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August 2016

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NY Prize City of Schenectady Community Microgrid Stage 1 Feasibility Study

NYSERDA PROJECT #67216

Prepared for: **The City of Schenectady**

Prepared by: **ASI Energy**

GE Energy Consulting

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August 31, 2016

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Foreword

This report was prepared for the City of Schenectady by ASI Energy, General Electric International, Inc. (“GEII”); acting through its Energy Consulting group (“GE Energy Consulting”) based in Schenectady, NY, and Proctors and submitted to the NYSERDA. Questions and any correspondence concerning this document should be referred to:

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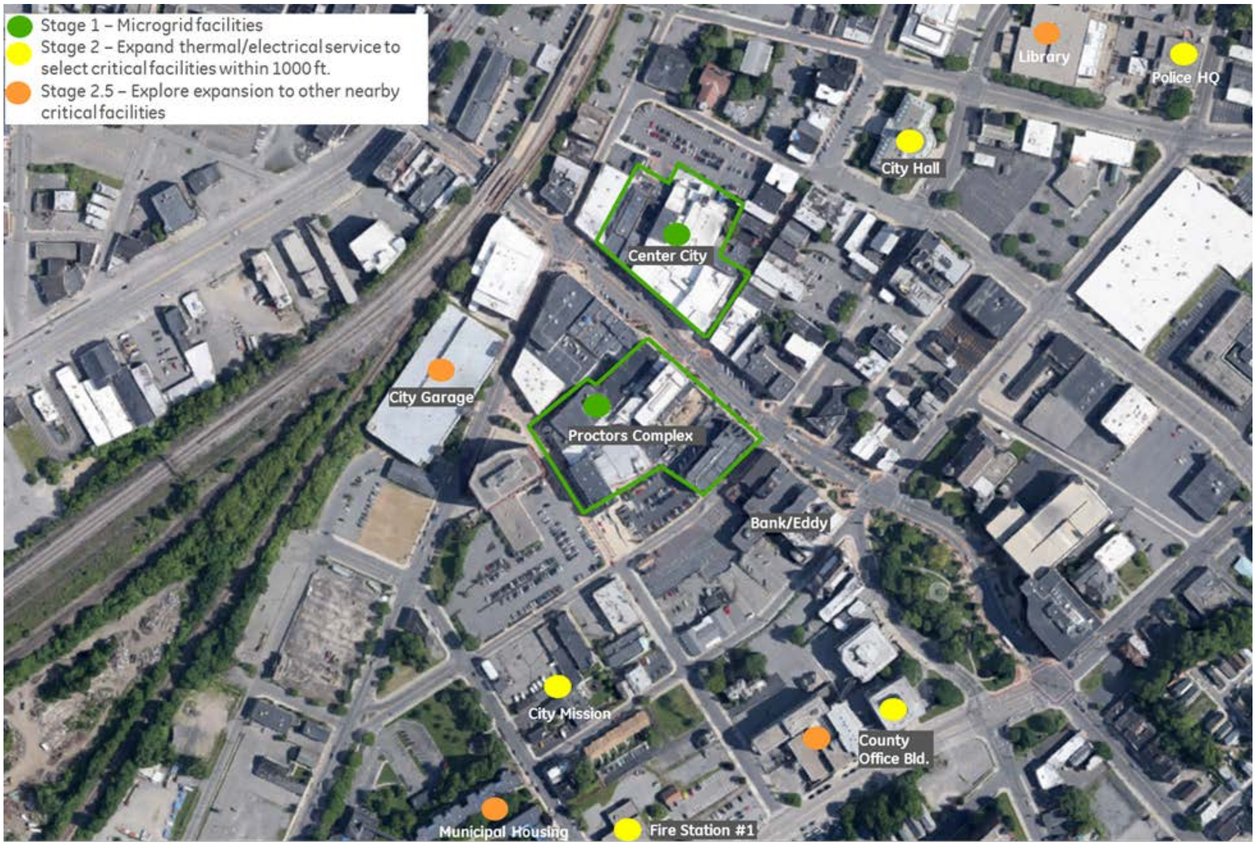
EXECUTIVE SUMMARY

The proposed Schenectady Community Microgrid project aims to solidify and strengthen recent efforts to revitalize the downtown Schenectady area while also enhancing the resiliency of the local power supply to grid outages and emergencies.

In 2004, Proctors embarked upon an expansion campaign that jumpstarted an abandoned downtown neighborhood, constructing a district energy system (DES) called Marquee Power to heat and cool most of the buildings on the block. Marquee Power has been an engine of redevelopment, lowering construction first-costs and maintenance costs, while increasing energy efficiency for its customers. It has leveraged more than $300 million in local redevelopment. The proposed microgrid will expand the Proctors DES to other customers on the North and South block of 400 State St, and provide resilient electrical service in addition to thermal service. This will further enhance Proctors' mission to revitalize the downtown area, lower construction and maintenance costs for redevelopment, and reduce the cost of energy.

The southern block includes: Proctors complex comprising an administration building, historic arcade and main theater, GE Theater, Marquee Power plant and Key Hall; the Parker Inn; TransFinder corporate headquarters; and the Hampton Inn. The northern block includes Center City which houses Wink, Metroplex, M/E Engineering, CVS Pharmacy, the YMCA and other offices. Both Proctors and Center City are designated places of refuge. Other critical facilities within a few blocks of Proctors which could be incorporated into the microgrid at various stages are identified with yellow and orange dots below.



Map Showing Critical Facilities in the Schenectady Community Microgrid Project within a 1,000-foot Radius

A key facility for the success of the project is the existing Marquee Power DES which currently has four 65-kW micro-turbines (not yet in service), a 250-kW diesel emergency standby generator, a 250-ton electric-screw chiller, two 500-ton electric centrifugal chillers, a 175-ton absorption, two 8780 BTU/hour hot-water boilers and one 3,655 BTU/hour hot-water boiler, a 1,000-ton evaporative-media tower, and a 500-ton air-cooled cooling tower. The project proposes to add a new 2,000 kW of combined cooling, heat, and power (CCHP) plant to the Marquee Power DES. The DES currently provides thermal services to the microgrid facilities. The facilities would be normally connected to the utility distribution system and microgrid generation would be used to offset grid consumption. During a grid outage, precipitated by a wide-scale emergency, the facilities will be connected directly to the microgrid generation which will supply both electrical and thermal needs.

Key features and benefits of the Schenectady microgrid include:

> **Serves Critical Services and Facilities of Refuge**: Critical loads supported during an outage include: multiple places of refuge at Proctors and Center City, which includes YMCA; and multiple commercial entities, which will be supplied with both electrical and thermal energy during prolonged outages in the early stages of the project. Other critical facilities include two emergency relief centers, three commercial kitchens, a bank, a pharmacy, two hotels and the telecommunications and physical infrastructure to accommodate relief effort coordination on the ground. There is also a potential for expansion of the microgrid in later phases to include emergency and life safety facilities such as Police and Fire HQ and an ambulance dispatch center; and residences for the elderly and economically disadvantaged.
>
> **Solid Financial Benefits**: The benefit-cost analysis (BCA) results highlight the potential of the project to provide a significant return on investment and to support the additional generation resource and by providing a business opportunity when the grid is down**.**
>
> **Improved System Design Redundancy**: The microgrid will functionally increase the resilience of electric service for all customers within the footprint, improving redundancy from “N-0” (typical of radial distribution systems) to “N-1” (typical of transmission systems and substations)[1]. Alternative solutions with commensurate benefits – e.g., building a feeder or substation – would cost an order of magnitude more to implement.
>
> **Provides Platform for Implementing REV Framework:** Potential REV related attributes to consider with the development of the Schenectady Community microgrid include Evaluation of the microgrid’s interaction with the distribution system platform (DSP) and the utility as the DSP provider, participation in the retail and wholesale market (i.e., market animation), and assessment of its operation under future LMP+D pricing schemes. In addition, the Schenectady microgrid will provide an opportunity to evaluate the potential for providing ancillary or grid-edge services, peak load support, and demand response to National Grid and its potential participation in the ISO energy, capacity, and ancillary services markets Depending on future regulatory and market developments in New York State, the microgrid owner may have opportunities to create new revenue streams similar to those being pursued by Community Choice Aggregation entities.

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[1] N-1 redundancy is a level of resilience that ensures system availability when a component fails.

Addressing Current Distribution System Issues: One of the barriers that this project will address is the technical challenge of back-feeding into a spot network without compromising the safe and reliable operation of the power system.

Several key findings and recommendations have also been identified through the process of completing this feasibility study. They include:

Findings

- When radial, spot and street network systems are intermixed in a single urban area, interconnection costs tend to increase significantly.
- The presence of a microgrid champion like Proctors Theater can accelerate and streamline the project development process
- Extant thermal district systems provide opportunities for deploying microgrids by allowing better matching of thermal and electrical loads and/or ensuring a higher utilization rate of generation assets.

Recommendations

- Clarify if and when microgrids must obtain a Certificate of Public Convenience and Necessity (CPCN) to install and operate electricity distribution facilities. In addition, clarify the circumstances under which microgrids qualify for an exemption from state regulation as an electric corporation.
- Consider creating a stakeholder collaborative to address challenges of interconnection for microgrid systems interconnected with more than one type of network system.
- Promote policies encouraging merchant microgrids to sell power or thermal energy to neighbors when doing so would take advantage of load diversity.
- Consider new regulatory models that recognize merchant microgrids as “mini-utilities” or establish “virtual private wires” regulations similar to those adopted in the United Kingdom, which allows CHP facilities to directly serve multiple public and private customers under the terms of a wheeling tariff with the local distribution company.

Background

The City of Schenectady, located on the south bank of the Mohawk River in Schenectady County, is an influential center of urban life, culture, and commerce in the Capital Region of New York State. Since 2004, Schenectady has undergone a renaissance leveraged by the expanded Proctors arts complex, two new hotels, a cinema, a dozen new restaurants, high technology companies, a YMCA, cafes, and loft housing in a resurging downtown district. The largest employers in the City are General Electric (“GE”), the Golub Corporation (owner of Price Chopper stores), Ellis Hospital, Schenectady County, Schenectady City School District, MVP Health Plan, and Union College. In the last several years, the community has brought in more than $600 million in new investment, with GE adding new jobs and technology companies such as Transfinder and Wink expanding in downtown Schenectady. With a resurging local economy informed by Smart Growth principles, there is a stated need for reliable, resilient power to meet expanding capacity and ensure the power quality required by high technology end-users.

Large portions of Schenectady, including sections of the downtown district and the historic Stockade neighborhood adjacent the microgrid footprint, are vulnerable to flooding. During Hurricane Irene in

2011, the Mohawk rose to over 26 feet, more than double the average elevation, flooding streets, homes, and buildings throughout Schenectady. A week later, Tropical Storm Lee caused more flooding in the Stockade, the East Front Street neighborhoods, and portions of downtown. The downtown district was evacuated. Electricity was out for almost a week and telephone service was limited. Due to the devastating impact of these weather events, the City is designated as a NY Rising community.


Schenectady after the storms
Source: Times Union

Most of the facilities in the microgrid area are served by National Grid's underground secondary network. Both proctors and Center City are on spot networks with no direct ties to the street grid. One of the barriers that this project will address is the technical challenge of back-feeding into a spot network without compromising the safe and reliable operation of the power system. Proctors and National Grid are currently working with GridEdge Technologies on a NYSERDA funded project (PON 3026) to test a PLC-based solution for desensitizing the existing network protectors to allow back-feed. The project team has high confidence that it will succeed in demonstrating a solution for underground applications, and has significant state and national implications for the development of microgrids, DERs, and innovative offerings in networked urban environments. However, the proposed microgrid will introduce a significant block of electrical load that would minimize the risk of back-feed. The design will also incorporate monitoring and control technology to allow rooftop PV and other DERs to supply the load in the network without putting the grid operation at risk. This will create opportunities for customers on the secondary network to interact with the grid, participate in the market, and define new streams of revenue and value.

Summary of Facility Loads

The table below lists the two major facilities in the microgrid as well as the electrical and thermal load and uses.

Summary of Schenectady Community Microgrid Loads

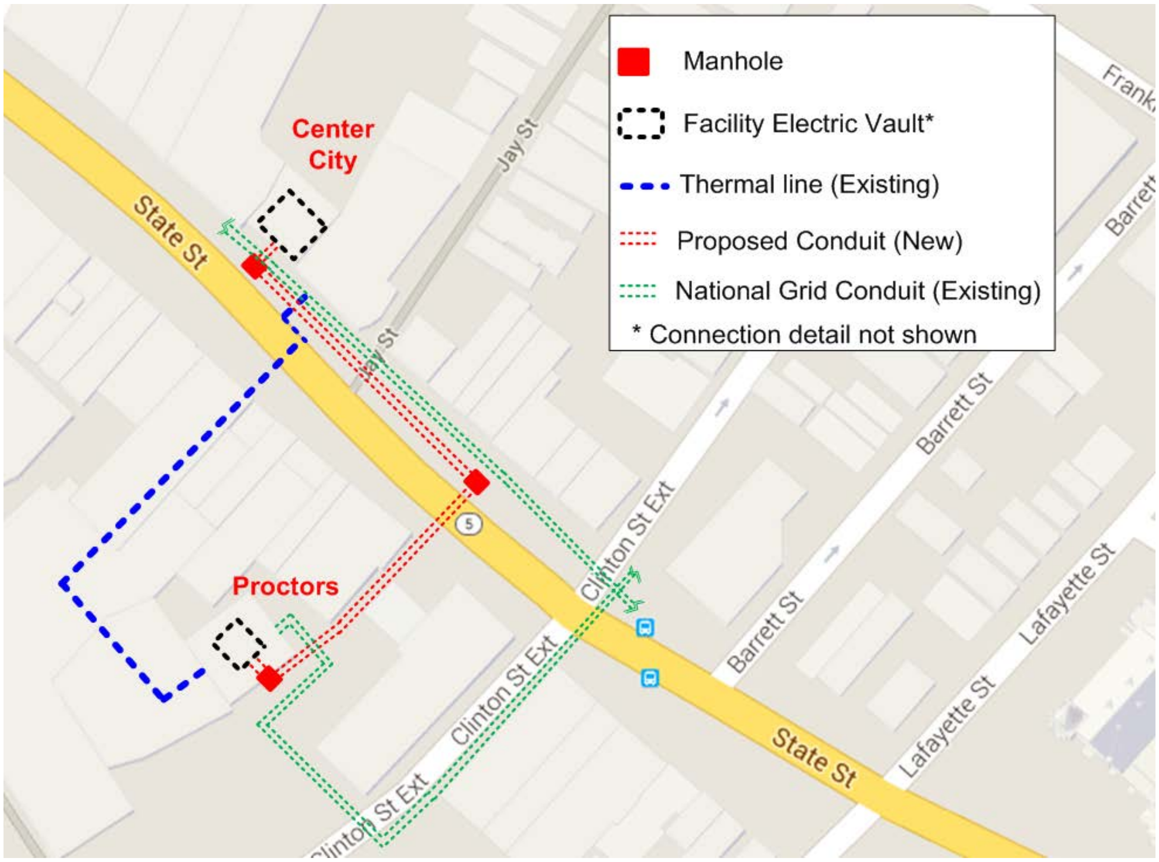
Building Name	Address	Square footage	Uses, Electrical and Thermal Load
Proctors complex	432 State St	160,000	City place of refuge, Theater, DES, hotel Electric Load: 2,606,682kWh; 953 kW peak
Center City complex	433 State St	220,000	Multiple tenants including CVS pharmacy, YMCA, bank; place of refuge Electric Load: 4,150,971kWh; 1,518 kW peak

Proctors is a designated Red Cross center of refuge, as is the YMCA in Center City across the street. In the event of a natural disaster, it is the only central location that has the size, resources and facilities to accommodate people from multiple adjacent neighborhoods, along with the capacity to maintain life systems. Its critical facilities include two emergency relief centers, three commercial kitchens, a bank, a pharmacy, two hotels and the telecommunications and physical infrastructure to accommodate relief effort coordination on the ground.

T&D Infrastructure

Proctors and Center City currently receive grid power via dedicated spot networks served by three feeders and two feeders respectively, out of the Front Street Substation. The two spot networks have one feeder in common (No. 7) and are designed to at least N-1 standard (meaning loss of one feeder or transformer would not interrupt load). This is an extremely reliable design that is *likely* only compromised by a transmission system failure, substation failure, or network collapse or shutdown.

The figure below shows a simplified layout of the Schenectady microgrid, expressing several options for the electrical interconnection of Proctors and Center City. The existing thermal piping is shown in blue. This is used to meet the heating and cooling needs of the Center City block. The two options for new electrical conduit are shown in red and green. The red option involves construction of 600 feet of new conduit under the Hampton Inn parking lot, across State Street, and then along State Street to Center City. The green option proposes to route new cables through existing National Grid conduits to connect the Proctors to Center City, a total distance of 1,100 ft. These options have been discussed with National Grid on a preliminary basis and will be further explored in Stage 2.



Simplified layout of Schenectady microgrid showing routing of electrical connection

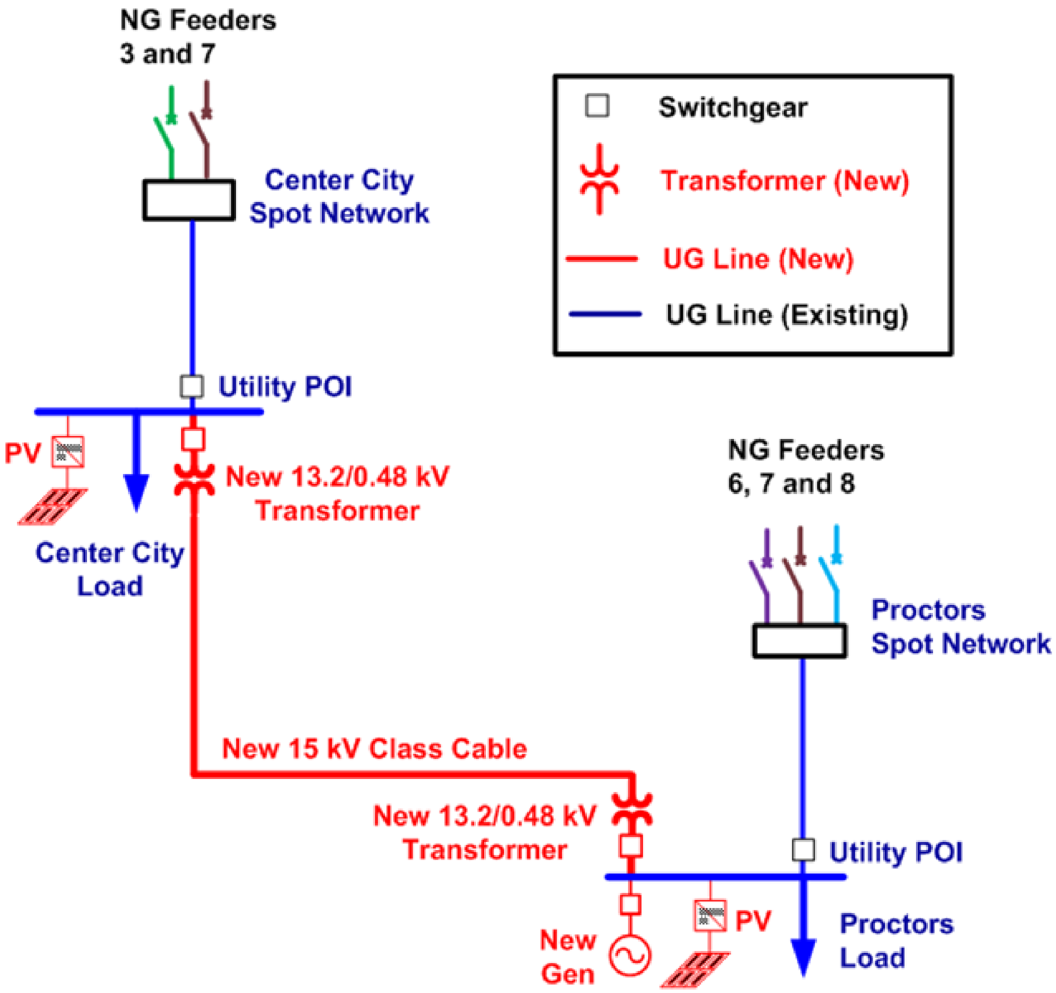
Generation Resources

The table below shows the existing and planned (bold) generation resources for the microgrid.

Microgrid Generation Resources

DER Type	Facility Name	Energy Source	Nameplate Capacity (MW)
Existing Backup	Proctors	*Diesel*	.250
Existing Backup	Center City	*Natural Gas*	.150
4 x Microturbines	Proctors	*Natural Gas*	.260
CHP-1	**Proctors**	***Natural Gas***	**1.00**
CHP-2	**Proctors**	***Natural Gas***	**1.00**
Rooftop PV	**Proctors and other locations**	***Solar***	**.550**

The DERs are shown on the one-line diagram below. New equipment is shaded in red. Proctors has four 65-kW existing microturbines which will be part of the baseload microgrid portfolio. The new generation resources are two 1,000 kW CCHP units at Proctors and a total of 550 kW of rooftop solar PV at various locations.



Schenectady microgrid one-line diagram showing generation sources and major equipment

Controls & Communications Infrastructure

The proposed microgrid control and communications architecture consists primarily of a Microgrid Energy Management System (or microgrid controller) which orchestrates all control actions and provides the utility interface, and Microgrid Edge Control Nodes (multifunction controller/IEDs) that provide automation and physical interface to switchgear and sensors and existing generation. The suggested communication infrastructure design assumes industrial-grade, long range, point-to-multipoint wireless communication with MIMO (Multiple-In, Multiple-Out) antennas.

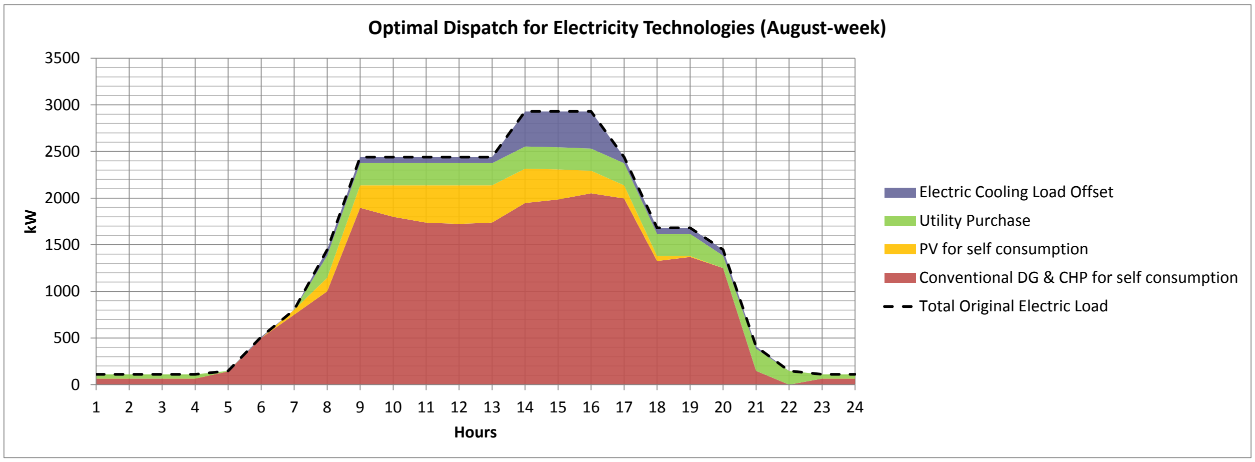
The control hierarchy will use the generation resources to maintain frequency and voltage in islanded mode. The CCHP units and the microturbines tend to be better suited to baseload operation than frequency control. For this reason, the majority of fast frequency regulation will be provided by the standby generation at Proctors and Center City, provided they are ultimately integrated into the microgrid control system. To augment this frequency regulation, load may need to be controlled. Additionally, it may be necessary for solar production to be curtailed. The specific demands for power matching/frequency regulation will be determined through study, and the microgrid controller will manage assets in response to changing conditions.

Normal and Emergency Operations

Under normal conditions the microgrid facilities will be served by the National Grid network system, as well as the CCHP generation at Proctors and PV generation at various locations. The new tie-lines may or may not be connected during blue sky days. In either case, the in-network generation will be monitored and controlled to ensure that it is less than the total load to reduce the risk of back-feeding.

Under emergency condition (such as a widespread outage or substation failure), the critical facilities will be transferred to the new microgrid lines via a sequence of switching operations. The principal source of power for the microgrid during emergency periods is the 2 MW of CCHP generation from the Proctors Marquee Power Plant as well as the microturbines and the PV generation.

The figure below shows the load and supply balance over a weekday of operation for the entire microgrid on a normal day in August (which is the peak electrical load month based on the assumed load shapes). The relative economics of on-site generation based on the microgrid resource efficiencies and fuel costs versus the electricity purchase from the grid with its energy delivery and market rates, and the demand charge rates, determines the dispatch of the onsite generation for all loads.

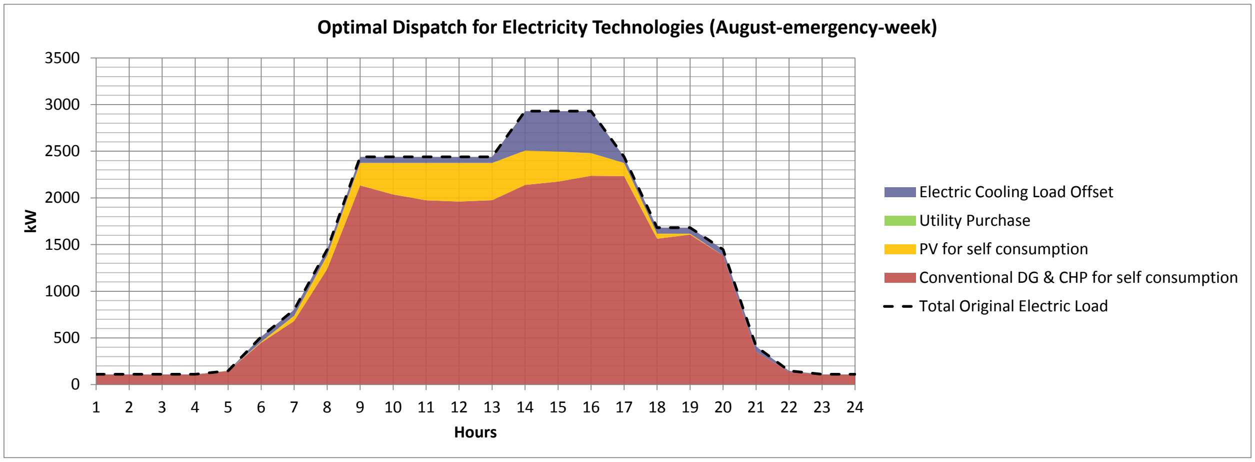


Microgrid Dispatch to Meet Electrical Load – August Normal Weekday

The dotted line represents the total original electrical load. The burgundy colored area represents the on-site generation by the microgrid (CCHP + microturbines). The yellow colored area is the solar PV production. The green colored area is the additional electric energy purchased from the utility. The purple colored area is the reduction in the original electric load due to use of absorption chillers, which replaces the electric usage by central chillers.

As discussed later in Section 2, load following during low load night time occurrences can be accomplished by cycling the CCHP units down to their minimum load point, and relying the 65-kW microturbines to provide even more turn-down flexibility. However, note that in grid-connected mode, load-following, frequency and voltage regulation services are mostly provided by grid resources (i.e. excess microgrid generation may be exported from the control area). During normal operation, the microgrid may still purchase energy from the grid during some periods (as opposed to higher CCHP output) if it is the most economic option.

By contrast, the figure below shows the microgrid operation during an emergency weekday in August (the month with the highest microgrid load based on the assumed load shape. As can be observed, there is no utility purchase, and all microgrid load is met by on-site generation, including solar PV during daylight hours. There is no need for load curtailment during this week, although the system can curtail up to 10% of the individual facility peak loads (about 247 kW).



Microgrid Dispatch to Meet Electrical Load – August Emergency Weekday

Microgrid Revenue Streams

There are several revenue streams that may be available to pay for additions to the microgrid's DER assets. They initially include the first three of the four categories below. The fourth revenue stream does not currently exist, but DER owners connected to the microgrid could pursue those revenues if local energy markets exist in the future.

