Specify the peak electricity demand (in MW) **per customer**. Note that in the case of facilities with multiple, similar customers, such as multi-family apartment buildings, this value will be different from peak demand for the facility as a whole.
- **Percent of average usage the microgrid could support in the event of a major power outage:** Specify the percent of each facility's typical usage that the microgrid would be designed to support in the event of a major power outage (i.e., an outage lasting at least 24 hours that necessitates that the microgrid operate in islanded mode). In many cases, this will be 100%. In some cases, however, the microgrid may be designed to provide only enough energy to support critical services (e.g., elevators but not lighting). In these cases, the value you report should be less than 100%.
- **Hours of electricity supply required per day in the event of a major power outage:** Please indicate the number of hours per day that service to each facility would be maintained by the microgrid in the event of a major outage. Note that this value may be less than 24 hours for some facilities; for example, some commercial facilities may only require electricity during business hours.

| Facility Name | Rate Class | Facility/Customer Description (Specify Number of Customers if More Than One) | Economic Sector Code | 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 Supply Required Per Day During Major Power Outage |
|---|---|---|---|---|---|---|---|
| SUNY Geneseo Campus | Large Commercial/Industrial (>50 annual MWh) | University campus consisting of over 50 buildings | All other industries | 22909 | 4.8 | 100% | 24 |
| Wastewater treatment plant | Small Commercial/Industrial (<50 annual MWh) | Village of Geneseo-owned wastewater treatment plant | All other industries | 24.7 | 0.004 | 100% | 24 |
| 119 Main Street | Large Commercial/Industrial (>50 annual MWh) | Building housing Village of Geneseo offices, court, and police | All other industries | 53.8 | 0.02 | 100% | 24 |
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| | Choose an item. | | Choose an item. | | | | |
| | Choose an item. | | Choose an item. | | | | |
| | Choose an item. | | Choose an item. | | | | |

2. In the table below, please provide information on the distributed energy resources the microgrid will incorporate. Use the two examples included in the table as a guide.

- **Distributed energy resource name:** Please identify each distributed energy resource with a brief description. In the event that a single facility has multiple distributed energy resources of the same type (e.g., two diesel generators), please use numbers to uniquely identify each (e.g., "Diesel generator 1" and "Diesel generator 2").
- **Facility name:** Please specify the facility at which each distributed energy resource is or would be based.
- **Energy source:** Select the fuel/energy source used by each distributed energy resource from the dropdown list. If you select "other," please type in the energy source used.
- **Nameplate capacity:** Specify the total nameplate capacity (in MW) of each distributed energy resource included in the microgrid.
- **Average annual production:** Please estimate the amount of electricity (in MWh) that each distributed energy resource is likely to produce each year, on average, **under normal operating conditions.** The benefit-cost analysis will separately estimate production in islanded mode in the event of an extended power outage. **If the distributed energy resource will operate only in the event of an outage, please enter zero.**
- **Average daily production in the event of a major power outage:** Please estimate the amount of electricity (in MWh per day) that each distributed energy resource is likely to produce, on average, **in the event of a major power outage.** In developing your estimate for each distributed energy resource, you should consider the electricity requirements of the facilities the microgrid would serve, as specified in your response to Question 1.
- **Fuel consumption per MWh:** For each distributed energy resource, please estimate the amount of fuel required to generate one MWh of energy. This question does not apply to renewable energy resources, such as wind and solar.

| Distributed Energy Resource Name | Facility Name | Energy Source | Nameplate Capacity (MW) | Average Annual Production Under Normal Conditions (MWh) | Average Daily Production During Major Power Outage (MWh) | Fuel Consumption per MWh | |
|---|---|---|---|---|---|---|---|
| | | | | | | Quantity | Unit |
| CHP Generator | Central heating plant | Natural Gas | 2.4 | 20,239 | 55.4 | 9.3 | MMBtu/MWh |
| Solar | Land adjacent to campus | Solar | 2 | 2920 | 8 | N/A | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |

***B.*** *Capacity Impacts*

3. Is development of the microgrid expected to reduce the need for bulk energy suppliers to expand generating capacity, either by directly providing peak load support or by enabling the microgrid's customers to participate in a demand response program?