1. **Demand response/Capacity-based revenues**: Demand Response (DR) participation represents a mature revenue opportunity for microgrids. Depending on the characteristics of its load and DER, a microgrid could participate in one of many DR programs offered by the utility or the NYISO.
2. **Energy sales/power exports**: On-site generation creates an opportunity to export power back to the grid. The overall value of this depends highly on local market and regulatory conditions, including the availability of feed-in tariffs or net metering.
3. **Resilience against outages**: Loss of load can create high costs for consumers; the societal and economic values of mitigating these lost loads can be very significant, depending on the nature of the operations occurring within the microgrid.
4. **Local energy markets**: These REV based markets and expected REV market animation with LMP+D pricing scheme would create the potential for future revenue streams and also for peer-to-peer transactions between DER owners connected to the microgrid.[2]

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[2] See Michael Stadler, *Value Streams in Microgrids: A literature Review*, APPLIED ENERGY (Oct. 2015).

Benefit Costs Analysis

Industrial Economics, Incorporated (IEc) completed a benefit-cost analysis for all of the feasibility studies completed under Phase 1 of NY Prize based on information provided by the project teams under Task 4. The analysis relies on an Excel-based spreadsheet model developed for NYSERDA to analyze the societal 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 over a 20-year operating period. 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.

According to the BCA completed by IEc, the Schenectady Community Microgrid Project yields a benefit/cost ratio of 0.8. The results suggest that if no major power outages occur over the microgrid's assumed 20-year operating life, the project's costs would exceed its benefits (*from a societal point of view*). In order for the project's benefits to outweigh its costs, the average duration of major outages would need to exceed approximately 1.1 days per year (Scenario 2). In this scenario, the internal rate of return is 6.7%. The complete IEc results are included in Appendix A.

Note however, that all revenue derived from operating the District Energy System and the ensuing economic vitality are not included in IEc's evaluation. The co-op like nature of Marquee Power passes on cost savings from any plant upgrade or efficiency to all participants, serving as a long-term economic development incentive for the neighborhood. Proctors, as a customer, reinvests these cost savings back into the community in the form of a variety of education programs.

The project team's best estimate of initial design and planning costs is approximately $740,000. The present value of the project's capital costs is estimated at approximately $7.73 million, including costs associated with the total of 2 MW of new CCHP and absorption chillers; utility interconnection; upgrades to the distribution circuit; and other system software and controls. 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 $3.06 million, or $270,000 per year (see completed Task 4 questionnaires in Appendix B). A recent grant from the NYS Legislature to support the addition of new customers and facilities to the DES extends benefits to both existing customers and new ones. In this way, the one-time construction costs accrue cost savings that continue to grow over time.

Conclusion

The ultimate goal of the Resilient Schenectady Plan is to enhance the efficiency, reliability, and resiliency of the area power supply. Given the ongoing revitalization in downtown Schenectady, and the potential for severe weather events such as flooding, wind, and winter storms and other major grid outages, the implementation of a community microgrid could provide the microgrid participants and the downtown area with long-lasting tangible benefits that could spur economic activity for years to come.

The microgrid will also enable the Utility to test and validate various REV market constructs and possibly help it meet load reduction and energy-efficiency goals. New bilateral revenue streams could also provide benefits to both the Utility and microgrid participants.

One key consideration is that this project will demonstrate the economic and technical viability of an advanced community microgrid in an underground secondary network, utilizing state-of-art technology to allow behind-the-meter DERs to participate in emerging REV markets. This is a model that is scalable and replicable in many communities across New York State.

The Schenectady project provides a compelling opportunity to pursue an innovative merchant microgrid ownership model. It will provide substantial public benefits and establish a favorable benchmark for evaluating future proposals to construct merchant microgrids in New York State.

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1 TASK 1 DESCRIPTION OF MICROGRID CAPABILITIES

1.1 Minimum Required Capabilities

1.1.1 Critical Facilities

The Schenectady microgrid will utilize the current Proctors/Marquee Power footprint (circled in green below) as its anchor. The southern block includes: Proctors complex comprising an administration building, historic arcade and main theater, GE Theater, Marquee Power plant and Key Hall; the Parker Inn; TransFinder corporate headquarters; and the Hampton Inn. The northern block includes Center City which houses Wink, Metroplex, M/E Engineering, CVS Pharmacy, the YMCA and others. Both Proctors and Center City are designated places of refuge. Other critical facilities within a few blocks of the Marquee Power footprint that were discussed for incorporation into the microgrid at various phases are identified with yellow and orange dots on the map below. Table 1-1 summarizes these facilities.

Figure 1-1 Map Showing Critical Facilities Considered for the Schenectady Project

Table 1-1 Listing of Critical Facilities Originally Considered for the Schenectady Project

Building Name	Address	Sq footage	Uses, Electrical and Thermal Load
Proctors Complex	432 State Street	160,000	City place of refuge, CCHP system Load: 2,551,316 kWh, 29,102 MMBtu
Center City	433 State Street	220,000	Multiple tenants incl. pharmacy, YMCA, bank, City place of refuge
Eddy Senior Care	500 State Street	80,000	Medical and long-term healthcare Load: 1,050,620 kWh, 1,374 MMBtu
City Mission	425 Hamilton Street	140,000	Community outreach, meals, shelter; drug and alcohol recovery programs
City Hall	105 Jay Street	60,000	Mayor's office, city planning, city courts, city council, city utilities
Public Library	99 Clinton Street	70,000	Education and recreational programs
Police HQ	531 Liberty Street	52,500	Public safety & emergency management, Fire coordinators office
County Jail	320 Veeder Avenue	100,000	County Sherriff's office Load: 1,699,661 kWh, 10,606 MMBtu
Fire Station #1	360 Veeder Avenue	90,000	Fire, EMS response

After discussions with National Grid, and examining the electrical maps, it became clear that the mix of electric service types among the critical facilities would impact the microgrid configuration. The Proctors Complex is on a dedicated 277/480 V spot network with no *secondary* electrical ties to other critical facilities. City Hall, the Library and Police HQ to the north are on the 120/208 V secondary network (street grid). To the south, the County Office Building/Courthouse is on the 120/208 V network, but, City Mission, the Fire Station, and the Municipal Housing complex are on overhead radial service at 120/208 V and 120/240 V. In the current configuration, generation at Proctors cannot be evacuated to other facilities in the footprint through National Grid's network; a dedicated service line would have to be established. Proctors has received permission from the NY PSC to provide electrical service to its block, but presently does not have permission to "cross the street". With this in mind, four (4) microgrid concepts or options were originally discussed in Task 1:

1. Design a microgrid encompassing the identified critical facilities by including dedicated underground runs to tie facilities with disparate service types together. This would require additional equipment, and possible special regulatory dispensation, which would be identified as part of the design.
2. Design a microgrid focused on the facilities on the network system, centered around Proctors, their currently connected thermal tenants on the block, and the Center City block across the street. This might require construction of a dedicated "across the street" tie line to connect Proctors and Center electrically, or utilization of National Grid's infrastructure with appropriate isolation devices. This option includes possible future expansion of the district energy system (DES) to the City Hall, Library and Police HQ.
3. Design a microgrid focused on the overhead radial portion of the footprint, centered around the County Jail to the south, and including City Mission, Fire Station #1, and possibly some municipal

housing facilities. This would take advantage of the existing overhead infrastructure, and would less isolation equipment.

4. Design a microgrid with the facilities in option #3 above and include the Proctors block. This would involve moving Proctors from the current spot network service onto the nearby overhead radial feeder currently serving the County Jail (which is a design that National Grid proposed several years ago).

After several discussions with major stakeholders, and a multi-criteria decision-making exercise, option #2 was selected as the focus of the Stage 1 study. The microgrid configuration would serve several physically separated critical facilities located on the two blocks. These are shown in the figures below.

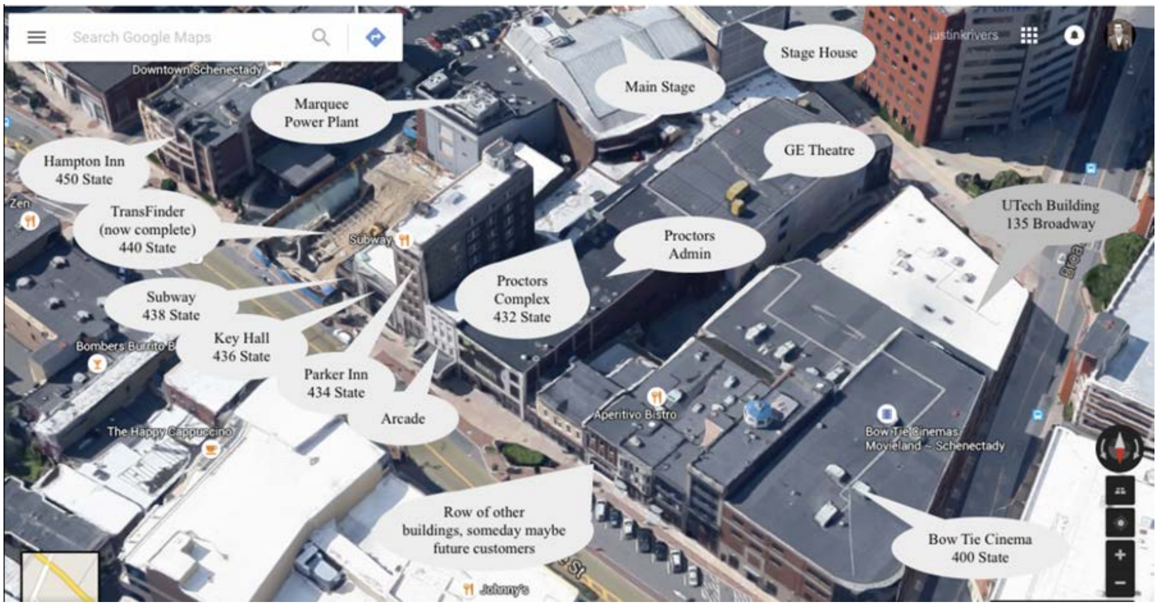

Figure 1-2 Facilities on South Side or Proctors Block

Figure 1-3 Facilities on North Side or Center City Block

Schenectady has a large amount of river frontage and nearby neighborhoods are classified by New York State as extreme high risk flooding zones. Proctors is a designated Red Cross center of refuge, as is the YMCA in Center City across the street. In the event of a natural disaster, it is the only central location that has the size, resources and facilities to accommodate people from multiple adjacent neighborhoods, along with the capacity to maintain life systems. Its critical support facilities include two emergency relief centers, three commercial kitchens, a bank, a pharmacy, two hotels and the telecommunications and physical infrastructure to accommodate relief effort coordination on the ground. The Marquee Power/Proctors Block footprint for the microgrid has direct stakeholders in three sectors - private, non-profit, and public. Along with the density of facilities and the number of people served by them, this footprint has the ingredients to create a significant gravitational force for implementing the microgrid. By contrast, a microgrid focused on the county cluster or on City Hall would have a narrower stakeholder base, and potentially fewer reasons and interests aligned in developing the microgrid further.

One of the barriers that this project will address is the technical challenge of back-feeding into a spot network without compromising the safe and reliable operation of the power system. Proctors and National Grid are currently working with GrideEdge Networks on a NYSERDA funded project (PON 3026) to test a PLC-based solution for desensitizing the existing network protectors to allow back-feed. The project team has high confidence that it will succeed in demonstrating a solution for underground applications, and has significant state and national implications for the development of microgrids, DERs, and innovative offerings in networked urban environments.

1.1.2 Primary Generation Source

The Proctors Marquee Power plant includes four 65-kW micro-turbines which are not in service yet, but will be used as generation capacity in the prospective microgrid. In addition, there is a 250-kW diesel emergency standby generator, a 250-ton electric-screw chiller, two 500-ton electric centrifugal chillers, a 175-ton absorption chiller, two 8780 BTU/hour hot-water boilers, one 3,655 BTU/hour hot-water boiler, a 1,000-ton evaporative-media tower, and a 500-ton air-cooled cool tower which can be used in economizer mode during the fall and spring. In subsequent tasks, the Team evaluated the need for additional generation sources and the possibility of locating them in the Center City complex. Ultimately, a new 2,000-kW CCHP unit was proposed at Proctors. The team has also identified several buildings that can potentially host roof-top solar installations which will feed into the microgrid. This includes the rooftops of the Proctors Complex and Center City shown in Figure 1-2 and Figure 1-3, as well as other buildings on the block such as Bow Tie Cinema, and nearby facilities such as the city garage. 550 kW of rooftop Solar PV was proposed at Proctors and other locations (being discussed).

In previous microgrid feasibility assessments performed by team members, natural gas engines were shown to be preferable to diesel engines, provided that there is an existing natural gas network, with sufficient capacity, to fuel the generator. In addition, in all cases, according to the facility owners and managers, natural gas access has proven to be highly reliable, with no interruption even during severe weather events.

One of the factors against selection of diesel engines has been the unavailability of adequate fuel storage to ensure uninterrupted operation of the microgrid for a period of at least two weeks. In most cases, the existing diesel storage systems are sized to enable diesel engine operations for a day or two during short-term grid outages. Proctors currently has 10,000 gallons of diesel storage for their emergency backup system, which is sufficient for about 500 hours or 3 weeks of continual operation at full load. In an emergency, the diesel tank can be refueled by truck within 5 days of request, provided that there is physical access.

However, in the absence of a formal emergency fuel delivery structure, for the purposes of this study (with the objectives of replicability and scalability in mind), the Team did not assume continued and extended availability diesel fuel supply.

Assuming availability of natural gas and diesel, other factors being equal, a key driver of the generation technology decision is the comparative price of natural gas to the price of diesel fuel. A natural gas based system, due to its significantly lower variable cost of generation, may allow for economical operation of the microgrid even in grid-connected mode during normal non-emergency periods, particularly during hours when the marginal cost of microgrid generation is lower than the electricity supplier's (or wholesale market) hourly price of electricity. Significantly higher diesel prices would preclude a diesel-based microgrid from economic operation during normal non-emergency periods.

The analysis shows that new natural gas generation is the least-cost option; existing back-up diesel generators can still be used as a standalone backup generation (as in their pre-microgrid role) as a last resort in the event of both larger grid and microgrid contingencies, or in load-following mode during islanded operation.

Newer natural gas engines can meet the 10-second startup requirements for backup systems, and hence, diesel engines no longer have an inherent startup/ramp-up capability advantage over the gas engines. Therefore, diesel engines are not a significant portion of the baseload generation for this project.

A key question in the downtown Schenectady area is the availability of an adequate supply of natural gas for the microgrid. National Grid has indicated that the gas supply in the vicinity is resilient, but their State reports indicate that natural gas systems in Schenectady were compromised during Tropical Storm Lee[3]. The Team requested data from National Grid to confirm gas resiliency. National Grid has also indicated that there is sufficient gas capacity for the new micro-turbines at Proctors, but they will have to determine whether there is sufficient capacity for new generation. Currently the gas distribution system for the area is in the process of evaluation by National Grid Engineering.

1.1.3 Operation in Grid Connected and Islanded Mode

The microgrid will be connected to the main grid at the spot network at Proctors and at the spot Network at Center City. These two points will represent isolation points and potentially points of interconnection (POIs) or points for common coupling (PCCs) for the microgrid. In grid connected mode, the microgrid facilities will be able to offset thermal and electrical demand with in-network resources, represented by the micro-turbines at Proctors, the proposed 2 MW of CCHP units at Proctors, and roof-top PV. Because the microgrid will have two points of connection to the main grid, back-feed will have to monitored and controlled at these two points. Technologies and processes to enable in-network generation, such as active load control, minimum import relays, and smart inverters will be explored for operation in Stage 2. In islanded mode, the team considered application of a Microgrid Control Systems with the capability to actively monitor and dynamically control load and generation in the network. This requires appropriate

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[3] NY Rising Community Reconstruction Plan for the City of Schenectady and Town of, March 2014

sensors to monitor electric properties (voltage, phase angle, frequency, and real and reactive power flow) at the POI; which are used to modify generation and load in a feedback loop to prevent back-feed.

In islanded mode, the same generation sources are expected to be available to support the microgrid load. The new CCHP units are expected to provide a strong voltage reference that would allow inverter-based generation to function in islanded mode. To avoid a collapse of the island, some generators would switch from baseload to frequency control and excess (curtailable) load may be shed to maintain balance. This is further discussed in Section 2.3.6.

To enable these operations, a Microgrid Control System with the capability to actively monitor and dynamically control load and generation in the network will be considered in Stage 2. A number of commercial microgrid control system platforms are available as candidate solutions, in addition to advanced control systems being developed by GE, National Renewable Energy Laboratory (NREL) and others. The available commercial platforms vary in functionality. A complete control solution will typically be comprised of an integrated suite of both hardware and software components. Depending on the microgrid site use cases, the control solution will often require some level of custom code development or configuration scripting to support integration with electric distribution equipment, the building energy management systems (BEMS), controllable loads, and generation assets within the microgrid, the ISO control center, as well as National Grid enterprise systems which include energy management systems (EMS), distribution management system (DMS), and outage management systems (OMS). More detail on the control and communications design for Schenectady is given in Section 2.5.

1.1.4 Intentional Islanding

Islanding is the situation where distributed generation or a microgrid continues energizing a feeder, or a portion of a feeder, when the normal utility source is disconnected. For a microgrid to sustain an islanded subsystem for any extended duration, the real and reactive power output of the generation must match the demand of that subsystem, at the time that the event occurs. Exact real and reactive power equilibrium on a subsystem is improbable without some means of control. If there is a mismatch, the subsystem voltage and frequency will go outside of the normal range, and cause the DG to be tripped on over- or under-frequency or voltage protection. The amount of time required for voltage or frequency excursion to trip the DG is a function of the mismatch, parameters of the circuit, as well as the trip points used. Without active voltage and frequency regulation controls providing stabilization, an island is very unlikely to remain in continuous operation for long. The Team will consider switching technologies that would allow the microgrid to seamlessly and quickly transition to islanded mode, and also incorporate appropriate communications and controls technologies (discussed further in Section 2.5) that would allow the microgrid to remain electrically viable and persist for the duration of the emergency (subject to fuel availability).

The current concept includes two points of interconnection with the grid at the Proctors and Center City spot networks. When these two points are disconnected (and Proctors and Center City are tied together electrically), an intentional island would be formed. To sustain the island, the microgrid logic controller would shed load (if necessary), and actively monitor and control voltage and frequency in the area. Some machines will operate as baseload generation, and others (perhaps some of the micro-turbines at Proctors, the diesel engine, or gas engine Center City) will operate in load-following mode to maintain load-generation balance in “real time”. One consideration is how to minimize the downtime during the transition from connected mode to islanded mode. If the micro-turbines and other generation are base-loaded even during normal operation this might be a significant issue.

1.1.5 Automatic Separation from Grid

As currently configured, the Schenectady microgrid will have two (2) points of interconnection to the main grid. When the utility source is lost, the controller monitoring voltage at the POIs would initiate the transition process from grid-connected to islanded mode. The specific nature of the transition is discussed later in Section 2.1 along with the power and communication equipment necessary to facilitate the transition. Furthermore, strategies for re-connecting and the equipment necessary to accomplish these strategies are also considered.

1.1.6 Requirements for Scheduled Maintenance

The Team explored the possibility of installing roof-top PV on the buildings that comprise the 400-block area of State Street. The amount of PV is less than 25% of the microgrid peak demand and an even less percentage of the energy. The microgrid generation has the range and flexibility to mitigate the expected variability of the PV generation. Energy storage was considered as an option, but considering the economics of storage in this size range, the Team focused other options such as controllable loads before recommending batteries. The project also includes sufficient base load resources from the new CCHP units at Proctors to ensure that the system can provide reliable output on a 24/7 basis.

The maintenance plan will adhere to and comply with manufacturer’s requirements for scheduled maintenance intervals for all generation. Marquee Power has a centralized monitoring system based on their Tracer BAS, and staff in place for operation and maintenance of their DES. In Stage 2, the Team will consider reliability-centered maintenance (RCM) strategies that focus more attention on critical pieces of equipment that could affect the microgrid operation (such as rotating machines, transfer switches, breakers) but will recommend periods during the day, week, and year when routine maintenance would be less likely to coincide with an outage event. Most routine maintenance activities can be accomplished during off peak periods, eliminating the possibility of incurring peak demand penalties from system down-time. Maintenance of longer duration can be scheduled for off peak hours. This is a data driven task that is likely to become more effective given a longer operating history.

1.1.7 Load Following

The current generation portfolio at Proctors includes four 65-kW micro-turbines and a 250-kW diesel emergency backup generator. Center City has a 150-kW backup gas engine. Additional fossil-fueled generation and PV generation were considered during the load and supply analysis subtask. The Team proposed to add a 2-MW of CCHP at Proctors and a combined 550 kW of rooftop PV at Proctors and other locations (being discussed). Microturbines can achieve load following by part-load operation. In multi-unit applications, the need for part load operation is lessened by sequential startup of additional units. The penalty for part-load operation, however, is reduced electrical and thermal efficiency. The CCHP units will also be able to provide some degree of load following.

In connected mode (parallel to the grid), microgrid generation resources would typically not be required to regulate frequency or voltage or follow load. These services are provided by generators under governor control. However, in islanded mode, microgrid resources must switch from baseload power control to frequency control and the bus voltage must be controlled either by a generator's voltage regulator or by some supervisory control (such as a microgrid controller). Some excess loads could also be shed to maintain balance. With multiple DERs of various types, and controllable loads in an area, a microgrid control system is needed for successful islanded operation. The team more fully explored these operational issues in later tasks, including the discussion in Sections 2.3.6 and 2.5.2.

1.1.8 Two-Way Communication and Control

The existing building automated system at Proctors (Trane Tracer®) is being considered for integration in the microgrid control system in Stage 2. The first step was to determine whether the microgrid solution will leverage existing networks or if there was a need to design and deploy new communications systems. Once the network platform was identified the Team selected platform and protocol compatible monitoring services as well as security services to satisfy the cyber security protection functions. More detail is available in Section 2.5 and 2.6.

The Team evaluated the use of existing communications systems in two important areas.

Cost Savings and Interoperability:

Reuse of existing communications systems can provide cost savings as the microgrid developer will not be required to deploy an entirely new communications fabric. Individual network segments or complete reuse of the communications system can be applied and significant cost savings can be achieved. Additionally, where reuse is leveraged, protocols and data models can be selected to achieve maximum interoperability and performance.

Security and Resilience:

There is a trade-off between cost savings acquired via reuse of existing communications systems and the reduced security and resilience attributes in older communications technology and design approaches. This will be analyzed, and cost and security considerations will be balanced to accommodate the site-specific functional requirements.

Maximum weather resilience and performance is achieved when underground fiber optic networks are deployed. Additional surety can be obtained by creating redundant fiber rings and including two-way communications. The use of fiber, redundant networks, and underground deployment makes this the most reliable and resilient method, but it is also the option of highest cost. The generation portfolio for the microgrid and potential use cases during connected and islanded modes would go a long way in determining the performance requirements for the communications infrastructure.

Cyber security addresses protection against hacking and malicious intent. In Stage 2, the team will consider options such as: modern hardware platforms and network nodes that incorporate device level authentication and authorization; adding security services to the microgrid control nodes and control center to address encryption of data at rest and data in motion; and adding a security architecture that applies defense in depth design principles which includes segmenting of data and system components across different levels of security zones to offer a hierarchy of authorization constraints and system access barriers. Note that cyber security services can be added as a security layer on top of existing communications when reusing networks but cannot change the existing physical security, resilience or performance limitations of the existing networks or device nodes.

1.1.9 Power to Diverse Group of Customers

The proposed microgrid will serve the facilities identified in Figure 1-2 and Figure 1-3 based on the cost of providing service, importance of providing power to the critical facility, and alternatives to connection to the microgrid. The Team evaluated these considerations during subsequent tasks in the Feasibility Study. The potential facilities comprise the 400 block of State St, on both sides of the street.

<u>North Side of State Street – Facilities and Impacted Entities</u>

- 433 State Street, Center City
    - CVS Pharmacy
    - Schenectady County Community College Classrooms
    - Wink
    - WiseLabs – Tech incubator
    - NBT Bank
    - Metroplex – County development authority
    - M/E Engineering Offices
    - YMCA (Designated Center of Refuge)
    - Johnny's Italian restaurant
    - Many other offices
- 401 State Street - Office building, NYS Commission on Quality Care for People with Disabilities
- 409 State Street, Metropolitan Building
    - Offices on first floor
    - Nine residential units on second floor
- 411 State Street, Paul Mitchell Building,
    - Paul Mitchell School
    - Other offices

<u>South side of State Street - Facilities and Impacted entities</u>

- Proctors
    - Theatre auditorium (Marquee Power provides heating, will include cooling next year)
    - Arcade (Marquee Power provides heating and cooling)
        - Empire State Youth Orchestra
        - Van Curler Music store
        - Open Stage Media (public access TV for Schenectady)
    - Proctors admin offices
- 436 State Street, Key Hall
    - Banquet Hall, special event space with full kitchen
- 434 State Street, Parker Inn
- 438 State Street, Subway restaurant
- 440 State Street, Transfinder Corporate HQ
    - Includes servers that support GPS software for routing school buses, snowplows etc.
- 450 State Street, Hampton Inn

In addition, there are nearby clusters of other critical facilities. Some of these clusters (City Hall/Library/Police HQ), the City Mission complex, a Senior Health Center, and the County Office/Courthouse/Jail structures are future candidates for connecting to the Marquee Power DES.

According to recent census data, the population of Schenectady is about 66,000 with a median age of 33.5 years. About 12% of the population is over 65 and approximately 24% is less than 18. The median household income is between $38,000 and $40,000, and 18% of families are below the poverty level. Since the 2000 census, the City's population has grown by 7%. About 2.5% of the City's population resides in downtown Schenectady where the median age is 25. With this revitalization in the local economy, there is a stated need for reliable and resilient power to supply expanding capacity, and ensure the power quality required by high technology end-users.

One of the key actors in the revitalization of the downtown district is Proctors, a non-profit theatre and arts center located at a restored 1926 vaudeville theatre in downtown Schenectady. Its mission*: through arts and community leadership, to be a catalyst for excellence in education, sustainable economic development and rich civic engagement, to enhance the quality of life in the greater Capital Region*. Ten years ago, the neighborhood was nearly abandoned, and the city's economy was in free fall. In response to this crisis, Proctors worked with the city, county and remaining downtown stakeholders to revitalize the area. To do so, Proctors expanded and constructed a district heating/cooling plant to provide added market incentive to redevelop nearby properties. The project jump-started a revitalization project that is an ongoing success.

The proposed microgrid would enhance the ROI for an existing Marquee Power thermal system. Building the microgrid based on the "400-Block" footprint supports future economic development and wealth creation. In other words, microgrid will provide resiliency and contribute to a stronger local economy, through cost savings, more easily redeveloped properties, and safeguards against power loss.

1.1.10 Uninterruptable Fuel Supply

Gas supply to the Marquee Power Plant has proven to be reliable and resilient since its inception. National Grid has stated that they have not had an issue with gas supply in the area at any time within recent memory. Currently, there is sufficient capacity to supply the four micro-turbines at the power plant (which are not currently in service). As part of the RFI, National Grid was asked to check on the available capacity for additional proposed generation within the microgrid. The backup diesel generator at Proctors has fuel storage to last about 20 days of continuous operation at full load.

There are at least two possible options the Team considered to improve fuel supply resiliency. One was to consider dual-fuel generation for additional units. These would run mainly with natural gas, but be capable of switching to diesel. Another possibility was to consider liquid or compressed natural gas storage that would be used in the event of the disruption to the main gas pipeline.

However, these options were too costly to include and implement, and in the case of natural gas storage, may prove problematic from environmental and safety considerations, let alone availability of proper space and location within the microgrid footprint.

1.1.11 Resiliency to Forces of Nature

The downtown Schenectady network is served by feeders out of the Front Street Station, which is exposed to severe weather events such as ice storms, windstorms and flooding. Therefore, it is conceivable that a district-energy nodal microgrid could significantly reduce the number of customer interruptions precipitated by major events impacting the substation and feeders out of the station that serve the network. The Proctors block where the microgrid is located is in a FEMA Moderate Risk flood zone.

However, it borders neighborhoods to the west (bounded by State Street, Washington Avenue, and Erie Boulevard) that are in Extreme Risk and High Risk 100-year flood zones. Schenectady is designated as a NY Rising Community because of the devastating impacts from recent extreme weather events such as Hurricane Irene and Tropical Storm Lee, which hit within a week of each other in 2011. Irene was a relatively fast-moving event that had a large impact across the entire east coast, most particularly on electric systems. Lee produced devastating damage to both the electric and natural gas systems as it stalled over much more concentrated areas, with rains and flooding reaching historic proportions. Schenectady was declared a Federal Major Disaster area during both storms.

Schenectady after the storms
Source: Times Union

CCHP systems have proven to be very resilient during these types of storm events. During Hurricane Sandy in 2012, six New York City hospitals and 12 New Jersey residential care facilities went dark despite diesel backup. As a result, 8% of NYC hospital beds were unavailable, and 1,408 patients had to be evacuated. However, among all the sites where the CCHP unit was designed to operate during grid outage, there was not a single site that lost power.

In Stage 2, the Team will work with National Grid and stakeholders to develop a resilient network design that incorporates hardening strategies commonly practiced by systems engineers in areas exposed to storms and outage events. This includes flood avoidance and flood control measures applied to generators, transformers, and switchgear, fault-tolerant and self-healing network designs, redundant supply or reconfigurable supply where it makes sense, remote monitoring and diagnostic equipment, robust construction, use of submersible equipment in underground construction, and a number of other time-tested measures. Flood avoidance and flood control measures for cable terminations, generators, transformers, and switchgear that could be impacted by flooding include the use of submersible equipment, flood walls, pumping equipment, watertight enclosures, and elevated construction. While the microgrid footprint is in close proximity to Extreme Risk flood zones, it is unlikely to experience significant flooding directly. Instead, its proximity and relatively safe position makes it an ideal location for an emergency shelter. In the absence of extreme flooding, it is assumed that all or the majority of buildings served by the district energy system could serve as places of refuge for the community.

1.1.12 Black-start Capability

As discussed later in Task 2, the emergency standby generators located at Proctors and Center are capable of operating without the presence of the distribution system which makes them ideal for black-start application. Also, the existing micro-turbines at Proctors, because they are inverter based generators, can easily incorporate battery storage to start the generators (independent of the grid) and provide black-start capability for the microgrid. The proposed microgrid will be designed to start automatically in sequence after either a specified time frame of sustained utility outage and/or based on a command from the microgrid operator to transfer from grid-connected to micro-grid operations (see Section 2.1).

1.2 Preferred Microgrid Capabilities

1.2.1 Operational Capabilities

The proposed microgrid is a microcosm of the modern electric power system, and to that extent, the application of advanced automation and control technologies will be explored to enable enhanced visualization, monitoring, control and interaction. The ultimate goal of “advanced, innovative technologies” is to enable safe, reliable, economic operation of the microgrid, in both connected and islanded mode. This includes: consideration of best in class distributed energy resources, including demand response, energy efficiency measures and energy storage to meet the instantaneous demand; smart grid and distribution automation technologies, such as solid-state transfer switches, and automatic fault location isolation and service restoration (FLISR) schemes, to ensure reliability and power quality; smart relays, adaptive protection, special protection schemes to ensure flexibility and safety.

During this study, the application of devices such as “smart” network protectors, minimum import relays and reverse power relays in a network system was considered for Stage 2. One barrier that has been discussed in this study is the technical challenge of back-feeding into a spot network without compromising the safe and reliable operation of the power system. National Grid has been working with Proctors to find a solution that will allow Proctors to operate the four micro-turbines installed in its Marquee Power plant. Recently, the Utility and Proctors won an award from NYSERDA to study and demonstrate a potential PLC-based solution from GridEdge Networks. National Grid will conduct an engineering and feasibility study that includes but is not limited to primary circuit protection studies and requirements, secondary network protection studies and requirements, secondary network studies to analyze the impact of exported generation and determine associated system limitations, and required customer equipment. GridEdge will work with National Grid to conduct field measurements and feasibility tests at the project location, construct hardware-based solutions with resulting data, with installation by National Grid at the project location if found feasible. GE is listed as a monitor on the project, and will assess the potential of this solution to allow the microgrid to back-feed into the main grid.

When the microgrid is in islanded mode, it is possible for a mature microgrid controllers to take on features of a DMS/OMS, monitoring the system for fault events and automatically isolating faulted areas and reconfiguring the system so that as little of the load is affected as possible. The Team assessed the existing SG-DA investment and plans by the utility and determined, conceptually, how they impact the microgrid operations, and what additions may be feasible.

1.2.2 Active Network Control System

A key functional requirement for this project is that the microgrid logic controller should be able to monitor the state of the network protectors and the flow of power through them. The prime objective is to balance load and supply within the microgrid area to reduce the need for back-feed, while controlling voltage and frequency in the area.

The Team has evaluated the current set of available commercial microgrid controllers. From our recent microgrid studies we are aware that available commercial microgrid controllers primarily support various levels of the most fundamental operating functions such as; load shedding, optimal dispatch, integration of renewables or energy storage, forecast and scheduling, and basic situational awareness. Advanced functions like deep control integration with external SCADA or DMS systems or deep monitoring integration with AMI and other data collection and analysis systems is typically a custom developed adapter built to support a specific microgrid use case and system configuration.

The GE team is participating in a separate DOE funded project on development and testing of microgrid controller. The project is managed by the GE Global Research Center in Niskayuna, NY. Additional work on developing various microgrid controller functionalities is being done by GE Digital Energy in the GE Markham Grid-IQ office in Ontario. Moreover, GE Energy Consulting is a collaborator in development and testing of an off-grid microgrid decision tool being developed by Lawrence Berkeley National Laboratory and a number of other national laboratories. Section 2.5 provides a fuller characterization of the microgrid controls and communications design.

1.2.3 Clean Power Supply Sources

The Team has considered opportunities to incorporate clean power and renewable resources into the generation mix for the microgrid.

The feasibility analysis evaluated expansion of the CCHP plant at Proctors which burns clean natural gas. As the map in Figure 1-1 shows, there are several buildings that may be good candidate sites for rooftop solar arrays which could be integrated into the microgrid. These include multiple buildings comprising the Proctors complex, including the administration building, stage house, Key Hall and GE theatre, several structures west of Proctors including Bow Tie Cinema, and the Center City complex on the north side of State Street. Currently, there are no rooftop solar installations in the downtown area, due to secondary network back-feed concerns, but there are ways to address this concern that will be further studied in other feasibility studies and in Phase 2. In addition, there is a number of EV charging sites in and around the downtown area, including public GE Watt Stations at the Hampton Inn near Proctors. The Team elected to include 550 kW at this stage and explore other options as the project moves forward.

1.2.4 Energy Efficiency and Demand Response Options

As the project moves forward into Stage 2, the facilities in the proposed microgrid, representing well over 1 million square feet of space, will be evaluated for deployment of green-building upgrades. Proposed upgrades could include measures such as lighting upgrades, daylighting, water, pump and motor efficiency, boiler and chiller optimization, HVAC upgrades, building envelope and insulation improvements, and advanced building- and energy-management system installations.

The current microgrid facilities have implemented a number of energy efficient upgrades in recent years Proctors, for example, has installed LED lamps in most of its domestic lighting instruments, including the marquees and signs. It also recently installed LED lamps in all of the main stage chandeliers and sconces. Trane system controls have been installed throughout Proctors and Marquee Power to fully economize current heating/cooling loads. System calibration allows careful control of HVAC systems. Carbon dioxide monitors in all dressing rooms provide automated detection of human activity, reducing heating/cooling loads on unused or unoccupied spaces within the facility, in addition to programmed controls in parts of the facility with more predictable demand.

The Marquee Power Plant upgrades include measures to drastically improve energy efficiency in its central heating/cooling plant and in the buildings it serves. Measures include installing two 500-ton centrifugal chillers, providing high efficiency at full and part loads (as well as important system redundancy) eliminating a natural-gas powered absorption chiller, converting the existing steam boiler system to hot water (estimated to improve heating efficiency by 35%), installing a "free cooling" heat exchange to reduce (and virtually eliminate) electric cooling loads in wintertime, replacing the aging rooftop AC units on the main theatre with chilled water lines from the district plant, and replacing the failing HVAC and boiler systems in adjacent Key Hall and the Parker Inn, drastically increasing efficiency for the entire systems and the specific buildings. Trane controls will provide additional fine-tuning and calibration to further economize the system. The ability to spin-up the four existing Capstone micro-turbines will significantly increase the overall efficiency of the power plant, and reduce cost for all customers in the footprint.

This study considered demand response options by working together with the facility owners/managers to identify potential demand response resources (curtailable and discretionary loads) and their size and location, and take them into consideration in the functional design of the control and communications infrastructure. Proctors currently participates in the NYS ISO demand response program. Each year they are given a day’s notice and a target load to shed for the following day. The team explored ways for the proposed microgrid to actively participate in the NY ISO demand response commodity market. The market rules are evolving to better integrate behind the meter resources and the project team intends to monitor those developments closely.

1.2.5 Installation, Operations and Maintenance

As discussed earlier, the existing electric distribution system in the area is a combination of underground spot networks and underground secondary networks. The proposed design focuses on the facilities that are on spot networks to limit the number of connections to non-microgrid facilities and the main grid. In Stage 2, there is a possibility that a dedicated underground line would need to be included in the design. to tie the North and South blocks together electrically. If this is necessary, the existing right of way for the thermal connection might be utilized. Use of existing National Grid conduits will also be explored. As the

Team developed the infrastructure design for the microgrid in Task 2, they identified the need for isolation switches, transfer switches, motor operated breakers and other switchgear, relays, transformers and other equipment. The installation requirements and resulting cost for additional equipment was also examined in Task 2.

The microgrid will have two main points of connection to the larger grid: at the Proctors spot network and at the Center City spot network. In connected mode, network protectors at these two points will be monitored for reverse power flow, either via power line carrier or other communication means. This might require conversion of the network protectors to microprocessor-based units. The load in the microgrid area will be monitored to ensure that it is above a minimum threshold, to avoid the likelihood of reverse power flow. The Team considered the use of minimum import relays or reverse power relays at certain points of the network, particularly where PV is interconnected. The microgrid logic controller will initiate transition to islanded mode via transfer switches at the points of interconnection, and appropriately placed isolation switches where needed. After receipt of full network information and discussion with National Grid, the team developed the operation strategy for the microgrid, which is discussed in Section 2.1.

Proctors has been operating and maintaining a district energy system (DES) called Marquee Power in the footprint for several years. They have four micro-turbines (not yet in operation) and are working to expand the DES both thermally and electrically. Marquee Power already has centralized data monitoring and maintenance schedule capacity. Expanding a microgrid from this core might be more feasible, given that there is already staff and relationships in place for the thermal systems in many of the facilities being reviewed.

The Team worked with the Utility to develop an understanding of the relevant features of the electric distribution system and to identify the current distribution network challenges in terms of parsing out a microgrid out of the current grid and ensuring that the larger grid will not be adversely impacted.

The type and the configuration of the underlying electric network of the microgrid is highly dependent on the current distribution network, locations and distances of the microgrid facilities on the feeders, and the technical requirements that were considered in the functional design of the microgrid electrical infrastructure. A very important consideration was the overall cost of various grid type options.

Based on the grid design, the Team assessed the requirements for the interconnection or interconnections between the microgrid and the larger grid, in terms of installation, operations, maintenance, and communications, and described such requirements in the functional design of the microgrid and its point or points of contact with the larger grid (see Chapter 2).

1.2.6 Coordination with REV

NYSERDA states that it expects that microgrid initiatives funded under NY Prize will embody the spirit of REV's policy objectives and contribute to the development of the State's envisioned microgrid framework. The stakeholders believe that this project will be a strong enabler for meeting REV and NY Prize objectives and will also be an ideal showcase in the state for demonstrating and validating new utility business models and associated market constructs discussed in the REV proceedings, particularly in network systems. The Team considered latest REV developments in exploring various business models and operational modes of the microgrid within the REV framework. In particular, the Team describes the options for the microgrid's operation during the normal days across the possible distribution system platform (DSP) and trading in the animated market, that most likely may involve dynamic trading (including buying and selling of power and demand resources) both at retail/distribution system level and also at NYISO/transmission system level. The Team understands that details of REV framework will keep evolving, and has accounted for that in development of the microgrid functionalities.

There are numerous outstanding regulatory issues, as evidenced by the comments filed by active parties in response to the Commission's request for comments on microgrids. As the project moves forward, the Team will work closely with the National Grid to identify those barriers and seek ways to overcome them. Some outstanding issues include the following: 1) types of payments for the services to be provided by the microgrid to the utility and those to be provided by the DSPP to the microgrid; 2) type of payment for utilizing existing distribution wires both in normal and islanded modes; 3) ownership and management of the wires installed between participants served by the microgrid; 4) control of the communications and control system when in normal operating and in islanded modes; 5) existing tariffs such as electric and steam standby rates, gas-delivery rates and others to ensure that the microgrid is not economically disadvantaged because of existing approaches; 6) integration of the microgrid into the Utility's new, in-process-of-being-implemented DR, energy-efficiency and large-scale renewables programs; and 7) interconnection processes and procedures for microgrids and the timetables in place that might impede interconnection.

The Team expects that the NY Prize process will be used to inform necessary regulatory and tariff changes in the State of New York. There are currently numerous regulatory and related barriers, and the Team believes that addressing these issues during Track 2 of the REV proceedings should be a priority.

1.2.7 Comprehensive Cost/Benefit Analysis

As part of the evaluation of the project's feasibility, Industrial Economics, Incorporated (IEc) completed a benefit-cost analysis to evaluate both the net societal benefits and also the costs and benefits from the perspectives of the various stakeholders.

On the cost side, the Team identified (a) various costs elements, covering the design, development, and deployment of the microgrid, capital costs of various components, fuel, variable operations and maintenance (VOM), and fixed operations and maintenance (FOM) cost of generation and demand side resources, (b) costs of the electrical network infrastructure, (c) costs of the control and communications infrastructure.

On the benefit side, the Team identified various potential revenue sources such as utility demand side programs, and those from participating as a virtual plant in the NYISO wholesale market. Additional benefits included estimation of avoided costs of power interruptions for different facilities within the microgrid.

The full IEc results are available in Appendix A and the Teams input (Facility and Microgrid questionnaires) is in Appendix B.

1.2.8 Leverage Private Capital

The Team developed a range of ownership and control models for what is inherently a complex and difficult type of project to finance, resulting from multiple asset types with varying productive lives. The goal is to finance directly as much as possible using shared-savings contracts and PPA structures that eliminate up-front payments for microgrid participants in areas such as CCHP, energy efficiency, solar PV and energy storage. Some of the new compensation mechanisms developed jointly between the Team and the Utility/DSPP will also help support these arrangements. Financing microgrids in New York State will require a creative approach to bundling various sources into an integrated package, helping to reduce risks for all investors. The Team has significant expertise in the range of available financing sources and the integration, structuring and negotiation of the terms of the bundled solution. Appropriate financing sources might include the following: PACE financing and shared energy savings models for energy-efficiency projects; securitized portfolio of assets that bundle natural gas and renewable energy assets; federal and state tax incentives, grants, low-cost loans and so on; infrastructure funds; large hedge funds; long-term asset investors such as pension funds; socially responsible investors; philanthropic organizations and NYS Green Bank credit-enhancement products.

The Team has designed the project and structure the financing to produce returns on investment and debt coverage that will attract private financing needed to complete the project. The team has also evaluated different ownership models that will help attract third party funding. The financial analysis will determine the amount of private funding needed to supplement any NYSERDA funding, and produce acceptable returns and risk for the private investors.

The Benefit/Cost Analysis (BCA) will include potential benefits and costs from various perspectives, including the microgrid as a single entity, and also from the viewpoint of the facility owners and the utility.

In addition, the BCA will include the societal net benefits/costs. The Team's contribution were based on learnings from the original NYSERDA 5-Site study which included consideration of various financial benefit and cost streams, and was supplanted by accounting for other non-tangible benefits and costs, including environmental benefits and avoided interruption costs. The latter, which is more difficult to quantify, can be estimated based on available benchmarks depending on the classification of the facility's type, critical loads impacted, number of persons impacted, and the duration of emergency period.

1.2.9 Tangible Community Benefits

The Project will benefit the community both by providing added reliability and resiliency for microgrid participants, and potentially reducing energy costs for the facilities. Proctors Theater is one of the key actors in the revitalization of the downtown district. It operates three channels of public access TV and supplies broadband internet, sidewalk snow-melt, and trash collection to the block. Its regional arts initiatives such as Tickets by Proctors and innovative management partnerships with Capital Repertory Theatre in Albany and Universal Preservation Hall in Saratoga Springs have fostered a growing regional coalition to support and nurture the Capital Region's creative economy, which currently employs more than 28,000 people. Proctors serves more than 650,000 people each year with more than 1,700 events at its multi-venue theatre and arts complex. 35,000 students from 400 schools and 100 districts participate in Proctors education programs each year.

In 2004, Proctors embarked upon an expansion campaign that jumpstarted an abandoned downtown neighborhood, constructing a district energy system called Marquee Power to heat and cool most of the buildings on the block. Marquee Power has been an engine of redevelopment, lowering construction first-costs and maintenance costs, while increasing energy efficiency for its customers. It has leveraged more than $300 million in local redevelopment. The proposed microgrid will expand the Proctors DES to other customers on the North and South block of 400 State St, and provide resilient electrical service in addition to thermal service. This will further enhance Proctors mission to revitalize the downtown area, lower construction and maintenance costs for redevelopment, and reduce the cost of energy.

The buildings involved, which were listed earlier, constitute about 1,000,000 square feet on a vital block in downtown Schenectady, encompassing stakeholders from three sectors - private, non-profit, and public. Critical facilities within the block include designated centers of refuge, a bank, and a pharmacy, County planning offices, NYS offices, and education facilities. In addition, the block has office space that is available to the City and County for emergency management operations. Besides the critical facilities within the microgrid block, there are a number other critical facilities and at risk communities within a 1200-foot radius of the microgrid. These include City Hall, Police headquarters, Fire Station #1, The County Offices, City Mission, a Senior Health Center, a Municipal Housing Complex, Amtrak Train Station, and a multi-story garage used to shelter vehicles of residents in the nearby flood prone Stockade District. The ultimate goal of the stakeholders is to expand the microgrid over time to encompass more of these critical facilities, and ultimately create a full-service resilient node in the downtown area.

1.2.10 Innovations that Strengthens Surrounding Grid

Currently, there are no rooftop solar installations in the downtown Schenectady area. As far as the Team is aware, no DERs of any kind have been allowed to operate on the secondary network likely due to the risk of back-feed issues (as discussed earlier). Proctors has purchased four micro-turbines which have not been allowed to spin up due to the fact that Proctors does not have enough load to offset the generation. National Grid has received funding from NYSERDA to test technology that would allow them desensitize the network protectors and trip the machines offline in the case of inadvertent islanding. The proposed microgrid will introduce a significant block of electrical load that would minimize the risk of back-feed. The microgrid will also incorporate monitoring and control technology to allow rooftop PV and other DERs to supply the load in the network without putting the grid operation at risk. This will create opportunities for customers on the secondary network to interact with the grid, participate in the market, and define new streams of revenue and value.

The Team has considered the options for interaction of the microgrid with the surrounding power grid, including both the distribution utility and the NYISO. The interaction with the surrounding grid across a Distribution System Platform (DSP) through market animation is a major aspect of the New York Reforming of Energy Vision (REV).

For instance, one possible innovation that may be considered within the REV framework is optimal economic operation of the resilient microgrid during normal days (i.e., during normal, non-emergency periods), by participation in the utility demand response programs and also NYISO’s energy, ancillary services, and capacity markets.

Active and dynamic scheduling of microgrid operations that would maximize the economic efficiency and technical reliability of the microgrid and the surrounding system will require both technical innovations and also reform of regulatory and policy regime that would enable market participation. The Team will elaborate on needed innovations and requirements that would enable such market participation. These may include complementary hardware that would provide more flexibility, such as integrated energy storage, and the smart scheduling software.

The Stage 2 design will describe the actionable information that would need to be made available to customers for economically efficient and technically reliable operation and scheduling of the microgrid resources. These include real-time load and supply status of the microgrid and the underlying variable costs of operations and the applicable seller and buyer prices on the DSP and/or NYISO. It should also be noted that such actionable information, although accessible to customers when requested or queried, would function and used mostly in the background in automated microgrid systems.

2 DEVELOP PRELIMINARY TECHNICAL DESIGN COSTS AND CONFIGURATION

2.1 Proposed Microgrid Infrastructure and Operations

2.1.1 Simplified Equipment Layout and One-Line Diagram

The figure below shows a simplified layout of the Schenectady microgrid, expressing several options for the electrical interconnection of Proctors and Center City. The existing thermal piping is shown in blue. This is used to meet the heating and cooling needs of the Center City block. The two options for new electrical conduit are shown in red and green. The red option involves construction of 600 feet of new conduit under the Hampton Inn parking lot, across State Street, and then along State Street to Center City. The green option proposes to route new cables through existing National Grid conduits to connect the Proctors to Center City, a total distance of 1,100 ft. A third (hybrid) approach would connect the new conduit across State Street into the existing National Grid ducts running parallel to State Street. These options have been preliminary discussed with National Grid and will be further explored in Stage 2.

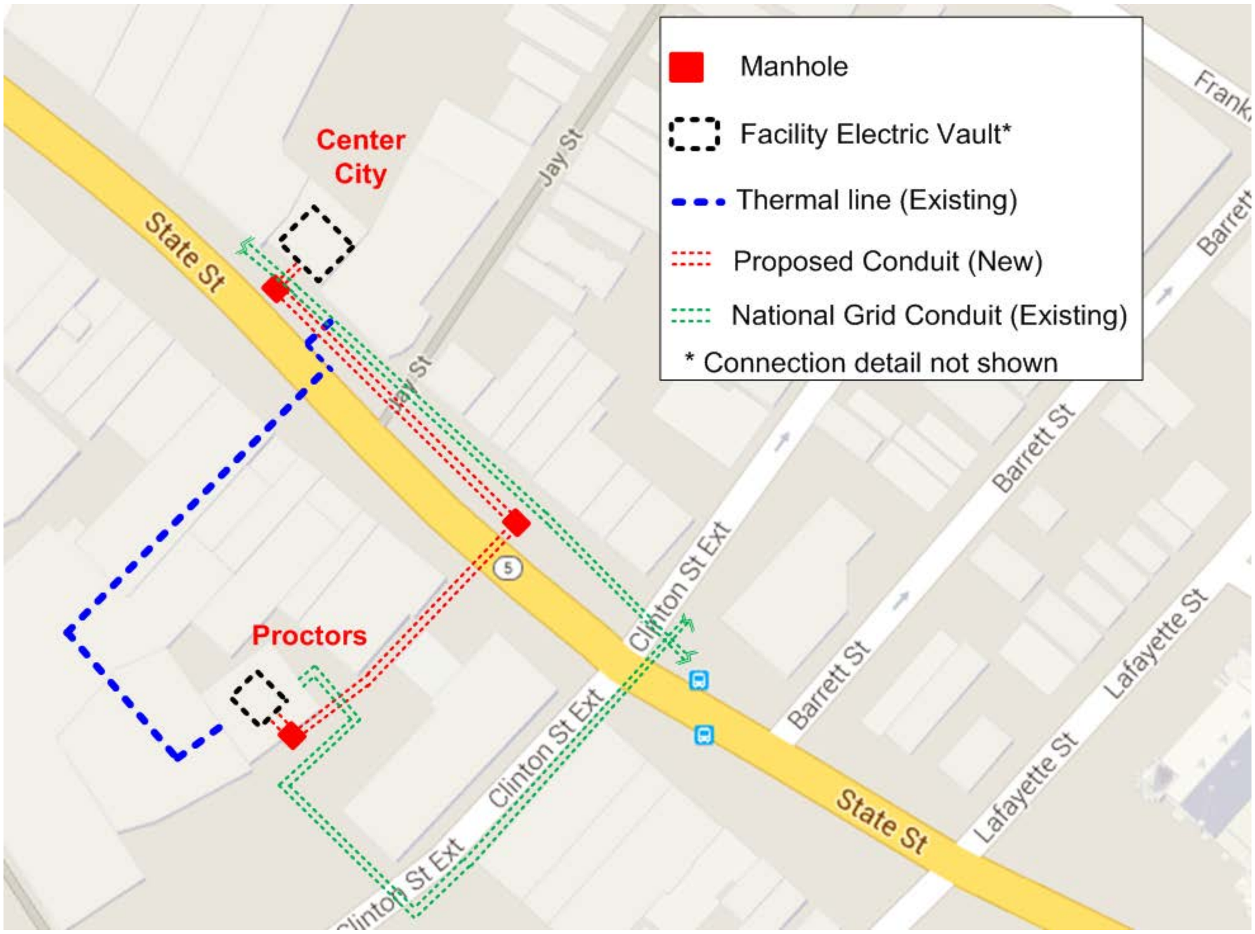

Figure 2-1 Simplified layout of Schenectady microgrid showing routing of electrical connection

Figure 2-2 below shows a simplified one-line with the location of the distributed energy resources (DER) and the points of utility interconnection (POI). The major additions, besides generation, are the 15-kV class cables connecting Proctors and Center City and the accompanying transformers and switchgear.

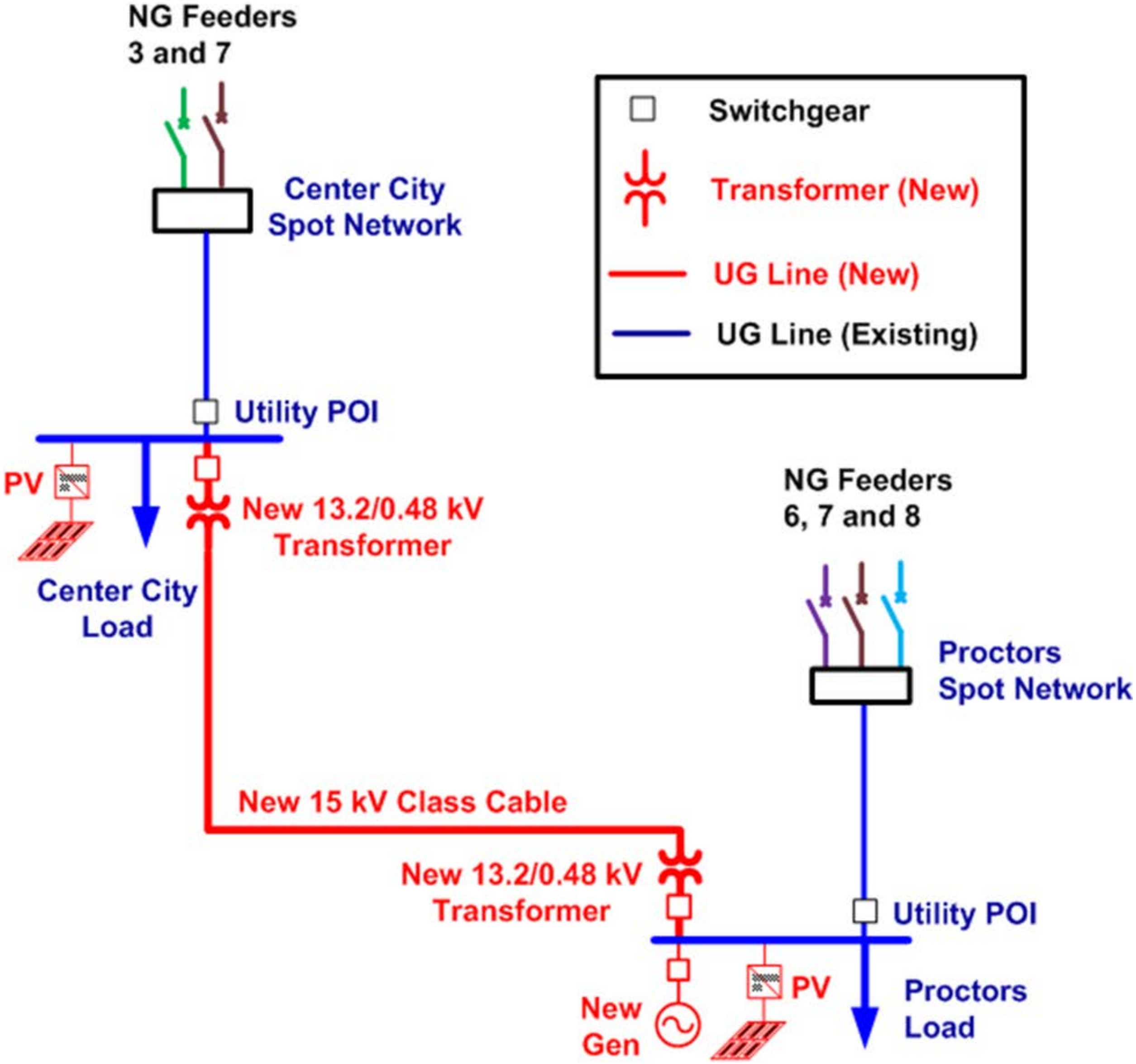

Figure 2-2 Schenectady microgrid one-line showing generation sources and major equipment

2.1.2 Operation under Normal and Emergency Conditions

Proctors and Center City currently receive grid power via dedicated spot networks served by three feeders and two feeders respectively, out of the Front Street Substation. The two spot networks have one feeder in common (No. 7) and are designed to at least N-1 standard (meaning loss of one feeder or transformer would not interrupt load). This is an extremely reliable design that is *likely* only compromised by a transmission system failure, substation failure, or network collapse or shutdown.