☒ No – proceed to Question 6

☐ Yes, both by providing peak load support and by enabling participation in a demand response program – proceed to Question 4

☐ Yes, by providing peak load support only – proceed to Question 4

☐ Yes, by enabling participation in a demand response program only – proceed to Question 5

Provision of Peak Load Support

4. Please provide the following information for all distributed energy resources that would be available to provide peak load support:

- **Available capacity:** Please indicate the capacity of each distributed energy resource that would be available to provide peak load support (in MW/year).
- **Current provision of peak load support, if any:** Please indicate whether the distributed energy resource currently provides peak load support.

Please use the same distributed energy resource and facility names from Question 2.

| Distributed Energy Resource Name | Facility Name | Available Capacity (MW/year) | Does distributed energy resource currently provide peak load support? |
|---|---|---|---|
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |

If development of the microgrid is also expected to enable the microgrid's customers to participate in a demand response program, please proceed to Question 5. Otherwise, please proceed to Question 6.

### Participation in a Demand Response Program

5. Please provide the following information for each facility that is likely to participate in a demand response program following development of the microgrid:

- **Available capacity:** Please estimate the capacity that would be available to participate in a demand response program (in MW/year) following development of the microgrid.
- **Capacity currently participating in a demand response program, if any:** Please indicate the capacity (in MW/year), if any, that currently participates in a demand response program.

| Facility Name | Capacity Participating in Demand Response Program (MW/year) | |
|---|---|---|
| | Following Development of Microgrid | Currently |
| | | |
| | | |
| | | |
| | | |
| | | |
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| | | |

6. Is development of the microgrid expected to enable utilities to avoid or defer expansion of their transmission or distribution networks?

☐ Yes – proceed to Question 7

☒ No – proceed to Section C

7. Please estimate the impact of the microgrid on utilities' **transmission** capacity requirements. The following question will ask about the impact on distribution capacity.

| Impact of Microgrid on Utility Transmission Capacity | Unit |
|---|---|
| | MW/year |

8. Please estimate the impact of the microgrid on utilities' **distribution** capacity requirements.

| Impact of Microgrid on Utility Distribution Capacity | Unit |
|---|---|
| | MW/year |

## ***C.*** *Project Costs*

We are interested in developing a year-by-year profile of project costs over a 20-year operating period. The following questions ask for information on specific categories of costs.

### Capital Costs

9. In the table below, please estimate the fully installed cost and lifespan of all equipment associated with the microgrid, including equipment or infrastructure associated with power generation (including combined heat and power systems), energy storage, energy distribution, and interconnection with the local utility.

| Capital Component | Installed Cost ($) | Component Lifespan (round to nearest year) | Description of Component |
|---|---|---|---|
| CHP | 7,295,878 | 20 | |
| Solar | 6,500,000 | 30 | |
| Distribution lines - Underground | 4,356,000 | 40 | |
| Transformer | 53,000 | 20 | |
| S&C PME Switch | 18,500 | 20 | |
| Smart Switch | 18,000 | 20 | |
| Automatic Transfer Switch | 685 | 20 | |
| 35kV breaker | 40,000 | 20 | |
| 12.47kV breaker | 15,000 | 20 | |
| 1500A PANELBOARD (208V) | 18,000 | 20 | |

| Capital Component | Installed Cost ($) | Component Lifespan (round to nearest year) | Description of Component |
|---|---|---|---|
| Manhole | 3,750 | 40 | |
| Building Controller | 700 | 15 | |
| Wired Communication in Buildings | 80,000 | 15 | |
| Master Controller | 100,000 | 25 | |
| Smart Meters | 1,000 | 15 | |
| E Bridge/Repeater | 350 | 15 | |
| Access Point | 1,500 | 15 | |
| Fiber Optic | 100,000 | 15 | |
| Relay | 3,000 | 20 | |
| Automatic Generation Controller | 2,508 | 20 | |
| SCADA Software | 100,000 | 25 | |
| OSIsoft Data Historian (PI) Full (50,000 tags) | 537,500 | 25 | |
| OSIsoft Data Historian (PI) Full (50,000 tags) + training | 690,625 | 25 | |

## Initial Planning and Design Costs

10. Please estimate initial planning and design costs. These costs should include costs associated with project design, building and development permits, efforts to secure financing, marketing the project, and negotiating contracts. Include only upfront costs. Do not include costs associated with operation of the microgrid.

| Initial Planning and Design Costs ($) | What cost components are included in this figure? |
|---|---|
| $2,979,599 | 15% of installed cost |

## Fixed O&M Costs

11. Fixed O&M costs are costs associated with operating and maintaining the microgrid that are unlikely to vary with the amount of energy the system produces each year (e.g., software licenses, technical support). Will there be any year-to-year variation in these costs for other reasons (e.g., due to maintenance cycles)?