Normal Conditions

Under normal conditions the microgrid facilities will be served by the National Grid network system, as well as the CCHP generation at Proctors and PV generation at both locations. The new tie-line shown in Figure 2-2 may or may not be connected during normal sky days. In either case, the in-network generation will be monitored and controlled to ensure that it is less than the total load to reduce the risk of back-feeding.

If the electrical tie-line is active, the total load of Proctors and Center City provides a larger sink for the CCHP generation at Proctors, and the PV at both locations. This will allow both facilities to reduce peak demand on the grid and lower their energy cost. If the tie line is not connected, Proctors would still be able to supply part of its electrical load with the CCHP generation and PV, but would have a higher risk of back-feeding the grid. Any PV at Center City would be able to supply a portion of the electrical demand, and would be small enough (and correlated with coincident peak demand) so as to have manageable risk of back-feed. Interconnection of the two facilities via the tie-line enables greater penetration of DER such as PV, than if both facilities were operated independently

Emergency Conditions

When power is lost to both buildings due to, for example, a catastrophic event on the bulk power system, loads in both facilities will be unserved. The microgrid controller which is monitoring the points of interconnection (POIs) with the main grid will sense loss of voltage and the CCHP generation and PV will go off-line (in accordance with anti-islanding protection procedures). Interconnection points with the utility (and between the facilities if the tie line is active) will open and gas and diesel emergency generators at both locations will start up to supply emergency “Life and Safety” facility loads. Once the facility is isolated from the utility system, the CCHP generators will restart in islanded mode (self-synchronized). When the CCHP generation is stabilized, the Proctors-Center City tie-line is closed in, the Center City and Proctors emergency generators shut down, and load at both locations can be sequentially picked up by the CCHP. Once the island is stable and active, PV would reconnect and begin generating. During islanded operation, the microgrid controller would actively monitor voltage and frequency in the island.

In cases when the grid is stressed but there is no forced outage, “seamless” transition (in a few cycles) to islanded microgrid mode is possible with advanced controller functions. In this scenario the CCHP generators would remain online during the transition, and the microgrid controller would shed load if necessary. Another option is to incorporate energy storage to enable seamless transition. However, at this stage of the project, the benefit-cost analysis is not definitive enough for the stakeholders to request that this feature be incorporated into the microgrid.

2.2 Load Characterization

2.2.1 Description of Electric and Thermal Loads

In parallel mode, the CCHP Units will be running at maximum output if the electrical tie-line between Proctors and Center City is active. Power will be imported from the grid to make up any shortfall over the load cycle. In islanded mode the CCHP units will modulate output to match the electrical demand of the island. Whenever demand exceeds CCHP generation capacity, curtailable load will be shed and/or backup generation could be brought online to supply emergency loads. The backup generation at Center City is a natural gas unit, and the diesel emergency unit at Proctors has a 10,000-gallon storage tank.

In parallel and islanded mode, Proctors supplies 100% of the thermal needs of Center City. Heat is supplied via the output of the CCHP units. Ideally, the CCHP units would run as close as possible to maximum output in order to use all the heat from the units. However, on the coldest days of the year the CCHP units may not be able keep up with the heating load. In other cases, the facilities may not be able to consume all the electricity and the excess cannot be exported, which causes the CCHP machines to throttle down. Shortfalls in thermal energy are made up by the firing of the existing boilers to accommodate loads in the coldest days of the heating season. Shortfalls in plant cooling will be accommodated via operation of the existing electrical chillers.

The tables below summarize the microgrid electrical and thermal load.

Table 2-1: Monthly Microgrid Electric Load

	Proctors Energy (kWh)	Proctors Peak (kW)	Center City Energy (kWh)	Center City Peak (kW)	Total Microgrid Energy (kWh)	Total Microgrid Peak (kW)
January	162,135	585	258,189	843	420,324	1,428
February	152,972	509	243,599	872	396,571	1,381
March	176,307	544	280,757	913	457,064	1,458
April	180,881	641	288,041	952	468,921	1,593
May	224,646	790	357,735	1,181	582,381	1,970
June	282,077	886	449,189	1,487	731,266	2,373
July	288,576	879	459,538	1,518	748,114	2,397
August	271,293	954	432,016	1,414	703,308	2,367
September	249,842	838	397,857	1,326	647,699	2,163
October	245,898	857	391,576	1,296	637,473	2,153
November	180,455	492	287,362	961	467,817	1,453
December	191,602	556	305,113	989	496,714	1,545
Year	**2,606,682**	**954**	**4,150,971**	**1,518**	**6,757,653**	**2,397**

Table 2-2: Monthly Microgrid Heating Load

	Energy (kWh)	Peak (kW)	Energy (MMBtu)	Peak (MMBtu /Hour)	Energy (Therm-Hour)	Peak (Therm)
January	1,708,180	2,701	5,829	9.217	58,299	92.19
February	1,469,512	2,573	5,014	8.778	50,154	87.80
March	1,427,398	2,257	4,870	7.702	48,716	77.03
April	424,493	1,257	1,448	4.290	14,488	42.91
May	224,679	1,039	767	3.545	7,668	35.46
June	203,456	635	694	2.167	6,944	21.67
July	171,930	524	587	1.787	5,868	17.87
August	176,345	593	602	2.022	6,019	20.23
September	213,323	745	728	2.540	7,281	25.41

October	270,691	1,045	924	3.564	9,239	35.65
November	919,329	2,179	3,137	7.435	31,376	74.36
December	1,343,531	2,124	4,584	7.249	45,854	72.51
Year	**8,552,865**	**2,701**	**29,184**	**9.217**	**291,906**	**92.19**

Table 2-3: Monthly Microgrid Cooling Load

	Energy (kWh)	Peak (kW)	Energy (MMBtu)	Peak (MMBtu /Hour)	Energy (Therm-Hour)	Peak (Therm)
January	39,619	247	135	0.843	1,352	8.44
February	45,823	278	156	0.948	1,564	9.48
March	75,667	342	258	1.167	2,582	11.67
April	176,472	1,292	602	4.409	6,023	44.10
May	354,658	2,637	1,210	8.996	12,104	89.99
June	554,626	3,501	1,892	11.946	18,929	119.49
July	618,667	4,179	2,111	14.259	21,115	142.62
August	558,897	3,566	1,907	12.167	19,075	121.70
September	425,276	3,065	1,451	10.460	14,514	104.62
October	222,457	1,918	759	6.544	7,592	65.45
November	91,492	623	312	2.126	3,123	21.26
December	59,872	164	204	0.561	2,043	5.61
Year	**3,223,526**	**4,179**	**10,999**	**14.259**	**110,018**	**142.62**

2.2.2 Hourly Load Profile

The sources of data are the electric and fuel billing statements. Proctors provided statements for their monthly electrical load and the Marquee Power plant heating and cooling loads. Center City's electrical load was estimated based on the square footage of the buildings. The monthly energy and peak information and the resulting monthly load factors were applied to various 12 x 24 load profiles from the DER-CAM model for appropriate facility types in order to develop the individual 12 x 24 facility load profiles, and then aggregated into the total microgrid load.

Due to lack of available data, a simple thermal load profile was assumed throughout the week, with similar load levels during weekday and weekends.

The microgrid's 12 x 24 electrical and thermal load profiles in tabular and graphical forms are provided in the following tables and charts.

Table 2-4: Microgrid 12x24 Electrical Load (kW)

Day-type	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
week	1	20	51	20	53	20	55	94	157	297	497	516	516	529	529	529	529	529	516	350	331	283	88	19	42
week	2	21	46	23	53	25	57	107	173	322	539	551	552	561	562	563	564	565	558	386	376	326	110	42	59
week	3	57	107	60	112	62	179	310	543	984	1366	1396	1396	1416	1416	1416	1416	1416	1257	949	876	593	177	53	88
week	4	53	92	55	101	56	193	345	612	1096	1441	1458	1458	1470	1470	1470	1470	1470	1268	992	915	572	161	52	77
week	5	68	67	71	69	75	283	478	892	1533	1646	1646	1655	1655	1655	1655	1655	1646	1190	1107	969	331	84	62	61
week	6	67	67	69	69	71	355	586	1098	1886	1886	1886	1886	1886	1886	1886	1886	1886	1284	1284	1098	273	66	66	66
week	7	75	75	76	76	76	391	641	1221	2070	2108	2108	2134	2134	2134	2134	2134	2108	1433	1393	1193	302	75	75	75
week	8	82	82	82	82	82	447	738	1383	2375	2375	2375	2375	2375	2375	2375	2375	2375	1617	1617	1383	344	82	82	82
week	9	83	83	83	83	83	430	705	1344	2277	2321	2321	2351	2351	2351	2351	2351	2321	1578	1531	1311	332	83	83	83
week	10	79	80	81	81	83	415	684	1289	2203	2217	2217	2227	2227	2227	2227	2227	2217	1509	1493	1278	320	78	78	78
week	11	69	82	69	86	70	283	505	936	1623	1876	1898	1914	1929	1929	1929	1929	1912	1479	1263	1117	510	135	69	76
week	12	70	100	73	107	75	296	503	929	1612	1882	1893	1909	1917	1917	1917	1917	1901	1484	1263	1129	530	147	68	87
weekend	1	14	16	17	17	17	17	33	28	70	95	157	157	181	181	181	181	181	157	97	46	43	33	11	16
weekend	2	11	16	13	16	14	16	33	31	73	103	166	166	188	188	188	188	188	166	103	50	49	33	10	12
weekend	3	32	37	37	39	38	49	84	103	201	297	420	438	482	482	482	482	465	382	224	125	110	75	27	37
weekend	4	27	34	30	36	32	55	86	127	226	341	442	466	502	502	502	502	478	374	216	132	111	61	26	28
weekend	5	27	30	28	31	29	69	91	192	282	455	495	553	562	562	562	562	505	348	175	147	107	46	27	29
weekend	6	29	29	29	30	29	90	105	246	346	560	560	636	636	636	636	636	560	346	165	165	104	29	29	29
weekend	7	33	33	33	33	33	102	119	284	399	645	645	733	733	733	733	733	645	399	190	190	119	33	33	33
weekend	8	36	36	36	36	36	112	130	310	436	706	706	801	801	801	801	801	706	436	207	207	130	36	36	36
weekend	9	36	36	36	36	36	116	135	316	448	721	721	814	814	814	814	814	721	445	216	216	135	36	36	36
weekend	10	34	34	34	34	34	103	120	289	403	657	657	751	751	751	751	751	657	406	189	189	120	34	34	34
weekend	11	31	31	32	32	32	85	113	227	351	548	602	657	676	676	676	676	621	424	229	184	130	49	30	32
weekend	12	35	35	38	36	39	74	106	202	311	494	566	624	649	649	649	649	591	422	221	163	122	61	33	38

Table 2-5: Microgrid 12x24 Heating Load (kW)

Day-type	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
week	1	2054	2054	2054	2054	2440	2440	2440	2440	2440	2702	2702	2702	2440	2440	2440	2440	2440	2054	2054	2054	2054	2054	2054	2054
week	2	1956	1956	1956	1956	2324	2324	2324	2324	2324	2574	2574	2574	2324	2324	2324	2324	2324	1956	1956	1956	1956	1956	1956	1956
week	3	1716	1716	1716	1716	2039	2039	2039	2039	2039	2258	2258	2258	2039	2039	2039	2039	2039	1716	1716	1716	1716	1716	1716	1716
week	4	252	252	252	252	761	761	761	761	761	1258	1258	1258	761	761	761	761	761	252	252	252	252	252	252	252
week	5	156	156	156	156	242	242	242	242	242	1038	1038	1038	242	242	242	242	242	156	156	156	156	156	156	156
week	6	127	127	127	127	348	348	348	348	348	636	636	636	348	348	348	348	348	127	127	127	127	127	127	127
week	7	105	105	105	105	282	282	282	282	282	524	524	524	282	282	282	282	282	105	105	105	105	105	105	105
week	8	119	119	119	119	261	261	261	261	261	593	593	593	261	261	261	261	261	119	119	119	119	119	119	119
week	9	149	149	149	149	324	324	324	324	324	745	745	745	324	324	324	324	324	149	149	149	149	149	149	149
week	10	209	209	209	209	329	329	329	329	329	1045	1045	1045	329	329	329	329	329	209	209	209	209	209	209	209
week	11	871	871	871	871	1453	1453	1453	1453	1453	2179	2179	2179	1453	1453	1453	1453	1453	871	871	871	871	871	871	871
week	12	1615	1615	1615	1615	1919	1919	1919	1919	1919	2125	2125	2125	1919	1919	1919	1919	1919	1615	1615	1615	1615	1615	1615	1615
weekend	1	2054	2054	2054	2054	2054	2054	2486	2486	2486	2486	2702	2702	2702	2486	2486	2486	2486	2486	2054	2054	2054	2054	2054	2054
weekend	2	1956	1956	1956	1956	1956	1956	2368	2368	2368	2368	2574	2574	2574	2368	2368	2368	2368	2368	1956	1956	1956	1956	1956	1956
weekend	3	1716	1716	1716	1716	1716	1716	2077	2077	2077	2077	2258	2258	2258	2077	2077	2077	2077	2077	1716	1716	1716	1716	1716	1716
weekend	4	252	252	252	252	252	252	818	818	818	818	1258	1258	1258	818	818	818	818	818	252	252	252	252	252	252
weekend	5	156	156	156	156	156	156	251	251	251	251	1038	1038	1038	251	251	251	251	251	156	156	156	156	156	156
weekend	6	127	127	127	127	127	127	372	372	372	372	636	636	636	372	372	372	372	372	127	127	127	127	127	127
weekend	7	105	105	105	105	105	105	301	301	301	301	524	524	524	301	301	301	301	301	105	105	105	105	105	105
weekend	8	119	119	119	119	119	119	277	277	277	277	593	593	593	277	277	277	277	277	119	119	119	119	119	119
weekend	9	149	149	149	149	149	149	343	343	343	343	745	745	745	343	343	343	343	343	149	149	149	149	149	149
weekend	10	209	209	209	209	209	209	344	344	344	344	1045	1045	1045	344	344	344	344	344	209	209	209	209	209	209
weekend	11	871	871	871	871	871	871	1514	1514	1514	1514	2179	2179	2179	1514	1514	1514	1514	1514	871	871	871	871	871	871
weekend	12	1615	1615	1615	1615	1615	1615	1955	1955	1955	1955	2125	2125	2125	1955	1955	1955	1955	1955	1615	1615	1615	1615	1615	1615

Table 2-6: Microgrid 12x24 Cooling Load (kW)

Day-type	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
week	1	1.9	1.9	1.9	1.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	38.5	38.5	38.5	4.8	4.8	4.8	4.8	4.8	4.8	1.9	1.9
week	2	2.2	2.2	2.2	2.2	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	43.3	43.3	43.3	7.4	7.4	7.4	7.4	7.4	7.4	2.2	2.2
week	3	2.7	2.7	2.7	2.7	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	53.3	53.3	53.3	13.6	13.6	13.6	13.6	13.6	13.6	2.7	2.7
week	4	10.0	10.0	10.0	10.0	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	200.7	200.7	200.7	16.9	16.9	16.9	16.9	16.9	16.9	10.0	10.0
week	5	20.5	20.5	20.5	20.5	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	409.1	409.1	409.1	28.6	28.6	28.6	28.6	28.6	28.6	20.5	20.5
week	6	27.2	27.2	27.2	27.2	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	544.7	544.7	544.7	71.9	71.9	71.9	71.9	71.9	71.9	27.2	27.2
week	7	32.5	32.5	32.5	32.5	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8	650.8	650.8	650.8	63.8	63.8	63.8	63.8	63.8	63.8	32.5	32.5
week	8	27.7	27.7	27.7	27.7	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	554.8	554.8	554.8	64.9	64.9	64.9	64.9	64.9	64.9	27.7	27.7
week	9	23.9	23.9	23.9	23.9	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	477.3	477.3	477.3	42.0	42.0	42.0	42.0	42.0	42.0	23.9	23.9
week	10	6.0	6.0	6.0	6.0	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	298.9	298.9	298.9	12.3	12.3	12.3	12.3	12.3	12.3	6.0	6.0
week	11	4.9	4.9	4.9	4.9	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	97.0	97.0	97.0	10.3	10.3	10.3	10.3	10.3	10.3	4.9	4.9
week	12	3.8	3.8	3.8	3.8	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	25.5	25.5	25.5	13.4	13.4	13.4	13.4	13.4	13.4	3.8	3.8
weekend	1	1.9	1.9	1.9	1.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	38.5	38.5	38.5	4.8	4.8	4.8	4.8	4.8	4.8	1.9	1.9
weekend	2	2.2	2.2	2.2	2.2	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	43.3	43.3	43.3	7.4	7.4	7.4	7.4	7.4	7.4	2.2	2.2
weekend	3	2.7	2.7	2.7	2.7	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	53.3	53.3	53.3	13.6	13.6	13.6	13.6	13.6	13.6	2.7	2.7
weekend	4	10.0	10.0	10.0	10.0	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	200.7	200.7	200.7	16.9	16.9	16.9	16.9	16.9	16.9	10.0	10.0
weekend	5	20.5	20.5	20.5	20.5	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	409.1	409.1	409.1	28.6	28.6	28.6	28.6	28.6	28.6	20.5	20.5
weekend	6	27.2	27.2	27.2	27.2	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	544.7	544.7	544.7	71.9	71.9	71.9	71.9	71.9	71.9	27.2	27.2
weekend	7	32.5	32.5	32.5	32.5	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8	650.8	650.8	650.8	63.8	63.8	63.8	63.8	63.8	63.8	32.5	32.5
weekend	8	27.7	27.7	27.7	27.7	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	554.8	554.8	554.8	64.9	64.9	64.9	64.9	64.9	64.9	27.7	27.7
weekend	9	23.9	23.9	23.9	23.9	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	477.3	477.3	477.3	42.0	42.0	42.0	42.0	42.0	42.0	23.9	23.9
weekend	10	6.0	6.0	6.0	6.0	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	298.9	298.9	298.9	12.3	12.3	12.3	12.3	12.3	12.3	6.0	6.0
weekend	11	4.9	4.9	4.9	4.9	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	97.0	97.0	97.0	10.3	10.3	10.3	10.3	10.3	10.3	4.9	4.9
weekend	12	3.8	3.8	3.8	3.8	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	25.5	25.5	25.5	13.4	13.4	13.4	13.4	13.4	13.4	3.8	3.8

A "large office" 12x24 electrical load shape from DER-CAM database was used to generate the monthly load shapes, resulting in the same annual electrical load as the microgrid with similar, if not exact, average annual load factor. The coincident peak of the two facilities (i.e. peak of the total microgrid) is very close to the sum of the peak of the individual facilities (Proctors and Center City).

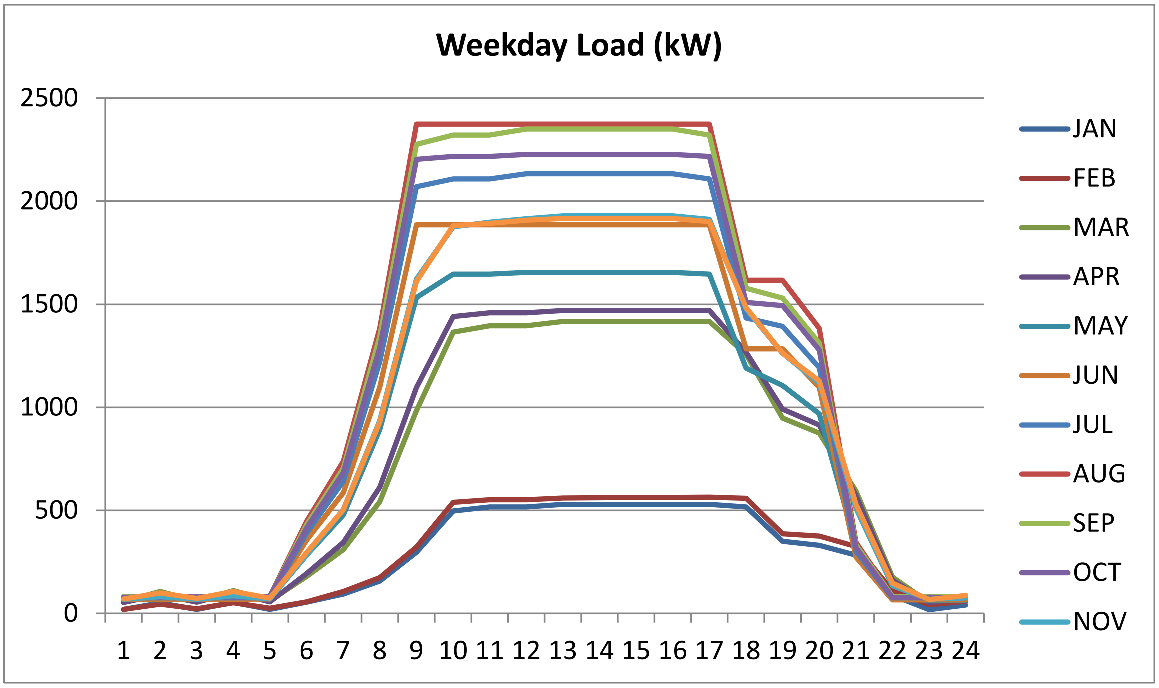

Figure 2-3: Microgrid Weekday Electrical Load

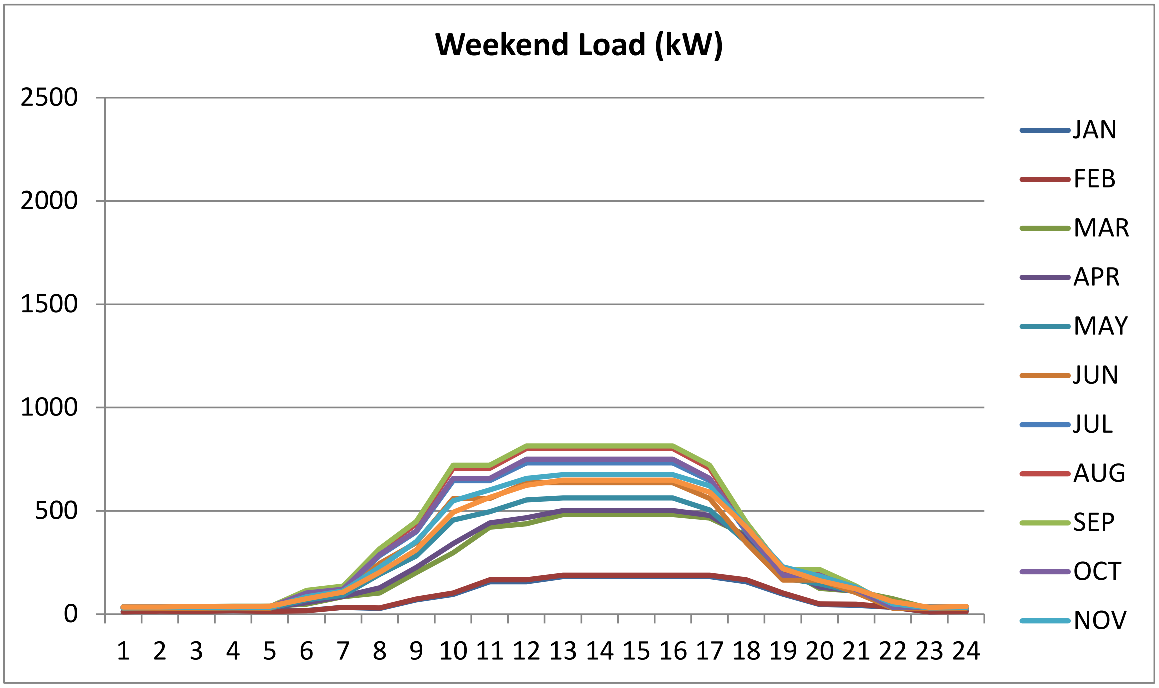

Figure 2-4: Microgrid Weekend Electrical Load (kW)

The 12x24 heating load shapes have a simple form to allow adjustment of monthly energy, peak, and load factors. The monthly load shapes have been scaled to provide exactly the same monthly energy, peak, and load factor as the data provided by Proctors. The high monthly load factors result in relatively flat load shape.

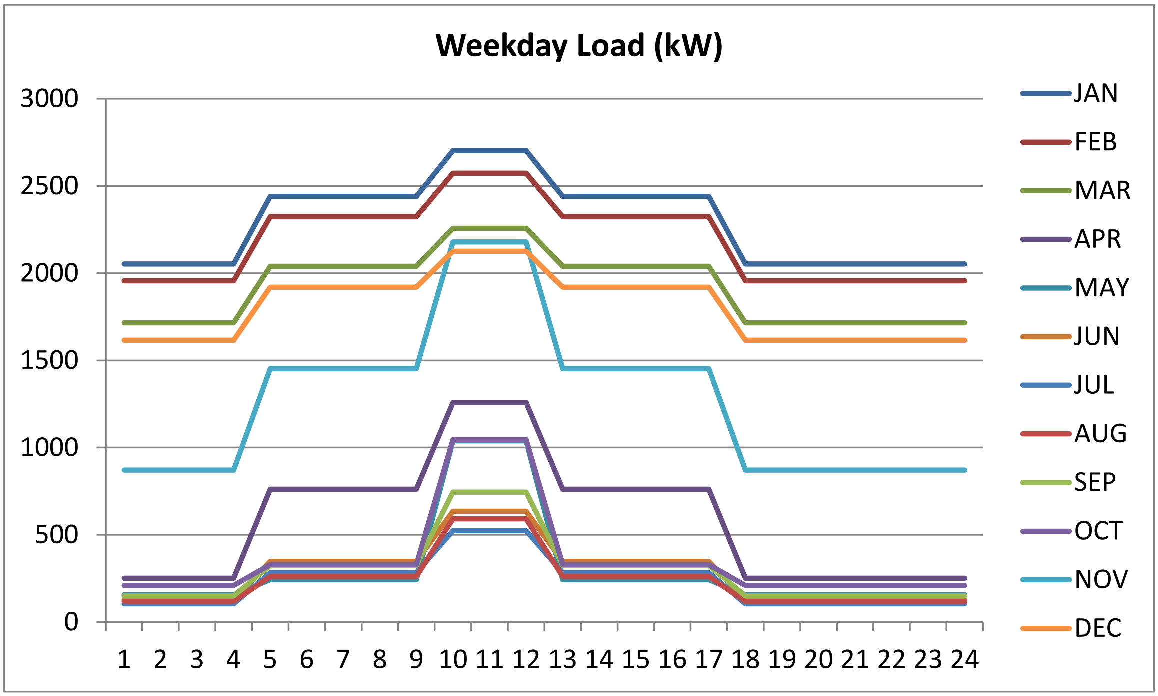

Figure 2-5: Microgrid Weekday Heating Load (kW)

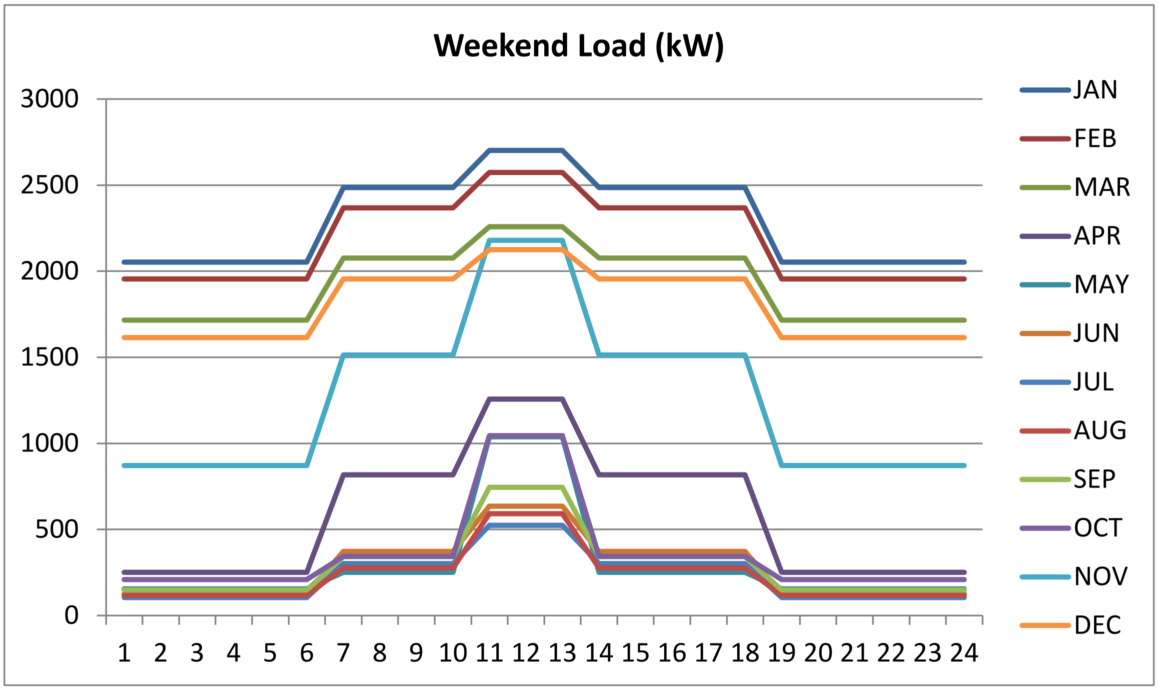

Figure 2-6: Microgrid Weekend Heating Load (kW)

Similarly, the 12x24 cooling load shapes have a simple form to allow adjustment of monthly energy, peak, and load factors. The monthly load shapes have been scaled to provide exactly the same monthly energy, peak, and load factor as the data provided by Proctors. The very low monthly load factors result in relatively high load during very few hours. Making the load shape more evenly distributed will result in much higher load factors compared to the provided data.