☒ No – proceed to Question 12

☐ Yes – proceed to Question 13

12. Please estimate any costs associated with operating and maintaining the microgrid that are unlikely to vary with the amount of energy the system produces each year.

| Fixed O&M Costs ($/year) | What cost components are included in this figure? |
|---|---|
| 288,750 | Routine inspections, scheduled maintenance |

Please proceed to Question 14.

13. For each year over an assumed 20-year operating life, please estimate any costs associated with operating and maintaining the microgrid that are unlikely to vary with the amount of energy the system produces.

| Year | Fixed O&M Cost ($) | What cost components are included in this figure? |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |
| 16 | | |
| 17 | | |
| 18 | | |
| 19 | | |
| 20 | | |

## Variable O&M Costs (Excluding Fuel Costs)

14. Please estimate any costs associated with operating and maintaining the microgrid (excluding fuel costs) that are likely to vary with the amount of energy the system produces each year. Please estimate these costs per unit of energy produced (e.g., $/MWh).

| Variable O&M Costs ($/Unit of Energy Produced) | Unit | What cost components are included in this figure? |
|---|---|---|
| 12.47 | $/MWh | Overhauls, operating labor |
| | Choose an item. | |
| | Choose an item. | |
| | Choose an item. | |
| | Choose an item. | |

## Fuel Costs

15. In the table below, please provide information on the fuel use for each distributed energy resource the microgrid will incorporate. Please use the same distributed energy resource and facility names from Question 2.

- **Duration of design event:** For each distributed energy resource, please indicate the maximum period of time in days that the distributed energy resource would be able to operate in islanded mode without replenishing its fuel supply (i.e., the duration of the maximum power outage event for which the system is designed). **For renewable energy resources, your answer may be "indefinitely."**
- **Fuel consumption:** For each distributed energy resource that requires fuel, please specify the quantity of fuel the resource would consume if operated in islanded mode for the assumed duration of the design event.

| Distributed Energy Resource Name | Facility Name | Duration of Design Event (Days) | Quantity of Fuel Needed to Operate in Islanded Mode for Duration of Design Event | Unit |
|---|---|---|---|---|
| CHP Generator | SUNY Geneseo | Indefinite | | Choose an item. |
| Solar | SUNY Geneseo | Indefinite | | Choose an item. |
| | | | | Choose an item. |
| | | | | Choose an item. |
| | | | | Choose an item. |

16. Will the project include development of a combined heat and power (CHP) system?

☒ Yes – proceed to Question 17

☐ No – proceed to Question 18

17. If the microgrid will include development of a CHP system, please indicate the type of fuel that will be offset by use of the new CHP system and the annual energy savings (relative to the current heating system) that the new system is expected to provide.

| Type of Fuel Offset by New CHP System | Annual Energy Savings Relative to Current Heating System | Unit |
|---|---|---|
| Natural gas | 67,617 | MMBtu |
| Other - please specify: electricity | 5,347 | MMBtu |
| Choose an item. | | Choose an item. |
| Choose an item. | | Choose an item. |
| Choose an item. | | Choose an item. |

Emissions Control Costs

18. We anticipate that the costs of installing and operating emissions control equipment will be incorporated into the capital and O&M cost estimates you provided in response to the questions above. If this is not the case, please estimate these costs, noting what cost components are included in these estimates. For capital costs, please also estimate the engineering lifespan of each component.

| Cost Category | Costs ($) | Description of Component(s) | Component Lifespan(s) (round to nearest year) |
|---|---|---|---|
| Capital Costs ($) | | | |
| Annual O&M Costs ($/MWh) | | | |
| Other Annual Costs ($/Year) | | | |

19. Will environmental regulations mandate the purchase of emissions allowances for the microgrid (for example, due to system size thresholds)?

☐ Yes

☒ No

***D. Environmental Impacts***

20. For each pollutant listed below, what is the estimated emissions rate (e.g., tons/MWh) for the microgrid?

| Emissions Type | Emissions per MWh | Unit |
|---|---|---|
| $CO_2$ | 0.199609885 | Short tons/MWh |
| $SO_2$ | 1.70607E-06 | Short tons/MWh |
| $NO_x$ | 1.27955E-05 | Short tons/MWh |
| PM | 1.27119E-05 | Short tons/MWh |

## *E. Ancillary Services*

21. Will the microgrid be designed to provide any of the following ancillary services? If so, we may contact you for additional information.

| Ancillary Service | Yes | No |
|---|---|---|
| Frequency or Real Power Support | ☒ | ☐ |
| Voltage or Reactive Power Support | ☒ | ☐ |
| Black Start or System Restoration Support | ☐ | ☒ |

## *F. Power Quality and Reliability*

22. Will the microgrid improve power quality for the facilities it serves?

☐ Yes – proceed to Question 23

☒ No – proceed to Question 24

23. If the microgrid will result in power quality improvements, how many power quality events (e.g., voltage sags, swells, momentary outages) will the microgrid avoid each year, on average? Please also indicate which facilities will experience these improvements.

| Number of Power Quality Events Avoided Each Year | Which facilities will experience these improvements? |
|---|---|
| | |

24. The benefit-cost analysis model will characterize the potential reliability benefits of a microgrid based, in part, on standard estimates of the frequency and duration of power outages for the local utility. In the table below, please estimate your local utility's average **outage frequency per customer** (system average interruption frequency index, or SAIFI, in events per customer per year) and average **outage duration per customer** (customer average interruption duration index, or CAIDI, in hours per event per customer).

For reference, the values cited in the Department of Public Service's 2014 Electric Reliability Performance Report are provided on the following page. If your project would be located in an area served by one of the utilities listed, please use the values given for that utility. If your project would be located in an area served by a utility that is not listed, please provide your best estimate of SAIFI and CAIDI values for the utility that serves your area. In developing your estimate, please *exclude* outages caused by major storms (a major storm is defined as any storm which causes service interruptions of at least 10 percent of customers in an operating area, and/or interruptions with duration of 24 hours or more). This will ensure that your estimates are consistent with those provided for the utilities listed on the following page.[1]

| Estimated SAIFI | Estimated CAIDI |
|---|---|
| 0.85 | 2.32 |

SAIFI and CAIDI Values for 2014, as reported by DPS

| Utility | SAIFI (events per year per customer) | CAIDI (hours per event per customer) |
|---|---|---|
| Central Hudson Gas & Electric | 1.62 | 3.74 |
| ConEdison | 0.11 | 3.09 |
| PSEG Long Island | 0.76 | 1.42 |
| National Grid | 1.17 | 2.87 |
| New York State Electric & Gas | 1.34 | 2.97 |
| Orange & Rockland | 1.19 | 2.4 |
| Rochester Gas & Electric | 0.85 | 2.32 |
| *Statewide* | *0.68* | *2.7* |
| Source: New York State Department of Public Service, Electric Distribution Systems Office of Electric, Gas, and Water. June 2015. 2014 Electric Reliability Performance Report, accessed at: http://www3.dps.ny.gov/W/PSCWeb.nsf/All/D82A200687D96D3985257687006F39CA?OpenDocument. | | |

[1] The DPS service interruption 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 Con Edison's underground network system). SAIFI and CAIDI 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. The BCA model treats the benefits of averting lengthy outages caused by major storms as a separate category; therefore, the analysis of reliability benefits focuses on the effect of a microgrid on SAIFI and CAIDI values that exclude outages caused by major storms.

***G.*** *Other Information*

25. If you would like to include any other information on the proposed microgrid, please provide it here.

One other piece of the project is diverting food waste from the dining halls to the under-utilized digester at the wastewater treatment plant to produce methane in addition to the methane that is already being produced and flared. Based on the small size of the plant, the most likely scenario is to simply negotiate a contract with RG&E to inject the gas into their existing lines. The estimated volume of gas is 6,835,743 ft3/year. Estimating a wholesale price of $0.39/ccf, the revenue would be $26,659. The estimated capital investment is $400,000.

# Appendix D

## NY Prize Benefit-Cost Analysis: Facility Questionnaire

This questionnaire requests information needed to estimate the impact that a microgrid might have in protecting the facilities it serves from the effects of a major power outage (i.e., an outage lasting at least 24 hours). The information in this questionnaire will be used to develop a preliminary benefit-cost analysis of the community microgrid you are proposing for the NY Prize competition. Please provide as much detail as possible.

For each facility that will be served by the microgrid, we are interested in information on:

I. Current backup generation capabilities.

II. The costs that would be incurred to maintain service during a power outage, both when operating on its backup power system (if any) and when backup power is down or not available.

III. The types of services the facility provides.

If you have any questions regarding the information requested, please contact Industrial Economics, Incorporated, either by email (NYPrize@indecon.com) or phone (929-445-7641).