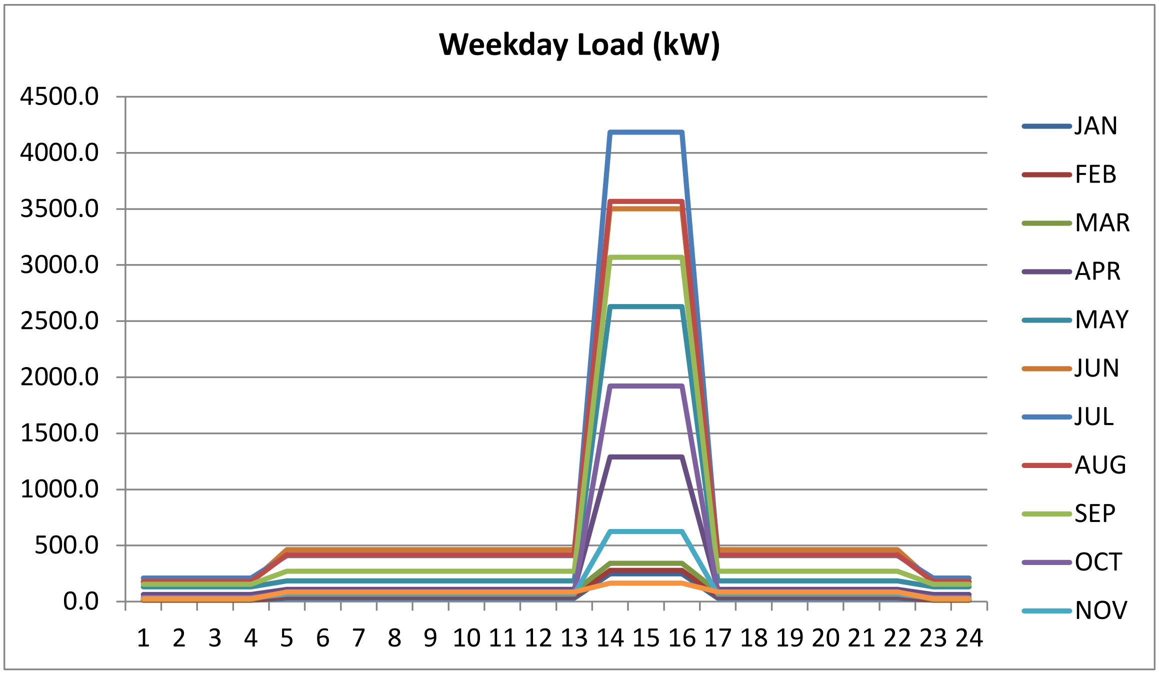

Figure 2-7: Microgrid Weekday Cooling Load (kW)

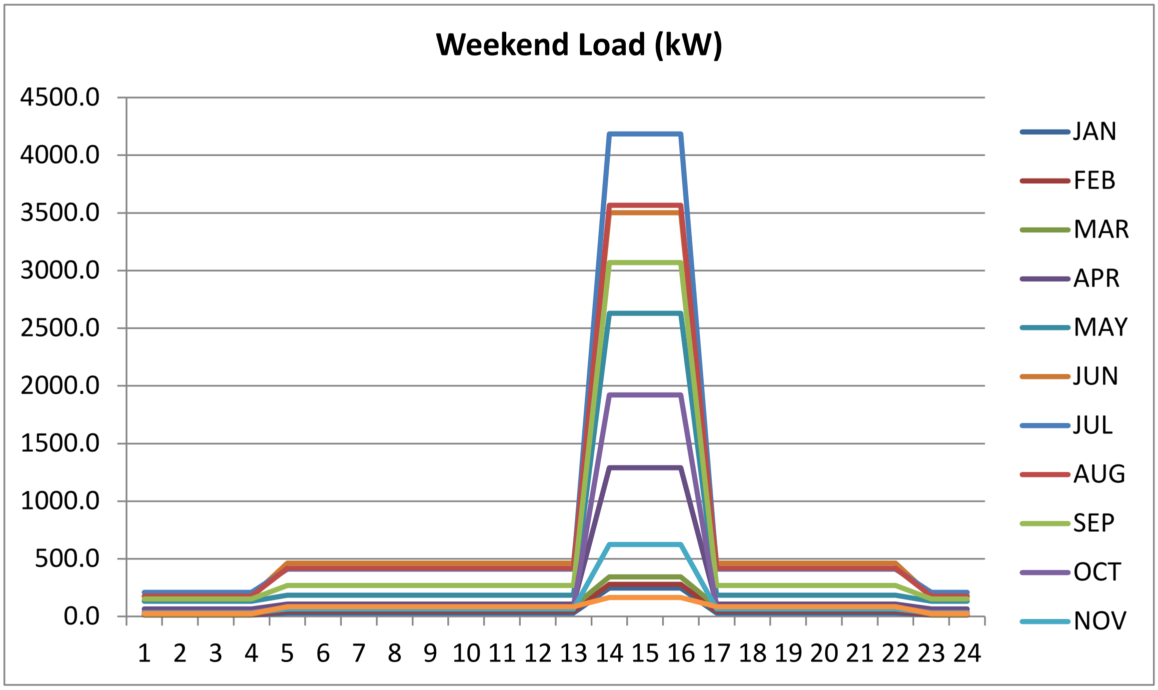

Figure 2-8: Microgrid Weekend Cooling Load

2.2.3 Description of Load Sizing

The microgrid total load is based on the total loads of Proctors and Center City to be served by the microgrid, as listed in Table 2-7 below. As mentioned earlier, Proctors' monthly electrical energy and peak load and Marquee Power's monthly heating and cooling energy and peak loads were provided by Proctors. Center City's electrical load was estimated based on square footage.

The estimated microgrid electrical peak load is 2,375 kW, but could be 2471 kW in the worst case (sum of the non-coincidental peak loads for Proctors and Center City, if using different load shapes). The 2 x 1,000 kW CCHP recips and 4 x 65 kW microturbines together will satisfy 2,260 kW of the microgrid load. However, possible load curtailments during an emergency are assumed to be about 10% of the individual peak loads or 247 kW. Hence, the total available electrical resources (generation + demand response) of 2,507 kW is more than sufficient to meet the total microgrid electrical load during a major emergency, not counting the 550 kW nameplate solar PV.

In the event of an outage of the largest generation resource, (i.e., a 1,000 kW CCHP unit), some additional load will have to be shed, but there will still be a total of 1,507 kW of supply and demand side resource, besides the solar PV. Hence, in the event of the outage of the largest resource, the microgrid may need additional resources. However, costs of additional supply side or demand side reserves needs to be weighed against the risk associated with additional contingencies. It should be noted that there is also a 250 kW emergency diesel generator at Proctors and a 150 kW natural gas back up engine at Center City. However, these machines are currently configured to serve dedicated "Life and Safety" circuits, and would have to be integrated into the microgrid control system.

Table 2-7: Summary of Microgrid Electrical, Heating, and Cooling Loads

	Electrical Load			**Heating Load**			**Cooling Load**		
Facility	**Energy (kWh)**	**Peak (kW)**	**Load Factor**	**Energy (kWh)**	**Peak (kW)**	**Load Factor**	**Energy (kWh)**	**Peak (kW)**	**Load Factor**
Proctors	2,606,682	953	31.2%	8,552,865	2,702	36.1%	3,223,526	4,184	8.8%
Center City	4,150,971	1,518	31.2%						
Total	**6,757,653**	**2,471**	**31.2%**	**8,552,865**	**2,702**	**36.1%**	**3,223,526**	**4,184**	**8.8%**

2.3 Distributed Energy Resources Characterization

2.3.1 DER and Thermal Generation Resources

The following table lists all the DER elements in the microgrid. The first two are existing diesel and natural gas based backup generation that will continue to function as backup resources. The existing microturbines will be part of the baseload microgrid portfolio. The proposed new elements are in bold font. These include 2 x 1,000 kW CCHP units. The CCHP units are planned to run most of the year, servicing a portion of the heating loads in the winter months and the cooling loads (via absorption chillers) in the summer. The solar resources include several sets of solar PV planned for the rooftop spaces of Proctors and other locations (being discussed), totaling 550 kW of nameplate capacity.

Table 2-8 Microgrid Generation Resources

DER Type	Facility Name	Energy Source	Name plate Capacity (MW)	Avg Annual Production Normal (MWh)	Avg Daily Production Emergency (MWh)	Fuel Consumption per MWh	
						Quantity	Unit
Existing Backup	Proctors	*Diesel*	.250	3	0.0	204.5	Gallons
Existing Backup	Center City	*Natural Gas*	.150	212	0.0	13.6	MMBtu
4 x Capstone Microturbines	Proctors	*Natural Gas*	.260	292	0.0	11.4	MMBtu
CHP-1	**Proctors**	***Natural Gas***	**1.00**	**3,083**	**17.6**	**9.5**	**MMBtu**
CHP-2	**Proctors**	***Natural Gas***	**1.00**	**2,263**	**8.4**	**9.5**	**MMBtu**
Rooftop PV	**Proctors and other locations**	***Solar***	**.550**	**950**	**3.3**	**N/A**	**N/A**

2.3.2 New DER and Thermal Generation Resources

New generation resources and their locations are listed in bold font in Table 2-8. All new CCHP units will be located in the Marquee Power plant, which currently houses the four Capstone microturbines. There is approximately 4,500 square-feet of space on the roof of the plant which could possibly be used to house the CCHP. However, to accommodate these units the roof would need to be reinforced and the layout of existing equipment and piping might have to be reconfigured. The indirect-fired absorption chiller will be housed inside in the boiler room. The CCHP units are shown collectively on the Proctors load bus on the one-line diagram in Figure 2-2. The details of the in-plant wiring are omitted at this point.

A total of 550 kW of new PV is planned on the roof-top of Proctors and other locations. Proctors has 5,000 square-feet of usable space (for solar PV) on the Proctors Stage House roof. Another possible location is Center City, which has 36,000 square-feet of usable space for solar PV. However, the availability of this space for solar PV is still under discussion. These PV units are shown on the load buses of Proctors and Center City in Figure 2-2.

2.3.3 Adequacy of DERs and Thermal Generation Resources

The DER-CAM model takes into consideration the 12-month x 24-hour daily average electrical and thermal profiles of the aggregate loads of Proctors and Center City.

The solar energy (based on the solar irradiance profile in Albany, NY) is available during on-peak hours.

Figure 2-9 provides a view of the “theoretical” load and supply balance over a weekday of operation on a normal day in the month of August. The DER-CAM model dispatches all the generation resources based on the comparative economics of on-site generation versus purchase from the utility. As can be seen, power is purchased from the utility during off-peak hours (there is a demand charge during on-peak hours). However, we have imposed a requirement that the CH units run for a minimum number of hours, during which they can modulate between a set minimum load and their maximum load.

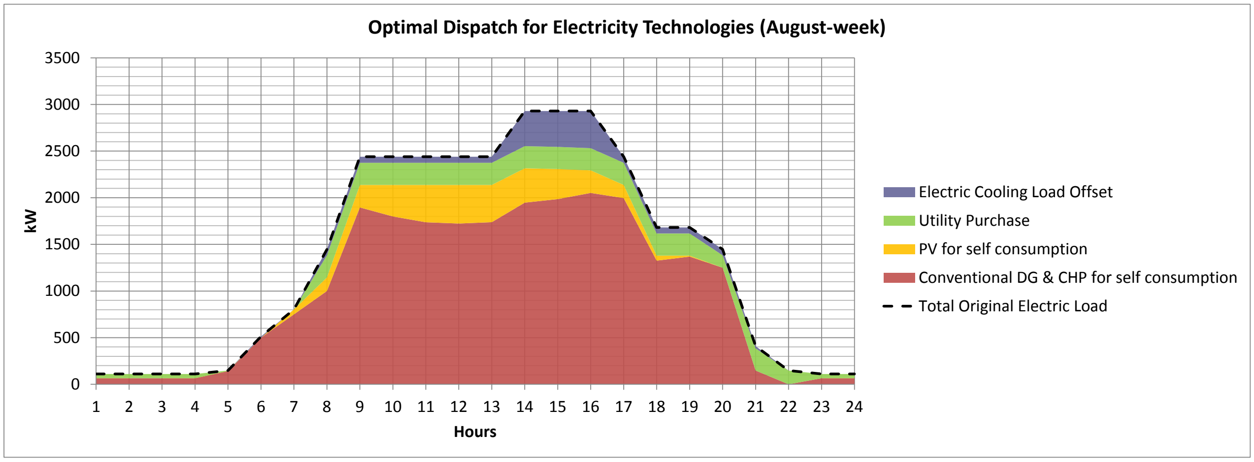

Figure 2-9: Microgrid Optimal Dispatch to Meet Electric Load – August Normal Weekday

In the above figure, the dotted line represents the total original electrical load. The burgundy colored area represents the on-site generation by the microgrid (CCHP + micro-turbines). The yellow colored area is the solar PV production. The green colored area is the additional electric energy purchased from the utility. The purple colored area is the reduction in the original electric load due to use of absorption chillers, which replaces the electric usage by central chillers. The relative economics of on-site generation based on the microgrid resource efficiencies and fuel costs versus the electricity purchase from the grid with its energy delivery and market rates, and the demand charge rates, determines the dispatch of the onsite generation. Load following, where required, achieved by cycling the CHP units and also relying on the microturbines during low-load hours. Grid resources can also provide most of the load-following and voltage/frequency regulation services in connected mode.

Figure 2-10 shows the microgrid operation during an emergency weekday in August (the month with the highest microgrid load based on the assumed load shape. As can be observed, there is no utility purchase, and all microgrid load is met by on-site generation, including solar PV. It is interesting to note that the combination of on-site generation and electric load reduction due to absorption chillers is sufficient to meet the electric load. There is no need for load curtailment during this week, although the system can curtail up to 10% of the individual facility peak loads (about 247 kW).

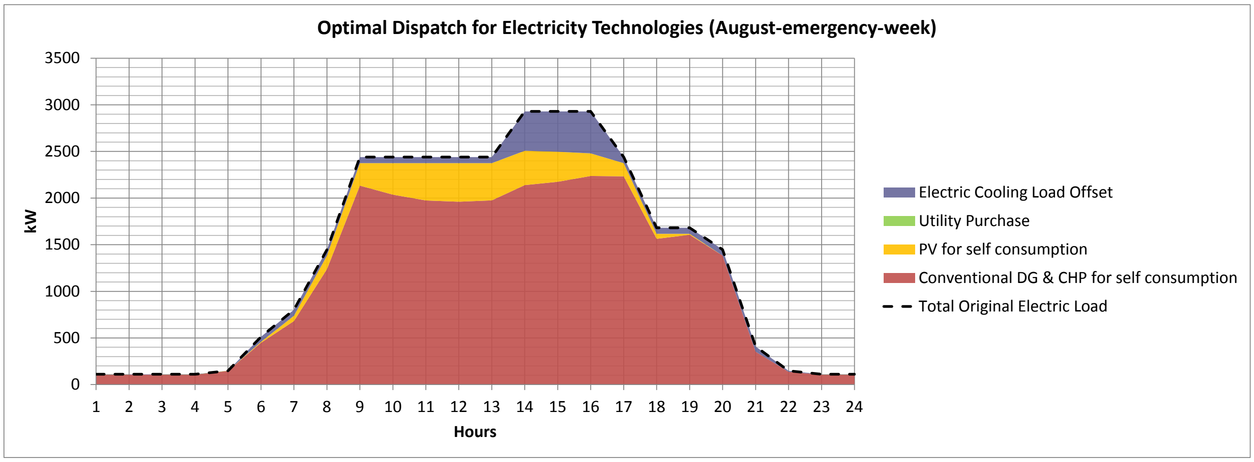

Figure 2-10: Microgrid Optimal Dispatch to Meet Electric Load – August Emergency Weekday

Figure 2-11 shows thermal dispatch for heat load during a normal weekday in August. The dotted line is the microgrid original total heat load. The additional thermal generation going above and beyond the heat load is actually the portion of the CCHP thermal energy that is used to run the absorption chiller, shown in the later figures. In hour 22, as CCHP production drops, there is a need for additional boiler-based thermal energy to make up the shortfall, represented by the small grey colored areas.

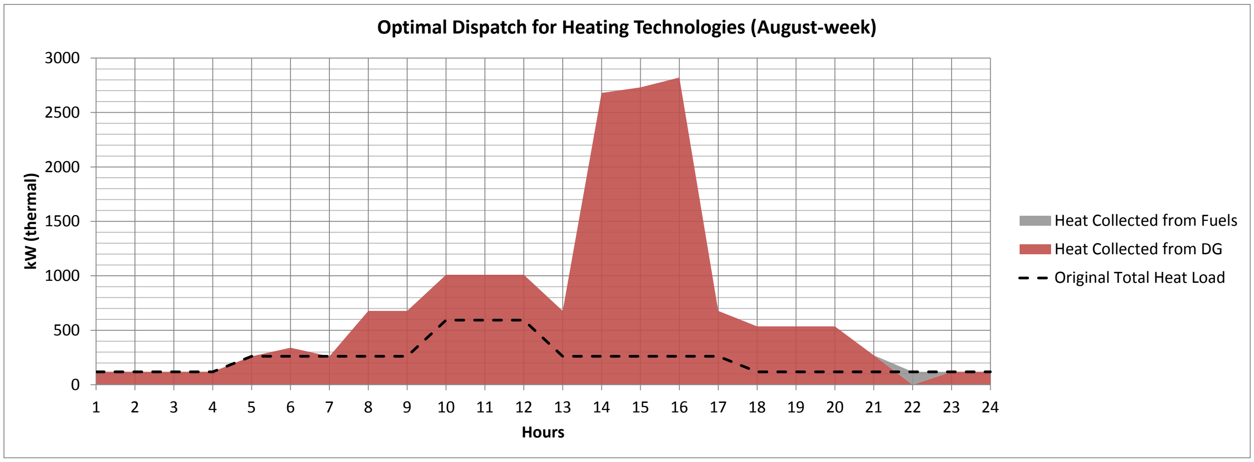

Figure 2-11: Microgrid Optimal Dispatch to Meet the Heat Load – August Normal Weekday

Figure 2-12 shows thermal dispatch for cooling load during a normal weekday in August. The dotted line is the microgrid original total cool load. Note that in DER-CAM, the cooling load size is not based on the final cooling energy output. It is actually based on the equivalent electric input of central dispatch that will provide that amount of thermal energy, and hence reflects the assumed Coefficient of Performance (COP), which we have assumed to be 4.5.

The burgundy colored area is the cooling load that is provided by the absorption chiller. As shown, there is a need for additional supply to meet the total cooling load - provided by the central chiller (blue colored area).

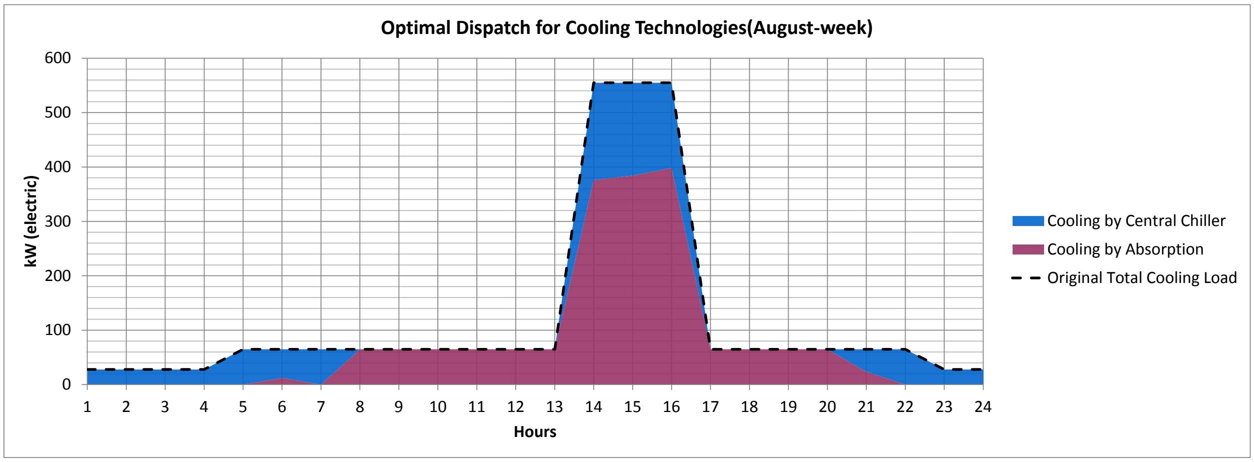

Figure 2-12 Microgrid Optimal Dispatch to Meet the Cooling Load – August Normal Weekday

2.3.4 Resiliency of DERs and Thermal Generation Resources

The new CCHP units will be installed above the flood plain on the roof of the Marquee Power plant and are therefore protected from most severe weather incidents, and flooding. According to the EPA Catalog of CCHP technologies[4], "*Micro-turbine systems in the field have generally shown a high level of availability … manufacturers have targeted availabilities of 98-99 percent. The use of multiple units or backup units at a site can further increase the availability of the overall facility*." The Capstone C65 can run up to 40,000 hours before replacement of major components. Natural gas engines, such as ENER-G CCHP units, have an availability of about 96% for units sized 100-800 kW, a forced outage rate of about 2%, and a scheduled outage rate of about 2.5%. These CCHP units, along with the emergency backup generation at both sites results in a collective power system with very high reliability that is insulated from the forces of nature. The expected forced-outage rate of the entire power plant will be analyzed in Stage 2.

According to National Grid, the natural gas supply has proven to be extremely resilient during past major events. Therefore, supply to the CCHP units is not expected to be interrupted in most emergencies (barring seismic activity or sabotage). The possibility of these events is remote enough to preclude consideration of propane tanks, CNG, or LNG.

The roof-top PV panels are at some risk of being partially or completely covered with snow cover during 4-5 months of the year. However, the actual contribution of these panels to the overall power profile is not substantial enough to warrant additional action besides an occasional cleaning during these months. The emergency backup generation at both sites is more than enough to compensate for any energy lost due to snow cover on PV panels. The microgrid controller should be able to recognize when PV panels are under-producing relative to normal operation, and can generate an inspection/maintenance signal. There will be a program from the solar leasing company to perform regular scheduled maintenance of the solar panels which includes cleaning, orientating, picking any weeds and grass that may start to grow and block sunlight.

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[4] http://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf

2.3.5 Description of Fuel Sources for DERs

Natural gas and solar are the energy/fuel resources used for base load generation in this project. Table 2-8 above shows the average annual production for microgrid generation resources under normal circumstances. The table also shows the fuel consumption for each MWh produced. For the 2,260 kW of CCHP generators, approximately 247 MMBtu/day of natural gas would be needed per day *during emergency conditions.* Proctors currently has a natural gas pipeline with a capacity of at least 272 MMBtu/day, based on the reported monthly heating and cooling load, and adjusted to reflect 80% boiler efficiency.

The emergency diesel generator at Proctors has 10,000 gallons of fuel storage, enough to last about 3-4 weeks of continuous operation at full load. The backup generation at Center City runs on natural gas and would consume about 50 MMBtu per day at full load.

Based on day-to-day analysis of weather patterns, the solar PV on Proctors and other locations (possibly Center City) are expected to produce energy for approximately 1,700 hours per year, or about 20% of the year.

2.3.6 Description of Operational Capabilities of DERs

During the formation of a microgrid, it is anticipated that the Proctors emergency diesel generator will be online for the transition, possibly providing black-start power for the microgrid CCHP units (see Section 2.1.2).

If the diesel emergency generation is not online, the CCHP gas engines generally require only batteries or compressed air to black-start. Reciprocating engines have high part-load efficiency, which ensures economical operation in load following applications.

The existing micro-turbines at Proctors, because they are inverter-based generators, can easily incorporate battery storage to start the generators and provide black-start capability for the microgrid if needed. Micro-turbines are generally designed to operate as base-loaded generation, but in this application some load-following could be achieved by sequentially turning on additional units which lessens the need for part load operation.

In connected mode (parallel to the grid), microgrid generation resources would not be required to regulate frequency, and would likely have a small role if any in voltage regulation. These services are provided by the bulk power system and the surrounding distribution system. However, in islanded mode, microgrid resources will need to provide for power balance/frequency control and reactive power balance/voltage control.

Some types of generators are more capable of providing frequency control than others. For the Schenectady microgrid, some assets will provide base load power while other assets would switch to frequency control mode. Both the CCHP and micro-turbines tend to be better suited to base load operation than frequency control. However, the reciprocating CCHP engines can also follow load and provide frequency regulation. Fast frequency regulation can also be provided by the standby generation at Proctors and Center City, provided they are integrated into the microgrid control system. To augment this frequency regulation, load may need to be controlled. Additionally, it may be necessary for solar production to be curtailed. The specific demands for power matching/frequency regulation will be determined through study, and the microgrid controller will manage assets in response to changing conditions.

Unlike power matching/frequency regulation where some generators are better suited to respond quickly to changes in real power, most generators are capable of providing VARs and reacting quickly to changes in voltage. Traditionally, a few types of generator controls are available: voltage control, VAR control, and power factor control. For the Schenectady microgrid, some combination of these modes will be employed depending on the asset type. For example, the CCHP units will likely be in voltage control mode to provide fast voltage regulation/reactive power balance and to support voltage during a fault to allow the protection system to operate correctly. The micro-turbines may be used in VAR control mode to supply a reactive power base, and the PV inverters may be in power factor control to smooth voltage variations due to intermittent power output. As with the power balance/frequency control, the specific roles of the different generation assets will be determined through study, and the microgrid controller will manage these assets in response to changing conditions.

New York State and National Grid interconnection requirements with respect to voltage and frequency response will apply to the microgrid generation when it is in grid-connected mode. Whenever voltage or frequency at the POI are outside the allowable bands, the microgrid controller should initiate a disconnect sequence. However, the microgrid generation and control system have the ability to ride-through grid events and regulate voltage and frequency at the POI to help in post-fault recovery. This action can be coordinated with the utility operations center if needed.