Microgrid site: 77. Village of Geneseo (SUNY)

Point of contact for this questionnaire:

Name:Steve Heinzelman

Address:807 Ridge Road, Suite 210B | Webster, NY  14580

Telephone: 585-750-7728

Email: sheinzelman@willdan.com

### I. Backup Generation Capabilities

1. Do any of the facilities that would be served by the microgrid currently have backup generation capabilities?
    a. ☐ No - proceed to Question 4
    b. ☒ Yes - proceed to Question 2

2. For each facility that is equipped with a backup generator, please complete the table below, following the example provided. Please include the following information:

    a. **Facility name:** For example, “Main Street Apartments.”

    b. **Identity of backup generator:** For example, “Unit 1.”

c. **Energy source:** Select the fuel/energy source used by each backup generator from the dropdown list. If you select "other," please type in the energy source used.

d. **Nameplate capacity:** Specify the nameplate capacity (in MW) of each backup generator.

e. **Standard operating capacity:** Specify the percentage of nameplate capacity at which the backup generator is likely to operate during an extended power

f. **Average electricity production per day in the event of a major power outage**: Estimate the average daily electricity production (MWh per day) for the generator in the event of a major power outage. In developing the estimate, please consider the unit's capacity, the daily demand at the facility it serves, and the hours of service the facility requires.

outage.

g. **Fuel consumption per day:** Estimate the amount of fuel required per day (e.g., MMBtu per day) to generate the amount of electricity specified above. This question does not apply to renewable energy resources, such as wind and solar.

h. **One-time operating costs:** Please identify any one-time costs (e.g., labor or contract service costs) associated with connecting and starting the backup generator.

i. **Ongoing operating costs:** Estimate the costs ($/day) (e.g., maintenance costs) associated with operating the backup generator, excluding fuel costs.

Note that backup generators may also serve as distributed energy resources in the microgrid. Therefore, there may be some overlap between the information provided in the table below and the information provided for the distributed energy resource table (Question 2) in the general Microgrid Data Collection Questionnaire.

| Facility Name | Generator ID | Energy Source | Nameplate Capacity (MW) | Standard Operating Capacity (%) | Avg. Daily Production During Power Outage (MWh/Day) | Fuel Consumption per Day | | One-Time Operating Costs ($) | Ongoing Operating Costs ($/Day) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Quantity | Unit | | |
| SUNY Geneseo | Bailey | Diesel | 0.250 | 100 | 5.4 | 480 | Gallons | 100 | |
| SUNY Geneseo | College Union | Natural Gas | 0.045 | 100 | 0.972 | 680 | cf/h | 100 | |
| SUNY Geneseo | DOTY | Natural Gas | 0.45 | 100 | 9.72 | 5890 | cf/h | 100 | |
| SUNY Geneseo | Erwin | Natural Gas | 0.1 | 100 | 2.16 | 1276 | cf/h | 100 | |