2.4 Electrical and Thermal Infrastructure Characterization

2.4.1 High-Level Description of Electrical and Thermal Infrastructure

The electrical infrastructure supporting the microgrid was shown earlier in Figure 2-2. The major portion of new infrastructure is a medium voltage class underground cable connecting load and generation at Proctors and to load and generation at Center City. Accompanying the cable are requisite step up and step down transformers and switchgear to connect and disconnect the cable as needed. As discussed earlier, the project team has identified two options for routing the cable: either by laying new conduit, or using space in existing National Grid conduits. These options are shown in Figure 2-1 and will be futher explored in Task 2.

Proctors currently operates a district thermal system that meets the heating and cooling needs of the Proctors complex, the Center City complex and several other facilities on the 400 block of State Street. Figure 2-1 shows the routing of the thermal piping that connects Proctors and Center City. No additional thermal delivery infrastructure is planned for the microgrid in this phase. However, the upgraded district energy system will allow Proctors to eventually expand thermal and electrical service to other nearby facilities, including City Hall and the Police Headquarters, reducing the cost of energy, and spurring further economic development in the area. Marquee Power’s long term plan is to incrementally expand its district system, when feasible, as a part of downtown Schenectady’s revitalization toolkit and reflective of Proctors’ community-based mission to instigate sustainable economic development.

2.4.2 Resiliency of Electrical and Thermal Infrastructure

The proposed microgrid is currently served by an underground networked distribution system. This particular microgrid site has historical high levels of reliability due to the supply configuration. Data from National Grid shows that the Front Street Network is served by 5 feeders and is designed to N-2 criteria (meaning it can sustain the loss of two feeders without impact to loads). Over the five years from 2010 to 2014, there were seven feeder faults that caused a breaker trip at the Front Street Station, but none of these resulted in a network customer interruption. The network infrastructure is submersible, and can remain energized during a flood.

The largest risks to the electrical infrastructure are: 1) a widespread transmission outage, such as the 2003 Northeast blackout, 2) failure of the Front Street substation, such as during a catastrophic weather event or transformer failure, 3) network collapse from multiple feeder failures. It should be note that in their response to the RFI, National Grid states that the "*Company has completed flood mitigation work at Front Street to reduce risk of floods impacting that substation*."

The microgrid thermal and electrical infrastructure is underground, hardened, and submersible, in stark contrast to the exposed, radial, overhead infrastructure prevalent in nearby (non-networked) low income and historic neighborhoods. During a widespread emergency (such as a blackout, substation transformer failure, or network collapse), the microgrid infrastructure would likely not be affected and would be able to form an island. The gas supply line is also resilient (according to National grid), and will allow the microgrid to be operational for as long as capacity exists. The emergency diesel generation at Proctors (dedicated to minimum safety systems) has enough storage for 3-4 weeks of continuous operation and can be resupplied periodically as needed. The major risk to the microgrid infrastructure is a seismic event or a major dig-in accident.

2.4.3 Microgrid Interconnection to the Grid

Figure 2-2 shows the two points of interconnection with the grid at Proctors and Center City. Because both facilities are on dedicated spot networks, there is no connection with the meshed street grid, which significantly reduces the number points that need to be controlled. A low voltage breaker or disconnect switch downstream of each spot network secondary bus will be required to isolate the microgrid from the grid, in accordance with New York State Standardized Interconnection Requirements.[5] These breakers will be used by the microgrid controller to island the system or reconnect to the main grid. Each point will have instrumentation (not shown) to allow the microgrid Energy Management System (or Controller) to monitor the voltage, current and frequency at the POI.

Because the microgrid sources are primarily rotating machines, traditional protection schemes based on high fault currents will likely be applicable when in islanded mode. While fuses are a low cost option for overcurrent protection, coordination of the protection schemes between grid-connected and islanded mode may require relays capable of being remotely switched between multiple modes or set-points.

In addition to Instantaneous/Timed Overcurrent protection (Functions 50P/50G/51P/51G), the microgrid protection scheme will employ some combination of the following:

- Over/Under Voltage (Functions 27/59)

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[5] http://www3.dps.ny.gov/W/PSCWeb.nsf/All/DCF68EFCA391AD6085257687006F396B?OpenDocument

- Over/Under Frequency (Functions 81O/81U)
- Reverse Power (Function 32)
- Transfer Trip
- Anti-islanding

2.5 Microgrid and Building Controls Characterization

2.5.1 System Control Architecture Description

The proposed microgrid control architecture consists of four control device types:

- **Microgrid Energy Management System** (MG EMS) (1 per microgrid)

  The MG EMS orchestrates all control actions as well as provides the utility interface. It serves as a main microgrid configuration and dashboard station. For instance, a station operator is able to provide scheduling policies through its web interface. The data historian and possibly other data bases are stored at MG EMS which also provides analytics applications.

- **Microgrid Master Control Station (1 per microgrid)**

  Master Control Station is a hardened computer that hosts critical real-time monitoring and control services. It performs forecasting, optimization and dispatch functions.

- **Microgrid Facility Control Node (1 per facility)**

  Facility Control Node coordinates control across multiple buildings composing a specific facility. This controller abstraction is utilized also for any building in the microgrid with local control functions, i.e. a building that hosts a generation unit or building management system (BEMS). Most facility control nodes would also be hardened industrial computers.

- **Microgrid Edge Control Node (1 per facility)**

  Edge Control Node is an automation controller or a feeder management relay with a direct switching interface to loads in a building. This is typically a multifunction controller/IED providing automation and physical interface to switchgear and sensors.

Figure 2-13 shows control devices for the proposed Schenectady microgrid as an overlay on the electrical one-line diagram.

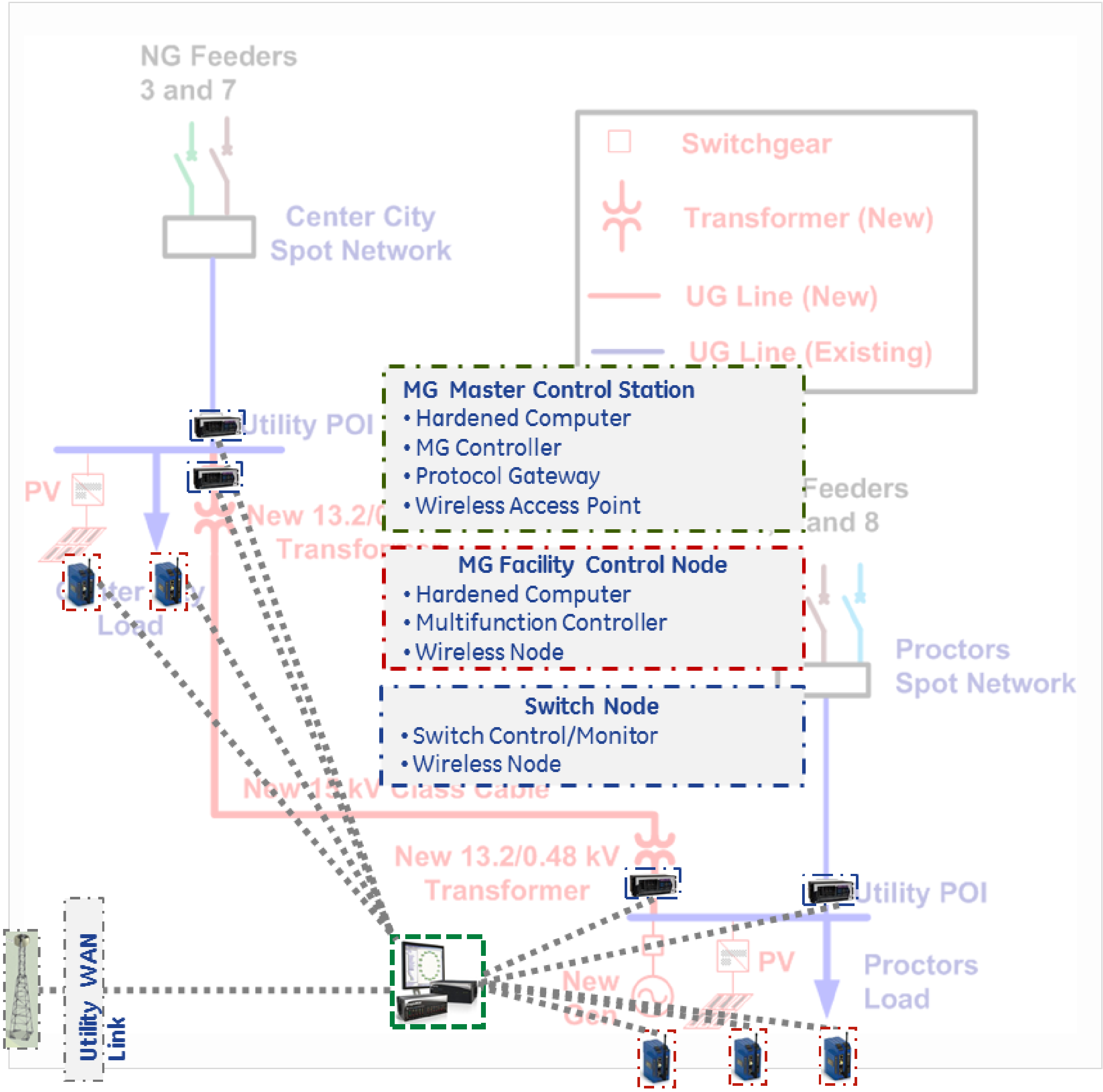

Figure 2-13 Schenectady Microgrid Electrical One-Line with Control and Communications Overlay

The microgrid master control station performs economic optimization, i.e. it periodically determines a combination of generation units to bring on or keep on such that the total cost of operation is minimal. This includes the CCHP gas engines, the micro-turbines, the solar PV units, and even the backup generation, which can be tied into the control system with Edge Control Nodes. The start/stop commands as well as optimal set points for real power, and sometimes even for reactive power, are sent to each generation unit.

The proposed 2x1,000-kW CCHP units and the existing Capstone 4x65-kW micro-turbines are equipped with microprocessor-based controllers that regulate both the natural-gas engines and the inverter-based power conditioning system. During a typical operation, while a unit is in standby or parallel modes, the controller issues power set points, while continuously adjusting the engine speed to optimize efficiency.

All mentioned local controller devices can interface with the external hierarchical control system via Modbus communications. This interface would be used to communicate necessary information between a microgrid facility control node and the local controller of the generation unit located in that facility. The facility control node would act as Modbus master, and the local controller would act as the Modbus slave, sometimes called a remote transmitter unit. The master device initiates all communication, sending commands or requests for information. The local controller would relay all of the AC power related information back to the facility control node including the voltage, current, frequency, and power factor. Thus, this interface will allow the microgrid control system to individually start, stop, and change the set point of any microgrid generation unit, as well as read all of its inputs and outputs.

The microgrid master controller will likely include load management for the economic optimization of microgrid assets. In such cases, it will communicate with building energy management systems to determine and set load set points. The diagram in Figure 2-13 assumes that the Proctors complex and Center City energy management systems will be included in microgrid optimization. Thus, we recommend that the microgrid control architecture be built on one of the open software control platforms such as Tridium JACE (Java Application Control Engine). Such a platform can be used to control a variety of BEMS systems, HVAC and DDC devices. This platform supports most of the open protocols for building automation systems sector such as LonWorks, BACnet, and Modbus.

2.5.2 Services That Could Be Provided by Microgrid

Automatically connecting to and disconnecting from the grid

At all times in grid connected mode, the microgrid control scheme must maintain enough generation, to supply the critical microgrid loads. When an event occurs, the microgrid control system would initiate a sequence of operations to transition from grid-connected to islanded mode. This was described earlier in Section 2.1.2. Seamless transition during an unplanned event is not foreseen due to current interconnection rules governing DER operation. However, it is conceivable that with advanced controller functionality and/or incorporation of energy storage, planned seamless transition can be achieved (see Storage Optimization discussion below).

The formation of a microgrid generally proceeds as follows:

- Detect abnormal conditions
- Isolate microgrid from utility system
- Isolate uninterruptable microgrid from rest of microgrid
- Stabilize generation and uninterruptable loads
- Add loads and generation to core microgrid

Note: some steps may be performed in parallel.

The steps listed above are a combination of predetermined operating procedures and automated control actions. For example, during the planning stages, the load and generation that makes up the core or uninterruptable microgrid will be determined and the sectionalizing scheme that isolates the core microgrid will be established. When an abnormal condition is detected (or and isolation signal is given), relay operations will then automatically perform the topology reconfiguration. At the same time, generation controls must be sufficiently flexible to survive a disturbance that may be associated with the abnormal grid condition that requires the microgrid to go into islanded mode. Actions such as the addition of loads and generation to the core microgrid may be manual.

Automatic disconnection: The Schenectady microgrid is interconnected to the surrounding distribution system at two locations (see Figure 2-2). At the points of interconnection, the microgrid will sense abnormal grid conditions such as loss of voltage (on all feeds) and automatically isolate from the grid. The microgrid will then form in the manner described above.

Automatic connection: The microgrid will also be capable of automatically reconnecting to the grid if desired. However, since the microgrid will be reconnecting into a network, the microgrid may be required to power down before reconnection. If automatic reconnection is desired, when the microgrid senses that the utility feed has returned to normal (generally for a period of time), the microgrid will sense the phase and magnitude of the voltage at the utility interconnection point. Using either active or passive synchronization, the microgrid controller may close the breaker that ties the microgrid to the utility system.

At the time of reconnection, the net load to the system from the microgrid will be minimal. The microgrid can coordinate the return of the additional microgrid loads to normal status with the utility to avoid undue stress on the recovering grid. Depending on the final design of the microgrid, this return to normal may be a combination of automatic and manual operations.

Load shedding schemes

Load management is also integral in islanded mode and in the transition to islanded mode. During microgrid formation, load can be shed to allow for stable transition. Once the microgrid is established, controllable loads may be used in much the same way as spinning reserve generation. On the Proctors load panel, critical loads are on their own distribution network with the emergency generator. They total 50-75 kW of life and safety loads, and are connected to the grid via multiple dedicated transfer switches.

Black-start and load addition

During an unplanned event, the microgrid must be capable of black-starting or energizing without an existing power system. Many grid-forming generators can be used for black-starting. Once the generator has been started and the core microgrid formed, the formation of the microgrid may proceed normally.

For the Schenectady microgrid the Proctors emergency generator may be used to black-start. Once the emergency generator is up, the CCHP units and the micro-turbines (as needed) may be added to the grid. Additionally, storage can be added to the micro-turbines to allow them to black-start without the standby generators.

Generators designed for standby operation such as those at Proctors and City Center are capable of maintaining voltage, frequency, and real and reactive power balance when the larger grid is not present; however, protection may be currently in place to prevent feeding a larger grid. The protection and control schemes of the standby generators will be evaluated to make sure the selected standby generators are capable of supporting the black-start scheme.

Once the standby generation is energized, load and CCHP will be added to the system in an incremental process. Standby generators will likely be used to follow load while the microgrid is being formed.

Performing economic dispatch and load following

The Schenectady microgrid will provide load following during emergency periods utilizing the new CCHP recips and existing backup generation if needed.

The economic dispatch of the microgrid plant during emergency periods will be performed by the microgrid controller and energy management system, based on the amount of generation needed to balance the time varying net load (i.e., load minus solar generation), and the microgrid generation unit efficiencies and constraints, fuel prices, and variable operations and maintenance (VOM) costs.

During normal days, the microgrid dispatch will be based on the thermal load needs, although the DER-CAM modeling does not currently have the flexibility of forcing CCHP dispatch based on thermal needs (it is based on economic considerations). It is plausible to assume that at some future point in time, a more complex decision process will determine the microgrid resource dispatch during normal days, more likely based on the relative economic costs of on-site generation versus purchase from the utility or even sales to the larger grid or NYISO, subject to applicable future REV framework. The trade-off between on-site generation and utility purchase is demonstrated in the DER-CAM modeling (illustrated earlier in Figure 2-9 for example). Although simplified compared to actual operations, the DER-CAM model illustrates how utility purchases vary with time, and shows their dependency on relative energy costs of on-site generation versus utility purchases, and the influence of utility monthly and daily on-peak demand charges.

Demand response

The same load resources that are available for load curtailment are also available for demand response. The initial plan is to have at least 10% of the microgrid peak load be curtailable during a long-term emergency when the microgrid goes into islanded mode. However, the same load resources can be used as demand response during normal days. The 10% of peak load of the combined facilities is about 247 kW, and should be available as demand response during normal days. The demand response resources can be utilized in various utility price-based or event-based demand response programs in the future, such as critical peak pricing (CPP) or critical peak rebates (CPR), or even as part of a portfolio of aggregated demand response resources under management of third party demand response providers who participate in the NYISO demand response and load management programs.

Storage optimization

The microgrid does not currently incorporate energy storage because the business case is not strong. If seamless transition from grid-connected mode during an emergency is a critical requirement, then storage may be option. At this stage of the project, the benefit-cost analysis is not definitive enough for the stakeholders to request that this feature be incorporated into the microgrid.

National Grid has not placed a definitive value on storage at this location. As the project moves forward, the team will continue to look at options for storage to provide services to the grid and the microgrid. If storage proves economical, storage will be optimized based on the application.

Maintaining frequency and voltage

When in grid-connected mode, the primary focus of the microgrid control systems will be to maintain system voltage within the acceptable range. This range is generally specified in ANSI C84.1 but may also be coordinated with utility conservation voltage reduction (CVR) schemes.

For the Schenectady microgrid, a large portion of the generation will be CCHP (2 MW). This CCHP generation will act as base-load generation with a reserve margin. The CCHP recips are also capable of load-following and regulation at part-load operation. Faster acting generators such as the standby units at Proctors and City Center can be used to manage fluctuations in load as well as variation in power output caused by solar. If additional control is needed, curtailable load may be used to help maintain the microgrid frequency, and PV generation may be curtailed or taken offline. The microgrid controller will assign the load-generation mix based on what is needed to satisfy the primary control objectives.

For reactive power/voltage control, CCHP and standby generators may be used. The microgrid controller will determine the appropriate control modes (voltage, pf control, VAR control, etc.) and set-points for the various microgrid assets.

PV observability and controllability; forecasting

PV production will be monitored by the microgrid controller and data will be communicated and stored so that it is available to microgrid operators and owners through a web interface. The controls and communications interface is shown in Figure 2-13. The total nameplate capacity of PV installations is 550 kW, less than 25% of peak load and about 11% of the energy. Given the size of PV relative to firm generation, forecasting is probably unnecessary. The load-generation balance and stable operation of the microgrid is planned without dependency on solar PV. The microgrid controller will monitor PV production and will 1) balance PV variability with fast-acting generation resources, 2) use load resources to offset variability, 3) if necessary, curtail PV production when it goes beyond a percentage of the load.

Coordination of protection settings

When the microgrid is in islanded mode, some key protection functions will be under the purview of the microgrid controller. Where fault current is insufficient to ensure that secure, safe, dependable, reliable operation of protection systems (such as fuses), the project team may consider another layer of protection predicated on transfer trip signals from the controller.

Because the microgrid sources are primarily rotating machines, traditional protection schemes based on high fault currents will likely be appropriate when in islanded mode. While fuses are a low cost option for overcurrent protection, coordination the protection schemes between grid-connected and islanded mode may require relays capable of being switched between multiple modes or set-points.

In addition to Instantaneous/Timed Overcurrent protection (Functions 50P/50G/51P/51G), the microgrid protection scheme will employ some combination of the following:

- Over/Under Voltage (Functions 27/59)

- Over/Under Frequency (Functions 81O/81U)
- Reverse Power (Function 32)
- Transfer Trip
- Anti-islanding

Selling energy and ancillary services

Subject to evolving NY REV framework, the NYISO market rules applicable to microgrids and distributed generation, and enabling technology (to allow back-feeding in the network), it is expected that the distributed generation within the Schenectady microgrid can sell energy into the larger grid though the Distribution System Platform (DSPP) model being developed within REV, but also participate in the NYISO energy, ancillary services, and capacity markets.

The details of qualifications for selling energy to the utility, and the requirements for NYISO participation are to be determined within the REV process and NYISO market design development. From a theoretical perspective, the on-site generation would sell energy at times when applicable Locational Marginal Price + Distribution Component (LMP+D) are higher than the marginal cost of on-site generation.

The ancillary services, including regulation up and down and spinning and non-spinning reserve can also be provided by the on-site generation subject to future market rules.

And finally, subject to qualification, on-site generation can participate in NYISO capacity auctions, and if they clear the market, they can be paid the applicable NYISO capacity prices.

Data logging features

According to the control architecture presented above, data logging is both local (at microgrid facility control nodes) and global (at microgrid master control station). These controllers, typically industrial PCs, record system data at regular intervals of time. A Human Machine Interface client for accessing data through a web interface exists at least at the master control station.

The data is stored in a round robin database that overwrites oldest values. The standard storage solutions (e.g., 1TB) are sufficient to store data for at least a full year. Depending on the devices that the facility control nodes regulate, such a node may be equipped with an event recorder that captures asynchronous events with high time resolution. This allows for fast, sub-second, data collecting and analysis.

2.5.3 Resiliency of Microgrid and Building Controls

The standard industrial-grade control and communication devices can withstand extreme operational temperature range of -40^o C to +70^o C. In addition, they are often enclosed in rugged aluminum chassis tested for shock and vibration according to military standards. Control boxes will also be elevated for flood avoidance

2.6 Information Technology (IT)/Telecommunications Infrastructure Characterization

2.6.1 Information Technology

Due to the lack of existing dedicated communication infrastructure, for the microgrid communications backbone we are proposing a wireless field network as shown in the Figure 2-13. The Microgrid Master Control Station is a hardened computer hosting monitoring, optimization and control services. It communicates to the utility wide area network through 3G/4G, WiMax, or 900 MHz communication links.

In addition, each microgrid facility is equipped with a Control Node, a hardened computer hosting local control applications. In both facilities control nodes will integrate with the existing building management systems. Communication with the master control station is achieved through 900 MHz or WiMax field network.

If there is enough space in the proposed new undergroud cable that will connect the two facilities or the existing thermal conduit, another solution for communications is possibly a dedicated fiber-optic link. Such a solution would yield the highest performance when it comes to bandwidth and reliability, although potentially at significant cost to the microgrid stakeholders. Since the length of a fiber optic link, i.e. the distance between the two microgrid facilities, is not relatively short (about 600 feet), efficient multimode fiber cables can be used.

In either case the communications network will provide at least 100 Mbit/s Ethernet which is expected to be sufficient for all monitoring and control applications and for the network of this size. The application-layer protocols will be selected among DNP3, Modbus TCP/IP, Modbus Serial, OPC or IEC61850 depending on MG deployed devices (e.g. IED’s, PLC, switchgear, relay, sensors, meters, etc.).

2.6.2 Communications

When the lack of communication signals from the utility is set as an abnormal condition, the microgrid can isolate from the utility and thus operate when there is a loss in communications with the utility. From that moment the local generation and load devices are under the control of the microgrid controller.

The suggested communication infrastructure design assumes industrial-grade, long range, point-to-multipoint wireless communication with MIMO (Multiple-In, Multiple-Out) antennas that provide robust communications. The other option that would utilize fiber optic link can be made more reliable by connecting all the controller devices through a ring topology network. In such a network, in the event that a fiber link is broken, the traffic can be redirected.

3 ASSESSMENT OF MICROGRID’S COMMERCIAL AND FINANCIAL FEASIBILITY

3.1 Commercial Viability - Customers

The Resilient Schenectady microgrid will connect the Proctors and Center City complexes to create a self-sufficient downtown node capable of meeting energy needs for several weeks during a wide-scale emergency. Both Proctors and Center City are designated places of refuge, and both facilities house a number of businesses that are critical to the community. As illustrated in the microgrid ownership model decision tree included below, the proposed microgrid is a “merchant microgrid.” Proctors intends to finance the microgrid project on its balance sheet.

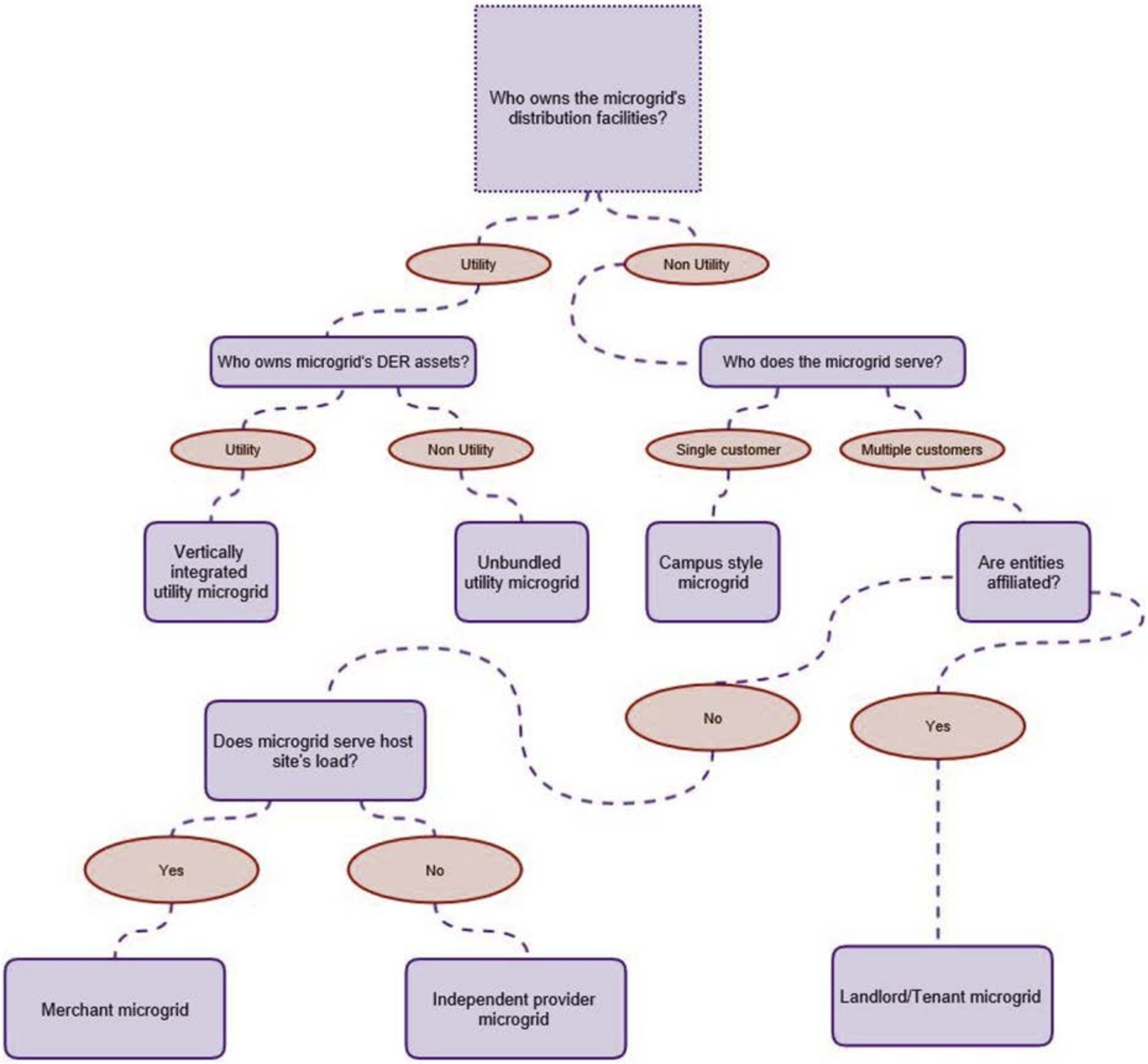

Figure 3-1 Microgrid ownership model decision tree

3.1.1 Individuals Affected By/Associated With Critical Loads

The proposed microgrid will serve a mixed group of commercial and municipal customers, many of which would experience some loss of power outage during an extended event without the proposed microgrid. The key facilities are the Center City and Proctors complexes which are both centers of refuge. The Proctors complex comprises of an administration building, historic arcade and main theater, GE Theater, Marquee Power plant and Key Hall. The Center City complex houses Wink, Wise Labs, Metroplex, M/E Engineering, CVS Pharmacy, the YMCA, educational facilities, and other state and county offices. Proctors can provide shelter to 900 people and Center City can provide shelter for 1,100 people in the event of an emergency. This is lodging people within 65% of floor space and assuming 100 square feet per person. This is in the event of emergencies. The microgrid will not serve any residential customers.