| Facility Name | Generator ID | Energy Source | Nameplate Capacity (MW) | Standard Operating Capacity (%) | Avg. Daily Production During Power Outage (MWh/Day) | Fuel Consumption per Day | | One-Time Operating Costs ($) | Ongoing Operating Costs ($/Day) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Quantity | Unit | | |
| SUNY Geneseo | Heating Plant | Natural Gas | 0.15 | 100 | 3.24 | 8 | Ft3/mo (test mode) | 100 | |
| SUNY Geneseo | ISC | Natural Gas | 0.45 | 100 | 9.72 | 5551 | cf/h | 100 | 100 |
| SUNY Geneseo | Letchworth Dining Hall | Diesel | 0.2 | 100 | 4.32 | 384 | Gallons | 100 | 100 |
| SUNY Geneseo | Milne Library | Natural Gas | 0.0125 | 100 | 0.27 | 277 | cf/h | 100 | 100 |
| SUNY Geneseo | Red Jacket | Natural Gas | 0.085 | 100 | 1.836 | 1,190,595 | Btu/h | 100 | 100 |
| SUNY Geneseo | Saratoga Heating Plant | Diesel | 0.250 | 100 | 5.4 | 480 | Gallons | 100 | 100 |
| SUNY Geneseo | South Hall | Natural Gas | 0.130 | 100 | 2.808 | 1420 | cf/h | 100 | 100 |
| SUNY Geneseo | Welles | Natural Gas | 0.0185 | 100 | 0.3996 | 277 | cf/h | 100 | 100 |
| SUNY Geneseo | Erie | Natural Gas | 0.04 | 100 | 0.864 | 584 | cf/h | 100 | 100 |
| SUNY Geneseo | Geneseo | Natural Gas | 0.035 | 100 | 0.756 | 585 | cf/h | 100 | 100 |
| SUNY Geneseo | Jones | Natural Gas | 0.03 | 100 | 0.648 | 572 | cf/h | 100 | 100 |
| SUNY Geneseo | Jones (cogen) | Natural Gas | 0.03 | 100 | 0.648 | 430 | cf/h | 100 | 100 |
| SUNY Geneseo | Livingston (cogen) | Natural Gas | 0.03 | 100 | 0.648 | 535,819 | Btu/h | 100 | 100 |
| SUNY Geneseo | Nassau | Natural Gas | 0.035 | 100 | 0.756 | 535,819 | Btu/h | 100 | 100 |
| SUNY Geneseo | Niagara | Natural Gas | 0.035 | 100 | 0.756 | 873,915 | Btu/h | 100 | 100 |
| SUNY Geneseo | Onondaga | Natural Gas | 0.06 | 100 | 1.296 | 585 | cf/h | 100 | 100 |
| SUNY Geneseo | Putnam | Diesel | 0.035 | 100 | 0.756 | 67.2 | Gallons | 100 | 100 |
| SUNY Geneseo | Seneca | Natural Gas | 0.25 | 100 | 5.4 | 277 | cf/h | 100 | 100 |
| SUNY Geneseo | Steuben | Natural Gas | 0.015 | 100 | 0.324 | 535,819 | Btu/h | 100 | 100 |
| SUNY Geneseo | Suffolk | Natural Gas | 0.035 | 100 | 0.756 | 535,819 | Btu/h | 100 | 100 |
| SUNY Geneseo | Wayne | Diesel | 0.035 | 100 | 0.756 | 67.2 | Gallons | 100 | 100 |

| Facility Name | Generator ID | Energy Source | Nameplate Capacity (MW) | Standard Operating Capacity (%) | Avg. Daily Production During Power Outage (MWh/Day) | Fuel Consumption per Day | | One-Time Operating Costs ($) | Ongoing Operating Costs ($/Day) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Quantity | Unit | | |
| Geneseo Wastewater Treatment Plant | Unit 1 | Diesel | 0.30 | 85 | 6.12 | 27.0 | MMBtu/hr | 1000 | 900 |

## II. Costs of Emergency Measures Necessary to Maintain Service

We understand that facilities may have to take emergency measures during a power outage in order to maintain operations, preserve property, and/or protect the health and safety of workers, residents, or the general public. These measures may impose extraordinary costs, including both one-time expenditures (e.g., the cost of evacuating and relocating residents) and ongoing costs (e.g., the daily expense of renting a portable generator). The questions below address these costs. We begin by requesting information on the costs facilities would be likely to incur when operating on backup power. We then request information on the costs facilities would be likely to incur when backup power is not available.

3. Please provide information in the table following for each facility the microgrid would serve which is currently equipped with some form of backup power (e.g., an emergency generator). For each facility, please describe the costs of any emergency measures that would be necessary in the event of a widespread power outage (i.e., a total loss of power in the area surrounding the facility lasting at least 24 hours). In completing the table, please assume that the facility's backup power system is fully operational. In your response, please describe and estimate the costs for:
    a. One-time emergency measures (total costs)
    b. Ongoing emergency measures (costs per day)

### *A. Cost of Maintaining Service while Operating on Backup Power*

Note that these measures do not include the costs associated with running the facility's existing backup power system, as estimated in the previous question.

In addition, for each emergency measure, please provide additional information related to when the measure would be required. For example, measures undertaken for heating purposes may only be required during winter months. As another example, some commercial facilities may undertake emergency measures during the work week only.

As a guide, see the examples the table provides.

| Facility Name | Type of Measure (One-Time or Ongoing) | Description | Costs | Units | When would these measures be required? |
|---|---|---|---|---|---|
| SUNY Geneseo | Ongoing Measures | Staff to oversee safety and logistics | 1000 | $/day | Each power outage |
| | Choose an item. | | | | |
| | Choose an item. | | | | |

4. Please provide information in the table below for each facility the microgrid would serve. For each facility, please describe the costs of any emergency measures that would be necessary in the event of a widespread power outage (i.e., a total loss of power in the area surrounding the facility lasting at least 24 hours). In completing the table, please assume that service from any backup generators currently on-site is not available. In your response, please describe and estimate the costs for:
    a. One-time emergency measures (total costs)
    b. Ongoing emergency measures (costs per day)

## B. *Cost of Maintaining Service while Backup Power is Not Available*

In addition, for each emergency measure, please provide additional information related to when the measure would be required. For example, measures undertaken for heating purposes may only be required during winter months. As another example, some commercial facilities may undertake emergency measures during the work week only.

As a guide, see the examples the table provides.

| Facility Name | Type of Measure (One-Time or Ongoing) | Description | Costs | Units | When would these measures be required? |
|---|---|---|---|---|---|
| Geneseo Waste-water plant | One-Time Measures | Hooking up additional portable generator | 2500 | $ | Year-round |
| Geneseo Waste-water plant | Ongoing Measures | Renting additional portable generator | 1,000 | $/day | Year-round |
| Village offices | Ongoing Measures | Renting portable generator | $150/day | | Year round, 7 days/week |
| Village offices | Ongoing Measures | Fuel for generator | 77 | $/day | Year-round |
| SUNY Geneseo | Ongoing Measures | Renting portable generator | 3,000 | $/day | Year-round |
| SUNY Geneseo | One-Time Measures | Hooking up portable generator | 7500 | $ | Year-round |
| SUNY Geneseo | Ongoing Measures | Staff to oversee safety and logistics | 5000 | $/day | Year-round |
| SUNY Geneseo | Ongoing Measures | Fuel for generator | 3456 | $/day | Year-round |

## III. Services Provided

We are interested in the types of services provided by the facilities the microgrid would serve, as well as the potential impact of a major power outage on these services. As specified below, the information of interest includes some general information on all facilities, as well as more detailed information on residential facilities and critical service providers (i.e., facilities that provide fire, police, hospital, water, wastewater treatment, or emergency medical services (EMS)).

During a power outage, is each facility able to provide the same level of service when using backup generation as under normal operations? If not, please estimate the percent loss in the services for each facility (e.g., 20% loss in services provided during outage while on backup power). As a guide, see the example the table provides.

| Facility Name | Percent Loss in Services When Using Backup Gen. |
| --- | --- |
| Geneseo Wastewater Plant | 5% |
| SUNY Geneseo | 40% |
| | |

### A. Questions for: ***All Facilities***

1. During a power outage, if backup generation is not available, is each facility able to provide the same level of service as under normal operations? If not, please estimate the percent loss in the services for each facility (e.g., 40% loss in services provided during outage when backup power is not available). As a guide, see the example the table provides.

| Facility Name | Percent Loss in Services When Backup Gen. is Not Available |
| --- | --- |
| SUNY Geneseo | 90% |
| Geneseo Wastewater Plant | 90% |
| Village building | 70% |

2. What is the total population served by the facility?

Click here to enter text.

***B. Questions for facilities that provide: Fire Services***

1. Please estimate the percent increase in average response time for this facility during a power outage:

   Click here to enter text.

2. What is the distance (in miles) to the nearest backup fire station or alternative fire service provider?

   Click here to enter text.

3. What is the total population served by the facility?

   Click here to enter text.

***C. Questions for facilities that provide: Emergency Medical Services (EMS)***

1. What is the distance (in miles) to the next nearest alternative EMS provider?
2. Is the area served by the facility primarily (check one):

   ☒ Urban
   ☐ Suburban
   ☐ Rural
   ☒ Wilderness

3. Please estimate the percent increase in average response time for this facility during a power outage:

   Click here to enter text.

4. What is the total population served by the facility?

   Click here to enter text.

***D. Questions for facilities that provide: Hospital Services***

1. What is the distance (in miles) to the nearest alternative hospital?

   Click here to enter text.

2. What is the population served by the nearest alternative hospital?

| |
|---|
| Click here to enter text. |

3. What is the total population served by the facility?

| |
|---|
| 8000 (Village offices) |

## ***E. Questions for facilities that provide: Police Services***

1. Is the facility located in a (check one):

   ☐ Metropolitan Statistical Area

   ☐ Non-Metropolitan City

   ☒ Non-Metropolitan County

2. Please estimate:

   a. The <u>number</u> of police officers working at the station under normal operations.

   | |
   |---|
   | 15 (SUNY Geneseo); 2-3 (Village offices) |

   b. The <u>number</u> of police officers working at the station during a power outage.

   | |
   |---|
   | 15 (SUNY Geneseo); 2-3 (Village offices) |

   c. The <u>percent reduction</u> in service effectiveness during an outage.