3.1.2 Direct/Paid Services Generated By Microgrid

In Stage 2, the project team will do an investment grade feasibility analysis. It was determined during Stage 1 that specific revenue streams could not be quantified without additional study. However, the general revenue streams include: utility demand side programs, those streams from participating as a virtual plant in the NYISO wholesale market, customer-delivered value from added resiliency, sale of electric and thermal energy, and other potential opportunities that are dependent on future regulatory developments.

3.1.3 Customers Expected To Purchase Services

During normal operation and emergency conditions each of the microgrid customers at Proctors and Center City will purchase a majority of their thermal energy services from the microgrid. During normal operation, they have the option to purchase electrical services if the tie-line is activated, but the utility is expected to be the default supplier. During emergencies, the microgrid customers are expected to purchase all their thermal and electrical services from the microgrid.

3.1.4 Other Microgrid Stakeholders

Everyone who uses the downtown block is a stakeholder (there are at least 650,000 people who come to Proctors each year), as well as the approximately 10,000 people who live in the adjacent neighborhoods that are within the FEMA 100-year floodplain. These at-large communities will benefit from having access to a resilient place of refuge within walking distance of their residencies. The resilient infrastructure will allow critical services to be effectively staged and deployed by emergency personnel during a prolonged emergency. Proctors has office space that is available to the City for emergency management and response coordination.

With distributed generation in the network and additional switching flexibility, grid restoration time could be improved by allowing National Grid to redirect resources to other areas, improving the overall quality of service for the customer base.

Area colleges and higher educational institutions such as SCCC and Union can also benefit by utilizing the microgrid as an educational tool and to potentially test new technologies and methodologies.

In addition, the microgrid’s economic development characteristics, as part of a portfolio for a non-profit organization with a mission to impact the economy, will have additional indirect impact through increased economic activity, job attraction and retention and redevelopment and investment in the neighborhood.

3.1.5 Relationship between Microgrid Owner and Customers

Proctors will have legal title and operating control over the microgrid’s T&D and power generating assets.

Marquee Power is the name of Proctors’ district energy system. It is not a separate legal entity but is used only colloquially for purposes of convenience in communication. It is not an official DBA. Technically, Marquee Power is a service operated by PTR LLC, which is wholly owned by Arts Center and Theatre of

Schenectady Inc. (DBA Proctors), a 501c3 entity.[6] However, it is likely that the conduits and any other T&D assets located outside of Proctors or outside the property of a microgrid customer will be leased and operated by National Grid. For example, as shown in Figure 2-1, one of the options for electrically connecting Proctors and Center City uses existing National Grid conduits. The Team has discussed this option with the utility and has learned that it is not infeasible but needs to be studied further in Stage 2.

3.1.6 Customers during Normal Operation vs. Island Operation

The core customers of the proposed microgrid remain the same in each scenario, i.e. the microgrid is expected to sell electricity to end-use customers of the Proctors and the Center City complexes during both normal operation and in island mode. However, during normal operation, any excess electricity would be either net metered to National Grid or made available to participate in the NYISO wholesale markets, provided that the ongoing National Grid project with GridEdge Networks allows the microgrid is allowed to back-feed (see Section 3.2.4). The project Team estimates that 1 MW of capacity over the demand will be available during certain times of the year.

3.1.7 Planned or Executed Contractual Agreements

As discussed earlier, National Grid will likely maintain control of T&D assets outside of the Proctors or Center City facilities (such as the cable in conduit). The ownership structure imagined for the operation of the in-facility non-generating and generating assets of the microgrid will be Marquee Power.

Because of this, Power Purchase Agreements (PPAs) will be executed between the customers and Marquee Power for the sale of: electricity, hot water, and chilled water. Each billing customer would be individually sub-metered. There would be a solar PV lease agreement with Proctors and (possibly) Center City to allow for a company to supply and install a financed solar PV array for use in the microgrid. The ability of solar PV to provide services during an emergency depends on several factors, including time of day, season, availability of battery storage systems and so forth. For purposes of this analysis, it is possible that the solar PV facility could provide power during an emergency.

Other contracts could include wholesale market contracts with NYISO, maintenance contracts necessary to maintain up-time, and various financing contracts necessary to provide the capital to install and maintain the microgrid. The specific financing contracts were not studied during Phase 1.

3.1.8 Plan to Solicit and Register Customers

Customers will be solicited via direct mail campaigns, outreach to community organizations, social networks and other channels. Proctors will also solicit additional suppliers by issuing a Request for Proposals for procuring additional resources from existing and potential customers of the microgrid. Proctors, as the generation owner of the microgrid, has relationships with the neighboring buildings that these utilities will be sold to. This is similar to the approach taken during the selling of Proctors Thermal

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[6] The district energy system is operated like a co-op, with each participant paying based on % of energy consumed, which means that Proctors could also be described as one of the system's customers. Thus, when there is an upgrade to the plant that improves efficiency, a benefit can be calculated to Proctors as well as a benefit to the other customers.

District PPAs. Based on the proposals submitted, Proctors will select and register new customers for the microgrid.

3.1.9 Other Energy Commodities

Hot water, chilled water, and electricity will be sold to the microgrid customers. The existing thermal district has a four-pipe system offering hot and chilled water year-round, which will enable the sale of thermal energy projects to microgrid customers at low cost.

3.2 Commercial Viability - Value Proposition

3.2.1 Benefits and Costs Realized By Community

This proposed Schenectady Community Microgrid is a major opportunity for the City of Schenectady's critical facilities - which were down during the two most recent major floods - to maintain operations. It will greatly improve the resiliency of the City in the case of another natural disaster event, while significantly increasing the safety and well-being of residents, community organizations, public facilities and businesses of the City of Schenectady. Residents living in relatively close proximity to the microgrid will have a place to conduct business during power outages, as well as safe places for shelter and refuge. The city borders the Mohawk River along several miles, which includes several neighborhoods designated by NY Rising as Extreme High Risk for flooding. The Project will benefit the community both by providing added reliability and resiliency for microgrid participants, and potentially reducing energy costs for the facilities. Proctors Theater is one of the key actors in the revitalization of the downtown district. It operates three channels of public access TV and supplies broadband internet, sidewalk snow-melt, and trash collection to the block. The Marquee Power district energy system has been an engine of redevelopment, lowering construction first-costs and maintenance costs, while increasing energy efficiency for its customers. It has leveraged more than $300 million in local redevelopment. The proposed microgrid will facilitate expansion of the Proctors DES and provide resilient electrical service in addition to thermal service. This will further enhance Proctors mission to revitalize the downtown area, lower construction and maintenance costs for redevelopment, and reduce the cost of energy.

3.2.2 Benefits to Utility

The proposed microgrid is expected to provide peak load support and could participate in demand response programs if needed. However, the microgrid is not expected to significantly defer transmission or distribution investments or upgrades in *the near term*. The distribution network feeders serving the facilities are loaded to less than 40% of capacity and load on the network is not expected to grow significantly over the next decade. However, the microgrid will provide the utility with additional flexibility for managing the electric system in the future, particularly for uneven growth on the feeders, or rapid expansion of the downtown load.

Another key benefit is that the microgrid will give the local utility greater visibility into the state of the network distribution system. Typically, this is a problem with underground network systems that could lead to prolonged outages and high O&M costs. The additional sensors, instrumentation, controls and communications installed in the network for the microgrid visibility would facilitate more effective and efficient operation of the network assets, reduce CAIDI and potentially reduce O&M.

The microgrid also benefits the utility by solving a known problem that prevents DERs on network systems from back-feeding to participate in net-metering and NY ISO markets, and to realize the ambitions of NY REV. Successful completion of the National Grid project with Grid Edge Networks and demonstration on the microgrid will open up possibilities, not only for network customers on National Grid systems, but for customers on network systems all across the state. The microgrid project will also evaluate other control and communications technologies and operating procedures that could allow DERs on network systems to participate in mini-markets within the network or safely evacuate power to the grid. This would facilitate more effective and efficient implementation of the REV framework.

3.2.3 Proposed Business Model

The proposed microgrid is based on the owner/merchant microgrid business model. As illustrated in the diagram below, under this business model, a microgrid serves the owner and other microgrid users that are unaffiliated with the owner, besides the affiliation resulting from the microgrid.

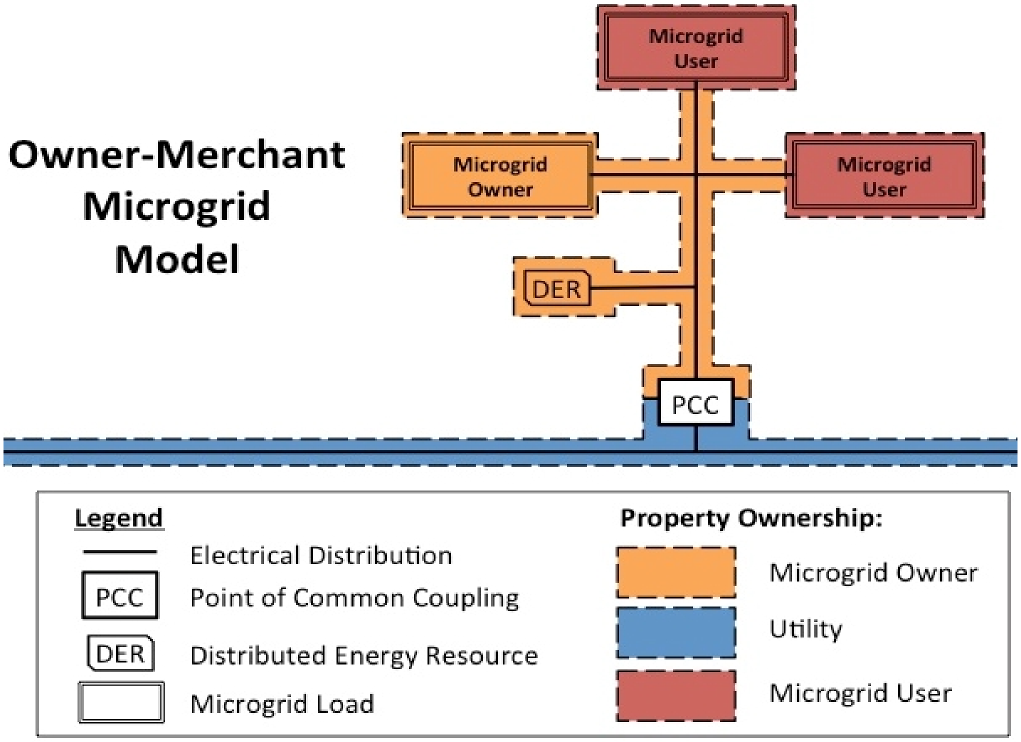

Figure 3-2 Owner-merchant microgrid model

Table 3-1 Microgrid SWOT

Strengths	**Opportunities**
Modular and Flexible architecture	Expanding DES capacity and connecting more nearby facilities to the MG
Heterogeneous power quality	Expanding renewables market and enabling customer participation (e.g. NEM on networks)
Energy resiliency	Avoided T&D investments for rapid load growth

Leveraging existing underground thermal and electrical delivery systems	Inverter and storage innovation
Multiple ownership models	Declining levelized costs
Diverse applications	Plug in electric vehicles
Weaknesses	Threats
Incentives diffuse	Obsolescence
Unclear road map	Lack of clear standards
Fragmented regulation	Competing business models
Utility operating concerns	Stranded assets

3.2.4 Unique Characteristics of Site or Technology

The microgrid project is in an area served by an underground secondary network. Customers on these types of systems are often precluded from having behind-the-meter generation or exporting power to the grid. This project addresses some unique design and operating challenges for microgrids in this environment. National Grid has been working with Proctors to find a solution that will allow Proctors to operate behind-the-meter DERs within the network. The utility conducting a NYSERDA-funded engineering and feasibility study that includes but is not limited to primary circuit protection studies and requirements, secondary network protection studies and requirements, and secondary network studies to analyze the impact of exported generation and determine associated system limitations, and required customer equipment. The project will demonstrate the potential of a PLC-based solution from GridEdge Networks to allow in-network DERs to safely back-feed to the grid.

The inclusion and expansion of the existing and successful Marquee Power DES is another unique element of this project, and should significantly improve the economic prospects of the microgrid.

The Team is evaluating the current set of available commercial microgrid controllers. A best of breed selection will be made to obtain alignment with the microgrid site’s requirements. The controller will include monitoring and control functions to reduce the risk of back-feed to the grid at the POI(s).

3.2.5 Replicability and Scalability

The proposed microgrid project’s business model is sufficiently flexible to accommodate a wide range of technical microgrid configurations and institutional settings. In particular, the ability to integrate multiple asset owners and diverse generating resources makes the business model broadly applicable to other communities.

One of the things that make the project scalable is the underground secondary network system in the area owned by National Grid. The team has discussed with National Grid the possibility of running additional cables in these ducts to connect other nearby facilities to the microgrid. As discussed earlier, there are a number other critical facilities and at-risk communities within a 1,200-foot radius of the microgrid. These include City Hall, Police Headquarters, Fire Station #1, County Offices, City Mission, a Senior Health Center, a Municipal Housing Complex, an Amtrak Train Station, and a multi-story garage used to shelter vehicles of residents in the nearby flood prone Stockade District. Figure 3-3 shows the location of these facilities. Proctors has already performed feasibility assessments for connecting some of these facilities to the district energy system. The build out of the full-service microgrid makes a stronger case for expansion.

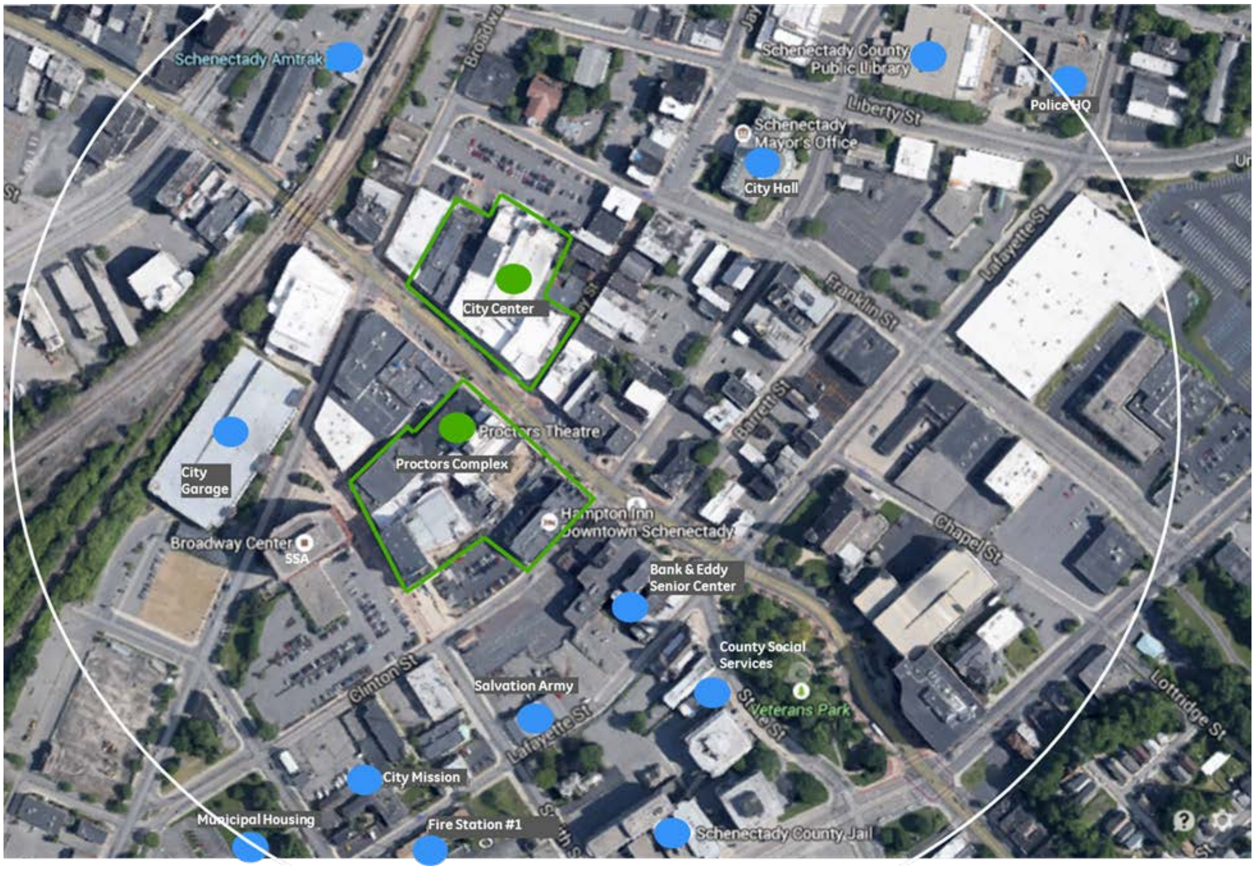

Figure 3-3 Critical Facilities within 1200 Feet of the Microgrid Footprint

Outside of this Downtown Node, there are several other critical facilities that can become anchor tenants for other nodes which will incrementally be incorporated into the Resilient Schenectady Plan. These facilities (shown on the map in Figure 3-4 below) include: Union College to the northeast; Ellis Hospital further out to the northeast; Golub corporate headquarters to the north; Mohawk Harbor, the proposed site for the Rivers Casino to the northwest; and Schenectady County Community College to the west with a newly constructed student housing, and a municipal public housing complex about ¼ mile south of Proctors. Several of these sites have existing backup generation and CCHP systems and have proposed facility improvements.

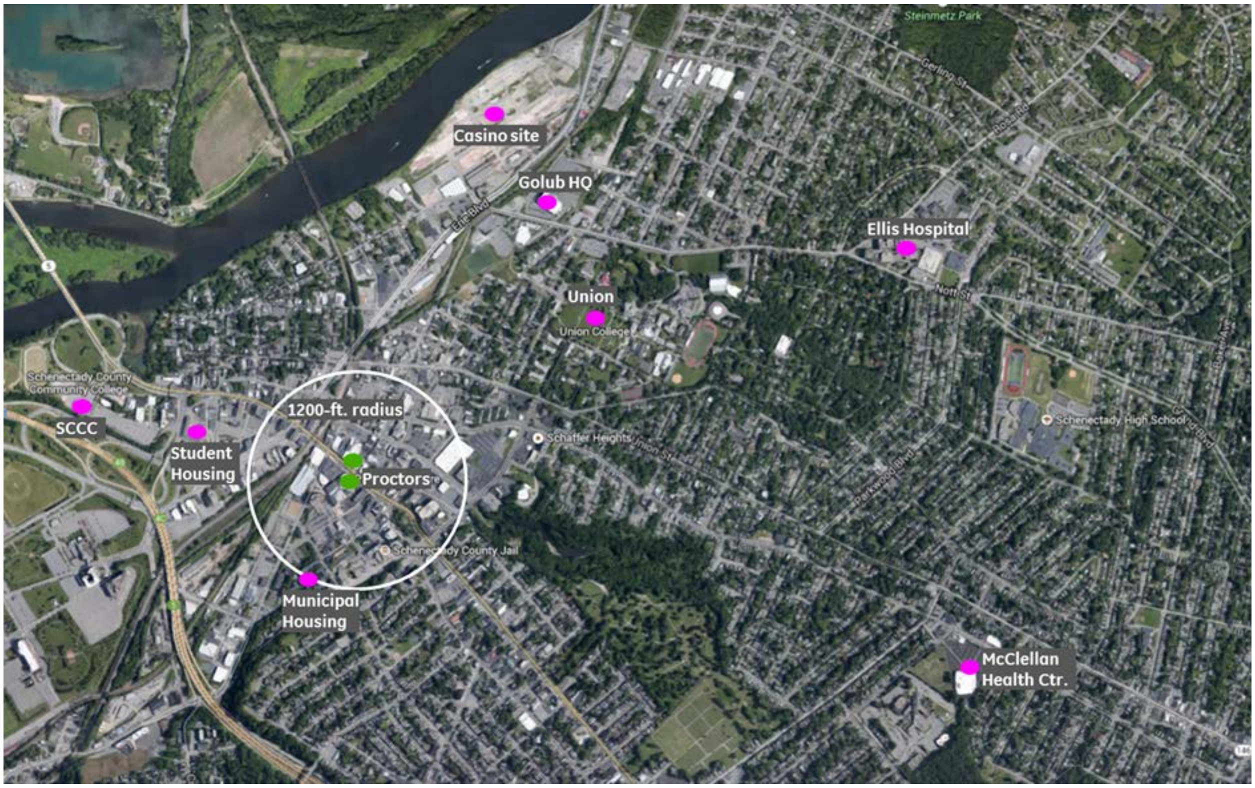

Figure 3-4 Other Critical Facilities Outside of the Downtown Node That Can be Anchor Tenants

3.2.6 Purpose and Need for Project

Large portions of Schenectady, including sections of the downtown district and the adjacent historic Stockade neighborhood, are vulnerable to flooding. During Hurricane Irene in 2011, the Mohawk rose to over 26 feet, more than double the average elevation, flooding streets, homes, and buildings throughout Schenectady. A week later, Tropical Storm Lee caused more flooding in the Stockade, the East Front Street neighborhoods, and portions of downtown. The downtown district was evacuated. Electricity was out for almost a week and telephone service was limited. Due to the devastating impact of these weather events, the City is designated as a NY Rising community.

The loss of electricity in downtown Schenectady caused significant and long-lasting damage to the local economy. The area has only recently begun to realize the gains of a major revitalization effort. The proposed microgrid project will ensure previous gains in the area are not jeopardized in the future, and will potentially provide a catalyst for future growth.

In the event of a natural disaster leading to electric outages and a loss of thermal support in downtown Schenectady, this proposed microgrid would allow the Proctors and Center City complexes to operate and aid City residents and businesses for at least one week, but practically speaking, for several uninterrupted weeks. The proposed CCHP and solar PV units will improve electrical and thermal system efficiency and reduce the environmental impacts of energy production.

The network design in the area is very reliable and is *unlikely* to be compromised by anything other than a transmission system failure, substation failure, or network collapse. But even though the network in general is very reliable, individual facilities on a single transformer, or on a spot network served by two feeders, such as Center City, can experience lengthy outages due to faults on the feeders. The microgrid is designed to be resilient to major grid outages and shutdowns (such as those precipitated by flooding or a network collapse), as well as shorter blue-sky events. The new delivery infrastructure will be hardened using submersible underground (UG) construction, and generation assets and service connections will be installed on elevated floors or on the roofs of buildings.

3.2.7 Overall Value Proposition to Customers and Stakeholders

The microgrid will benefit New York State and utility ratepayers generally by ensuring the continuous provision of critical services during a power outage or emergency. In addition, the microgrid will allow the distribution utility to accelerate power restoration and allocate scarce resources like portable generators more effectively during the outage. The proposed microgrid project will also enable the utility to evaluate various REV market constructs and programmatic options for implementing its demand response and energy efficiency programs to achieve required load reductions and energy-efficiency improvements.

During normal operations the microgrid offers cost effective power and thermal energy, leading to potential savings of approximately $0.02 cents per kilowatt hour, including the thermal savings. This net savings is inclusive of all necessary costs to maintain the microgrid (operating expenses) and those capital costs necessary to purchase and install the microgrid. A main design mission of this microgrid is to yield a financial return on investment.

3.2.8 Additional Revenue Streams, Savings and Costs

In addition to revenues from sale of electricity and thermal energy to the tenants, additional potential revenue streams could include the following:

- Demand response offerings to the National Grid and NYISO (Proctors is already participating in one such program)
- Ancillary services offerings to the utility
- Energy revenues from the NYISO energy market
- Capacity revenues from the NYISO capacity market
- Ancillary services revenues from the NYISO ancillary services market
- Additional tax revenues to the city, county, and state governments and local school systems from new businesses that move into the microgrid service territory.
- Lowered general liability insurance costs due to waste-heat-to-sidewalk-ice-melting (already in place in some parts of the microgrid) as reported by Proctors Theater.
- Potentially lowered insurance costs due to increased business uptime thus reducing risk of business continuity insurance to the extent applicable (not every business pays for continuity insurance).
- Resilient Business Infrastructure. Increasingly, tech and cloud-based companies require resilient server infrastructure to maintain global services. For example, TransFinder, a customer of Marquee Power, operates global servers that coordinate their GPS mapping products for customers around the world. A resilient business district offers a competitive advantage for city economic development strategy and for businesses reliant on internet infrastructure.

- Shared Service Platforms. As part of its regional mission, Proctors operates multiple platforms to share services and reduce costs for others. These include a venue management service, a web-based arts ticketing service, and will soon include a regional calendar platform, internship application platform, and creative sector workforce development programs. Dozens of organizations across the region utilize these services. Resiliency for the Proctors facility provides a competitive advantage for expanding these platforms while impacting multiple organizations in other municipalities through uninterrupted vital services.

3.2.9 Promotion of State Policy Objectives

An active and dynamic scheduling of microgrid operations that would maximize the economic efficiency and technical reliability of the microgrid and the surrounding system will require both technical innovations and also reform of regulatory and policy regime that would enable market participation. In Stage 2, the Team will elaborate on needed innovations and requirements that would enable such market participation. These may include complementary hardware that would provide more flexibility, such as integrated energy storage, and the smart scheduling software.

The Team will describe the actionable information that would need to be made available to customers for economically efficient and technically reliable operation and scheduling of the microgrid generation. These include real-time load and supply status of the microgrid and the underlying variable costs of operations and the applicable seller and buyer prices on the DSP and/or NYISO. It should also be noted that such actionable information, although accessible to customers when requested or queried, would function and used mostly in the background in automated microgrid systems.

As described in Section 3.2.2, the project will evaluate new controls and communications technologies that would allow DERs on network systems to safely back-feed power to the grid. This would allow the microgrid DERs to participate in new markets created by the REV framework.

3.2.10 Promotion of New Technology

Innovative characteristics of the Schenectady microgrid include: integration within a microgrid system of a large DER that currently provides wholesale power to the larger grid, through a secondary network system; the diversity of facilities that will be served; financing of the infrastructure in a multiparty community microgrid with large institutional participants; and ability of the approach to be replicated in similar communities across New York State. This project will also demonstrate new hardware solutions, monitoring and control technologies, and operating rules to allow behind-the-meter DERs in secondary networks to back-feed and provide services to the grid, allowing them to participate in NY REV. In particular, the project will incorporate a new PLC-based solution that National Grids will test and deploy with GridEdge Networks, and advanced microgrid controllers features to balance and control power flow at the POI.

The Microgrid Coordinator could also offer a suite of ancillary and distribution grid support services, including the following potential grid edge services: Network Voltage Data Service; Synchro-phasor Endpoint Data Service; Voltage Profile Flattening Service; Settable Fixed Power Factor Service; Voltage Damping Service – Power Quality Enhancement; Ramp Rate Setting Service and Voltage and Frequency Ride-Through Service.

3.3 Commercial Viability - Project Team

3.3.1 Securing Support from Local Partners

Key engagement strategies the project team has employed in connection with the proposed microgrid include the following:

- Establish a team of trusted advisors with expertise in regulatory, technical and financial aspects of energy projects and with strong track record for completing projects successfully;
- Customers will be solicited via direct mail campaigns, outreach to community organizations, social networks and other channels;
- Community awareness of the microgrid project and possible customers for future expansion of the microgrid system will be cultivated by outreach to community organizations and low-cost digital marketing strategies;
- Engage regulators, utilities and other stakeholders in front-end discussions, including utilities and other stakeholder groups in design and implementation of microgrid project; and
- Utilize the established relationships between Proctors and Marquee Power's district heating/cooling customers.

3.3.2 Team Member Roles in Project Development

The project developers include Proctors, ASI Energy and GE Energy Consulting. The breadth and depth of the project team's experience will allow it to provide the direction, implementation and project management capabilities required for developing the community microgrid, including the design, implementation, construction and operation of the proposed microgrid. The project team will draw upon their combined expertise in electric and thermal power engineering; operations; renewable energy project development, market development and financing; and substantial levels of experience in evaluating, designing, implementing and operating Community Microgrids. Proctors also has an existing thermal district upon which this microgrid is being expanded. This existing infrastructure will assist the team in connecting new customers. Proctors and Center City are in effect the clients. They will attend weekly project meetings, respond to communications, craft several press releases, and host the construction crews with appropriate space and access. For the solar leases on the roof Proctors will hold those contracts directly. Alternatively, this could be the MG SPV. ASI will operate during the design phase as the project manager, CCHP design professional with regards to financials, and selection of system. The installation portion of this design will be completed by a MEPs firm capable of CCHP projects, integrating a thermal district of this sort.