   | |
   |---|
   | 30 |

## ***F. Questions for facilities that provide: Wastewater Services***

1. Does the facility support (check one):

   ☐ Residential customers
   ☐ Businesses
   ☒ Both

2. What is the total population served by the facility?

| |
|---|
| 10,483 by 2010 census |

***G. Questions for facilities that provide: Water Services***

1. Does the facility support (check one):

   ☐ Residential customers
   ☐ Businesses
   ☒ Both

2. What is the total population served by the facility?

   | |
   |---|
   | Click here to enter text. |

***H. Questions for: Residential Facilities***

1. What types of housing does the facility provide (e.g., group housing, apartments, nursing homes, assisted living facilities, etc.)?

   | |
   |---|
   | Dorms, town houses |

2. Please estimate the number of residents that would be left without power during a complete loss of power (i.e., when backup generators fail or are otherwise not available).

   | |
   |---|
   | 3400 |

# Appendix E

This Appendix provides a brief analysis of the technical and economic potential for biogas production at the Geneseo wastewater treatment plant. Willdan recommends that if the village and university are interested in pursuing this project, they implement a pilot project to test the technical and economic feasibility. One reason for this recommendation is that different information sources give widely varying estimates for the gas production potential. Various sources indicated the number could be between 4 and 15 $ft^3$/lb of VS destroyed[1]. Other values, including the VS destruction and the heat content of the biogas, are dependent on the design of the digester, and the efficiency is dependent on the generation technology chosen. Costs can also vary widely depending on the design, and the composition of the feedstock and fuel tolerance of the engine can significantly affect costs. The table below outlines the gas production potential as well as costs as estimated by MRB Group. Based on the $57,767 annual power production value, a total capital cost of $1M, and annual O&M of $25,675, the project would have a 31 year payback period. This does not include any tipping fee or societal benefit calculations from removing food waste and other waste from the waste stream.

Table 32 indicates that the digester, as currently configured can accept approximately a ton of waste per day. SUNY Geneseo's Campus Auxiliary Services has estimated that the dining halls generate one ton of food waste per week during the academic year, although it's thought that the actual number may be a bit higher. Wegmans supermarket has also stated that they could provide 3-4 tons of food waste per week – this waste is currently being shipped to the Noblehurst digester. These two sources together would not provide a ton of waste per day, so in order to maximize the potential of the digester, waste would need to be collected from another source as well. One possibility is collecting waste from area farms. Another consideration is that any waste collected from the dining halls would need to be clean – it could not contain any plastic items that would clog the digester system.

[1] Two of these sources are Kanuparthy, Naga Bhanu Teja. "Feasibility of Upgrades to the Ithaca Area Wastewater Treatment Facility to Increase Its Biogas Output. A Thesis Presented to the Faculty of the Graduate School of Cornell University in Partial Fulfillment of the Requirements for the Degree of Master of Engineering." August 2010.
and
U.S. Environmental Protection Agency Region 9. "Anaerobic Digestion of Food Waste." Funding Opportunity No. EPA-R9-WST-06-004. Final Report, prepared by East Bay Municipal District. March 2008.
Other values were given in discussion with MRB Group and ClearCove.

*Table 32. Gas Production Potential*

| **Gas Production Potential** | |
|---|---|
| Existing lb/day VS to digester | 1700 - 1800 |
| Capacity lb/day VS to digester | 4000 |
| VS destruction (based on current design per MRB) | 50% |
| Destructive yield (SCF biogas/lb VS destroyed) | 15 |
| Annual biogas production ($ft^3$) | 10,950,000 |
| Gas to energy efficiency | 40% |
| Btu/SCF for biogas | 500 |
| Energy produced (Btu) | 2,190,000,000 |
| Energy produced (kWh) | 641,852 |
| Value of energy produced (assume $0.09/kWh) | $57,767 |
| **Costs** | |
| Auger conveyor ($200,000 - $500,000) | $200,000 |
| Gas pressure booster system | $200,000 |
| NG recip. Engine (assume $600/kW) | $75,000 |
| Engine O&M (assume $0.04/kWh) | $25,675 |
| Miscellaneous piping, gas storage | $100,000 |
| Gas cleaning | ??? |
| Upgrades to sludge drying beds if secondary digester converted to primary (may be able to use less expensive method of dewatering sludge) | $1-$1.5 million |
| Heating, mixing, sludge thickening equipment to utilize secondary digester as primary (would double VS capacity) | $500,000 |