GE will perform technical studies and analytical simulations to ensure stable, reliable, secure operation of the microgrid in both connected and islanded modes, develop functional specifications for equipment and technology, set protection strategy, specify and recommend enabling solutions, develop control algorithms, and work with a qualified AE firm (or in-house resources) to develop detailed engineering specifications and drawings.

3.3.3 Public/Private Partnerships

It is unlikely that a public-private partnership would be included as part of the proposed project. The primary reason is that the merchant microgrid business model envisioned for the proposed microgrid does not require a public-private partnership. However, it is possible that the evolution of the microgrid to a larger footprint (as discussed in Section 3.2.5) could lead to a public-private partnership at some point in the future.

3.3.4 Letter of Commitment from Utility

The Team has been working with the Utility to develop the project. The applicant's letter of commitment from the utility has already been submitted to NYSERDA at the proposal phase.

3.3.5 Applicant Financial Strength

Proctors is a not-for-profit organization with a cross-sector mission to impact the community. It has operated in Schenectady since 1977, when it began restoration of the 1926 vaudeville theatre. Since then, it has received multiple local, state and national awards for excellence in community development, arts management and historic preservation. A diverse portfolio of revenue sources sustains its operations while achieving a regional community mission. These include earned income from the sale of thermal energy, rental income, ticket income, as well as unearned revenue from individual, corporate and foundation donations. Proctors is currently engaged in a multi-year capitalization campaign to improve operating efficiency through capital projects that reduce costs, as well as fundraising initiatives to expand endowment funds, increase working capital and invest in entrepreneurial projects. Since 2008, Proctors has operated Marquee Power DES, selling thermal energy at cost to its neighbors.

3.3.6 Project Team Qualifications and Performance Records

The project team for Phase 1 includes: Proctors (which has owned and operated the existing microgrid for many years), ASI Energy and GE Energy Consulting. The breadth and depth of the project team's experience will allow it to provide the direction, implementation and project management capabilities required for developing the community microgrid, including the design, implementation, construction and operation of the proposed microgrid. The project team will draw upon their combined expertise in electric and thermal power engineering; operations; renewable energy project development, market development and financing; and substantial levels of experience in evaluating, designing, implementing and operating Community Microgrids.

Proctors has operated the DES since 2008. With an annual organizational budget of more than $25 million, Proctors operates a nationally recognized portfolio of community development and creative placemaking projects, including multiple shared service platforms. These include Marquee Power, the regional Ticket Me arts ticketing and venue management service, and management partnerships with Capital Repertory Theatre in Albany and Universal Preservation Hall in Saratoga Springs. Its management strategies incorporate feasibility studies, data analysis and harvesting best practices from other model organizations. It tracks performance of its cross-sector programs through dedicated, experienced staff.

Ithaca, New York-based Anodyne Solutions, Inc. (dba ASI Energy or "ASI") provides integrated, clean-energy solutions tailored to the requirements of commercial, institutional and industrial customers, utilities, grid operators and governmental entities primarily in the Northeast. ASI is building upon its expertise in designing and installing energy efficiency and combined heat-and-power (CHP) systems, which the company believes to be a key generation asset to enable the transition to a low-carbon economy and to provide flexibility and balancing services to the grid while supporting customer loads with fully resilient, reliable and cost-effective heating, cooling and power on a distributed basis. Because CHP is viewed as a core technology for the deployment of microgrids, hybrid energy solutions and district-energy systems, ASI is focused on the development, implementation and on-going management of these types of more complex projects.

In addition, ASI Energy has been actively involved in the Ithaca community for a decade and has deep on-going business relationships with local and county governments, various critical facilities, numerous community organizations, including those delivering emergency and related services, both Cornell University and Ithaca College, and a wide range of private-sector commercial and industrial businesses.

ASI Energy has been the primary driver since late 2010 in developing and implementing Energize Ithaca, a district-energy/community microgrid program for the City of Ithaca, which is a collaboration between ASI Energy, Ithaca local and regional governments, key community stakeholder groups, Iberdrola USA (the parent company of New York State Electric and Gas Corporation), and ASI Energy’s key private-sector partner, GE Digital Energy. The program’s goal is to transform Ithaca’s inefficient and aging downtown energy infrastructure into a next-generation, cost-effective and affordable community-energy ecosystem that fully integrates the area’s electric, heating and cooling needs. The program is initially comprised of a series of “energy islands,” comparable to St. Paul, Minnesota’s roll-out of its district-energy system, whose “nodes” will potentially be interconnected over time in a phased approach as economics and other factors allow. ASI Energy has already undertaken various technical and financial analyses of the downtown nodes, which include a variety of critical facilities; and the initial energy profiles of the nodes are positive.

Starting in 2006, ASI Energy was built upon a successful foundation of service-based businesses, including managing distress property conveyance for large financial institutions, technical project and construction management services, and over 300 energy efficiency projects and energy performance contracts for property owners in the Ithaca metro area.

These projects were primarily for residential, multi-family, and commercial buildings with over 200 of them supported from a variety of NYSERDA programs, such as EmPower NY, Flex Tech and PON 2568. ASI was the prime contractor/controlling contractor for all of these projects. ASI has also undertaken a variety of energy studies, including facility audits at such places as Tompkins County Chamber of Commerce, La Tourelle Resort and Spa, Beechtree Nursing Care Facility and others.

GE Energy Consulting (www.geenergyconsulting.com) is a core group of leading GE technical and business experts that has focused its collective energies on solving the electric power industry’s most pressing challenges with a goal to “pursue and execute engagements that expand the study portfolio and help define the energy industry of the future”. The foundational strength of GE Energy Consulting lies in the experience and expertise of its employees, a total staff of approximately 100, with most having advanced degrees in engineering disciplines, including more than 25 with doctoral degrees. GE Energy Consulting is distinguished by having six engineers on staff who have been elevated to the esteemed status of IEEE Fellow, the highest honor bestowed by IEEE. Cumulatively, GE Energy Consulting engineers have published hundreds of technical papers and authored or co-authored many textbooks. Our engineers on the team play an important role in the power industry by leading and participating in a number of industry organizations, including 30 IEEE Committees, Subcommittees and Working Groups, and 5 CIGRE Working Groups as well as international standards committees, such as IEC.

GE Energy Consulting has decades of experience conducting detailed engineering assessments in New York State, the Northeast and across the country. The recent interest in microgrids, driven by storm impacts in the Northeast, has resulted in a number of working opportunities with the states of New York, New Jersey, Pennsylvania, Connecticut, and Massachusetts, individual utilities in the Northeast, and various end-customers and communities. As a precursor and enabler to NY Prize, Energy Consulting was retained by NYSERDA to perform microgrid feasibility studies and develop the technical microgrid functional designs for five designated sites in New York State. The results of this work are found in the NYSERDA final report entitled Microgrids for Critical Facility Resiliency in New York State, December 2014.

3.3.7 Contractors and Suppliers

The project team will select the most qualified CCHP vendors, electricians, plumbers, mechanical contractors and other required contractors by relying on a two-part process that begins with a Request for Qualifications and is followed by a Request for Proposals. CCHP vendors will be selected to build and operate the CCHP systems. Local contractors will be selected through a conventional bidding process for performing the electrical, pipe fitting and digging activities. In particular, project team members will be selected by responding to an RFQ and then an RFI.

3.3.8 Financers and Investors

As the existing microgrid owner, Proctors is considering financing the proposed microgrid project on its balance sheet through debt and/or equity investment as a capital expenditure. In this scenario, the project would be financed and secured by Proctors Theater assets and/or future revenues.

3.3.9 Legal and Regulatory Advisors

ASI Energy has recruited Brookside Strategies, LLC to provide legal and regulatory guidance on the microgrid project. Brookside Strategies has been engaged by project developers, equipment manufacturers, investor-owned utilities and investment groups to perform due diligence on specific investment targets, advise on equity and debt financing options and manage complex international transactions related to renewable energy, natural gas and energy efficiency equipment. Brookside Strategies also has extensive experience managing risk and capturing cross-commodity synergies at the intersection of natural gas and electric power, especially in the Mid-Atlantic and New England markets.

3.4 Commercial Viability - Creating and Delivering Value

3.4.1 Selection of Microgrid Technologies

On the generation side, the “generation” technologies were selected based on the microgrid needs during a week of emergency and larger outage, and sized to meet the microgrid electrical load. The least expensive electric drivers were found to be reciprocating engine/internal combustion type engines.

The technologies considered included gas turbines (which were not selected due to long starting time and cost), micro-turbines (which were not selected since they come in small sizes and also higher cost than reciprocating engines), fuel cells (which were not selected due to long start up time, and also the trade-off between efficiency and flexibility). For certain facilities, if they had heating/cooling loads that could be met by addition of CCHPs, then CCHP options were selected. In such cases, the recovered CCHP thermal energy would replace the boiler thermal energy production.

Absorption chiller option was added if there was a potential for meeting part of the cooling load. Solar PV was considered for any site with sufficient available area and location that could be used for installation of solar PV panels. Electric battery storage was found to be not economical. These technologies were included in the DER-CAM model with assumed installed costs, annual fixed operations and maintenance costs, and variable operations and maintenance costs, and industry average efficiencies for each technology types and at different discrete capacity sizes.

The DER-CAM model in general appeared to select reciprocating/internal combustion engines both for electric only generation and CCHP option. To the extent possible, existing generation resources of various types were considered for inclusion in the microgrid, if they were of sufficiently larger size and if it was determined that they had existing automatic control options and could be integrated to the electrical and also control and communication network without substantial investments.

In this stage, the control design focused more on functionalities and architecture than equipment or vendor specifications. Controller functionalities were chosen based on the technologies and needs of the project, and features of commercially available products from a range of vendors, including GE. These include the ability to monitor multiple POIs, fast load-shedding, and economic optimization. The ability to integrate BEMS into the control architecture and communicate with external utility systems is also highly valued.

3.4.2 Assets Owned by Applicant and/or Microgrid Owner

Proctors has four Capstone C65 microturbines paired with an absorption chiller to use in this microgrid. Also Proctors owns an existing thermal district system which is the basis for expansion to a full microgrid that can provide electric and thermal service to the customers. As shown in Figure 2-1, there is existing thermal piping across the street used to meet the heating and cooling needs of the Center City block. As the project moves forward, this infrastructure, or the precedence, may be leveraged to facilitate an electric connection across the street. The existing cooling towers can be used in conjunction with the absorption chillers to reject heat to the atmosphere. The organizational assets of Marquee Power allow for a “next step” evolution to moving into selling electricity from their current thermal sales. Furthermore, Proctors has auxiliary heating and cooling machinery in the form of boilers and chillers that can be used to supplement the CCHP output during the hottest and coldest days of the year whereas the CCHP alone may not meet the thermal loads of the microgrid.

3.4.3 Load-Generation Balance

The specific demands for power matching/frequency regulation will be determined through study, and the microgrid controller will manage assets in response to changing conditions. Proctors and Center City have backup diesel and natural gas engines that are excellent for black-start and load-following applications. In connected mode (parallel to the grid), microgrid generation resources would not be required to regulate frequency, and would likely have a small role if any in voltage regulation. These services are provided by the bulk power system. However, in islanded mode, microgrid resources will need to provide for power balance/frequency control and reactive power balance/voltage control.

The existing micro-turbines at Proctors, because they are inverter- based generators, can easily incorporate battery storage to start the generators and provide black-start capability for the microgrid if needed. Micro-turbines are generally designed to operate as base-loaded generation, but in this application some load-following can be achieved by sequentially turning on additional units which lessens the need for part load operation.

For the Schenectady microgrid, some assets will provide baseload power while other assets would switch to frequency control mode. Both the CCHP and micro-turbines tend to be better suited to baseload operation than frequency control. For Schenectady, that means the majority of fast frequency regulation must come from the standby generation at Proctors and Center City. To augment this fast frequency regulation, load may need to be controlled. Additionally, it may be necessary for solar production to be curtailed. This will also be managed by the controller.

3.4.4 Permits and/or Special Permissions

To the extent the proposed microgrid project entails crossing a public road with an electrical line, the microgrid owner may need to request an exemption from one or more state utility regulations to avoid being treated as a public utility. Otherwise, there are no unique permits required to construct the microgrid.

The typical permits for these projects are: City building permit, City electrical permit, City Plumbing Permit, National Grid Interconnection process, City street permit, City Sidewalk permit, water permit, permission to run electricity across State Street which is a State Route. Also National Grid Standard Interconnection Requirements must be met and accepted. The EPA has emission limits that must be tested, documented, and as a regulatory authority the EPA has a permitting process for this.

3.4.5 Approach for Developing, Constructing and Operating

The microgrid is likely to be constructed under the design, build, own, operate and transfer (DBOOT) model. Customers would sign a long-term (20 years) Energy Services Agreement (ESA) with the third-party investor to pay charges for electric, heating and cooling services. The ESA would ensure that investors recovered their capital costs and expenditures relating to the construction of the generating projects. However, the specific details of these arrangements may evolve significantly during an investment-grade analysis of the most favorable structures available for project financing.

3.4.6 Benefits and Costs Passed to Community

Community members will benefit from the microgrid by receiving essential services during emergencies and grid outages. Within Proctors and Center City are a number of aforementioned convenience stores, restaurants, educational facilities, centers of refuge, and businesses that are critical to the downtown area.

3.4.7 Requirements from Utility to Ensure Value

The utility may need to operate and maintain a small set of T&D assets on behalf of Proctors, including the tie-cables and terminations in underground conduits.

3.4.8 Demonstrated of Microgrid Technologies

The technologies proposed to be included in this microgrid project are technologically mature. CCHP has been deployed extensively in campus microgrid systems, including New York University, Princeton University and many other university-owned microgrids. Solar PV is also a mature power generating technology that has been deployed extensively, including in microgrid settings. CCHP and solar PV have been deployed together in microgrid systems.

The Woking Town Centre Energy Station, owned by Thameswey Energy Limited in Woking Borrough, United Kingdom, is an example of an Independent Provider microgrid system. The Woking project makes use of a law that allows private wires to interconnect previously unaffiliated customers to CHP and other clean energy systems, subject to a maximum capacity limit. Thameswey Energy Limited (TEL), an energy services company in the UK already institutes a form of "virtual private wires" in the Borough of Woking. Under rules that allow the development of limited physical "private wires" schemes, TEL operates several community CHP facilities that directly serve multiple public and private customers.

In Japan, the Sendai microgrid operated continuously in the wake of the great earthquake of 2011 despite wide scale grid blackouts in the surrounding areas. According to the NEDO Microgrid Case Study: "It is evident that the key to the Sendai Microgrid's continuous power supply during the disaster was a diversity of energy sources. Equipped with gas engines and photovoltaics, the microgrid was capable of operating in island mode following the outage. Gas engines with access to an energy supply were central to the Sendai Microgrid's capability to supply power over the extended period of the outage when islanded due to service interruption from the distribution company. Fuel cells and PV arrays may not be sufficient sources of power during disasters; for example, solar panels can be broken during an earthquake and rendered useless during long periods of rain . . . The Sendai Microgrid is designed to use multiple sources of energy, most importantly natural gas supplied via a disaster-resistant medium pressure pipeline. This provides a stable energy supply in times of disaster."[7]

The Microgrid Control design may incorporate GE's proven U90Plus Microgrid Cost Minimizer to dispatch the DERs, and the D400 RTU/Controller to implement various operational control strategies. GE is currently developing a DoE funded Enhanced Microgrid Control System ("eMCS" controller) that expands upon the algorithms implemented in the U90Plus and incorporates many of the control functions that now reside in the D400. The eMCS will be tested at NREL in early 2016 and will be applied at a microgrid site on Potsdam, NY. The U90Plus algorithm is being incorporated into the D400 controller, and this solution will be deployed in mid-2016 on a Microgrid at the University of Ontario in Toronto.

Another proven solution that could be utilized is GE's proven C90Plus Fast Load Shed Controller. The C90Plus provides adaptive load shedding for loss of generation and/or a utility tie to trip non-critical load. The IEDs/relays communicate real-time load and generation values as well as status to the C90Plus via IEC 61850 GOOSE messaging. The C90Plus evaluates this information and will issue a fast trip GOOSE message to the IEDs/relays to trip non-critical loads to assure a generation-load balance. The tripping of the load breakers is initiated in less than 20 ms from detection of the triggering event. This compares to 200ms to 400ms for conventional load shedding schemes. This solution was recently successfully deployed and demonstrated at the Portsmouth Naval Shipyard under a DoD Environmental Security Technology Certification Program (ESTCP) contract.

3.4.9 Operational Scheme

The microgrid would be owned and operated by Proctors, which would retain any and all control over the microgrid as a private owner. Proctors is the sole owner of the microgrid's assets and will retain any and all control over the technical, financial, transactional and decision making responsibilities. For customer convenience, Proctors refers to the thermal service as "Marquee Power."

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[7] http://www.nedo.go.jp/content/100516763.pdf

3.4.10 Plan To Charge Purchasers of Electricity Services

Microgrid customers would sign a long-term (20 years) "Energy Services Agreement" (ESA) with Proctors. The metering would be done with legacy utility meters, except that submetering systems would be installed as needed to monitor and manage the flow of electricity to specific tenants. The existing thermal district already has thermal meters in place for heat distribution to customers.

3.4.11 Business/Commercialization and Replication Plans

The proposed microgrid project's business model is sufficiently flexible to accommodate a wide range of technical microgrid configurations and institutional settings. The unique aspects of the Proctors model may limit replicability to entities with sufficiently strong balance sheets to finance major capital upgrades internally. As a result, there are no specific or concrete replications plans under development yet. However, the project will certainly be a lighthouse project illustrating the importance and potential for using innovative clean energy solutions as an essential part of broader urban revitalization efforts.

3.4.12 Barriers to Market Entry

Technical barriers: The proposed barriers to entry for microgrid participants can be expressed in either technical or financial terms. Downtown Schenectady has three types of network systems– overhead radial networks, street networks and spot networks. This creates additional complications when trying to retrofit or connect facilities to each other. Resolving the issues of interconnecting and isolating facilities that are grid-tied in different ways seems, at present, unfeasible.

Spot-network back-feed issues have limited the ability of the microgrid to provide power to several clusters of critical facilities located outside of the "400-Block" footprint. Due to interconnection issues, these facilities, which include government-owned buildings like City Hall, the County Office and courthouse complex, are unable to participate in the microgrid. Adding these facilities to the microgrid would augment the resilience of the local economy.

Financial barriers: The primary financial barrier to entry for microgrid participants is bearing the incremental cost of interconnection. Unlike the typical interconnection costs, the cost of connecting to a microgrid commonly includes a supplemental investment in T&D infrastructure above and beyond the costs of interconnecting with the utility's distribution grid. In other words, a distributed generator or other type of microgrid participants must typically make (or have made on their behalf) a capital investment to connect to the microgrid.

3.4.13 Steps required to Overcoming Barriers

Interconnection barriers: Resolving the spot-network back-feed issue with PLC technology (currently a demonstration project underway at Proctors) may create new techniques to the interconnection/isolation toolkit.

Financial barriers: The key to reducing the financial barriers to customer participation in the microgrid is expanding the revenue streams captured by the microgrid owner, which can be used to offset the costs paid by the customers for the shared T&D investment. In the context of the proposed microgrid, the inability to connect additional facilities outside of the 400 block footprint may preclude opportunities for creating new revenue streams by limiting the diversity of loads and generating sources connected to the microgrid.

3.4.14 Market Identification and Characterization

The potential market served by the microgrid will encompass the facilities and entities in the graphic and list below, organized by geographic proximity to State Street and primary street address.

<u>North Side of State Street – Facilities and Impacted Entities</u>

- 433 State Street, Center City
  - CVS Pharmacy
  - Schenectady County Community College Classrooms
  - Wink
  - WiseLabs – Tech incubator
  - NBT Bank
  - Metroplex – County development authority
  - M/E Engineering Offices
  - YMCA (Designated Center of Refuge)
  - Johnny's Italian restaurant
  - Many other offices
- 401 State Street - Office building, NYS Commission on Quality Care for People with Disabilities
- 409 State Street, Metropolitan Building
  - Offices on first floor
  - Nine residential units on second floor
- 411 State Street, Paul Mitchell Building,
  - Paul Mitchell School
  - Other offices

<u>South side of State Street - Facilities and Impacted entities</u>

- Proctors
    - Theatre auditorium (Marquee Power provides heating, will include cooling next year)
    - Arcade (Marquee Power provides heating and cooling)
        - Empire State Youth Orchestra
        - Van Curler Music store
        - Open Stage Media (public access TV for Schenectady)
    - Proctors admin offices
- 436 State Street, Key Hall
    - Banquet Hall, special event space with full kitchen
- 434 State Street, Parker Inn
- 438 State Street, Subway restaurant
- 440 State Street, Transfinder Corporate HQ
    - Includes servers that support GPS software product, used for routing school buses and snowplows etc.
- 450 State Street, Hampton Inn
    - Marquee Power customer

3.5 Financial Viability

3.5.1 Categories of Revenue Streams

The microgrid owner is expected to capture revenues from one or more of the following four categories:

1. *Demand response* (DR): DR is a mature revenue opportunity for microgrids. Depending on the characteristics of its load and generating assets, a microgrid could participate in one of many DR programs offered by the utility or the NYISO.
2. *Peer-to-peer energy sales*: The microgrid's primary revenue will be generated by selling power to microgrid customer's under long-term energy services agreements.
3. *Energy market sales:* The microgrid owner may have opportunities to sell surplus power into the NYISO market. The ability to do conventional power grid and be compensated through the ability to do so and the overall value that results from doing so will depend highly on market conditions and any potential limits on power exports.
4. *Capacity-based revenues:* the microgrid owner may be able to participate in the NYISO's capacity market.

Depending on future regulatory developments, the microgrid owner may also be positioned to capture revenues from providing enhanced resilience against power outages. Loss of load can create high costs for consumers; the societal and economic values of mitigating these lost loads can be very significant, depending on the nature of the operations occurring within the microgrid.

3.5.2 Other Incentives Required or Preferred

- Renewable Energy Credits
- New York Green Bank
- U.S. Department of Energy's Loan Office Program

- PACE funding
- Community Choice Aggregation
- Clean energy and energy efficiency bonds
- Utility rebates
- PON 2568 CCHP Acceleration Program
- NYSERDA's Consolidated Funding Application (CFA) program
- Federal, state and local incentives
- Federal investment tax credits
- Bonus depreciation rules

Any reduction in the level of incentive support provided for projects or any delay in awarding incentives to projects could and likely would adversely affect the development and deployment of this project.

3.5.3 Categories of Capital and Operating Costs

Table 3-2 Microgrid Capital Costs

Capital Component	Installed Cost ($)	Component Lifespan (round to nearest year)	Description of Component
Project Management and admin	98,000	20	Turnkey install (design engineering not included)
Contract Admin and paperwork	13,000	20	Contracts, notices, PPAs
Construction Engineering	80,000	20	During build phase engineering consultation and support (submittals, RFIs)
Absorption Chiller 250T	300,000	20	Indirect fired absorption chiller
Cooling tower for above	150,000	20	Companion tower to chiller
motorized breakers x 3	50,000	20	Utility protection and island mode
Microgrid control and communications system	405,000	20	Controller, nodes, instrumentation, radios, switches, integration/configuration
Commission Capstones into this project	20,000	20	Existing CCHP needs some modification
2 x 1 MW CCHP engines	5,000,000	20	Supply, rig, pad, install, exhaust, duct, wire, breaching, etc.
Reinforce Proctors Roof to accommodate new machines	80,000	20	Swap membrane roof, put a super structure under the new machines.

Capital Component	Installed Cost ($)	Component Lifespan (round to nearest year)	Description of Component
UG Electric connects Proctors to Center City	150,000	20	Using NG conduit and vaults, run our own circuits, cable, switchgear, transformers, protection
Software	6,000	20	Billing software
Natural gas work	18,000	20	Run to new CCHP
Plumbing and electrical ty ins and utility shut downs	12,000	20	Connections made to existing head end utility gas and electric
Sub metering equipment	30,000	20	Billing Proctors tenants and Center City

Table 3-3 Microgrid Initial Planning and Design Costs

Initial Planning and Design Costs ($)	What cost components are included in this figure?
740,000	Engineering analysis, engineering design, project management, permitting, initial interconnect, legal, meetings.

Table 3-4 Microgrid Fixed O&M Costs

Fixed O&M Costs ($/year)	What cost components are included in this figure?
$87,500	Yearly maintenance mostly associated with chemicals in water, absorption chiller purging and filling, chiller maintenance, exercising machines, engineering updates and issues, updating software. Contract admin, walk-throughs, stakeholder management, reporting, testing, verification, and billing.

Table 3-5 Microgrid Variable O&M Costs

Variable O&M Costs ($/Unit of Energy Produced)	Unit	What cost components are included in this figure?
Maintenance Contract for 4 Capstone C65s	$22/MWh$22/MWh	Tune up, repairs, PM, monitor online, NYSERDA reporting
Maintenance Contract for 2x 1 MW CCHP	$19/MWh$19/MWh	Tune up, repairs, PM, monitor online, NYSERDA reporting

3.5.4 Business Model Profitability

The microgrid will enhance the value proposition for an existing thermal system operated by Proctors. The project's reliance on traditional on-balance sheet financing means the microgrid owner will potentially be able to accommodate longer payback periods and lower investment returns than would likely be possible if the project relied exclusively on financing from third party investors.

3.5.5 Description of Financing Structure

Traditional on-balance sheet financing will be used for the microgrid project. As the existing microgrid owner, Proctors is considering financing the proposed microgrid project on its balance sheet through debt and/or equity investment as a capital expenditure. In this scenario, the project would be financed and secured by Proctors' assets and/or future revenues. This financing option was considered to be the most efficient and effective option available by Proctors' leadership.

3.6 Legal Viability

3.6.1 Proposed Project Ownership

Proctors would own and operate – in part or entirely through Marquee Power – all of the generating and non-generating assets of the microgrid. The only possible exception to this would be ownership of the electrical connection in conduits under State Street and connecting Proctors and Center City. It is unclear whether Proctors could own these assets without prior approval of the PSC. One alternative under consideration by the project team, which is also being considered in other projects such as the Potsdam REV demonstration project is for National Grid to build, own, and operate the T&D assets and recover the cost from microgrid direct and indirect beneficiaries. This and other options will be explored with National Grid in Stage 2.

3.6.2 Project Owner

Proctors will be the microgrid owner.

3.6.3 Site Ownership

To the extent the project requires access to sites owned or controlled by National Grid or another third party, the microgrid owner will coordinate with National Grid and/or other third party to ensure site access.

3.6.4 Privacy Rights of Customers

The microgrid will evaluate industry best practices for protecting privacy in smart grid and microgrids. In particular, the project team will evaluate emerging and establish strategies and protocols for protecting customer privacy in the context of the smart grid.[8]

3.6.5 Regulatory Hurdles

Despite significant potential benefits, microgrid adoption rates have remained lower than one would expect at least partially because of uncertainties in the regulatory environment. Most current risks stem from regulatory uncertainty associated with the legal standing of a microgrid. These include:

- Franchise rights limiting the ability of non-utilities to cross public rights of way could complicate or preclude Proctors ownership of the conduits under State Street.
- Lack of tariff or rate structure for allocating costs of shared T&D infrastructure among microgrid customers;
- Lack of clarity on applicability of consumer protection laws to microgrid owners;
- Barriers to microgrid owners acting as DR aggregators in wholesale markets could impede Proctors options for participating in those markets or limit the value of participation; and
- Natural gas pipeline constraints and lack of mechanisms for procuring firm natural gas service could result in operating outages during periods of extreme cold when there is limited or no spare regional pipeline capacity.

4 INFORMATION FOR BENEFIT COST ANALYSIS

The purpose of this task was to provide input to Industrial Economics, Inc. (IEc) to allow them to conduct a screening-level analysis of the project's potential costs and benefits. To facilitate data collection, two questionnaires were provided to aggregate pertinent data for the benefit-cost analysis (BCA). The sections below discuss how the data and information were obtained and developed for the questionnaires and summarizes of the input provided to IEc and the results of IEc’s analysis.

4.1 Facility and Customer Description

The microgrid will utilize the current Proctors/Marquee Power District Energy System footprint as its base. As such, the microgrid includes two main facilities serving a diverse set of customers. The top half of Table 4-1 below summarizes the facilities, their rate class, and describes the types of customers in each facility.

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[8] For a more robust discussion of specific privacy protection practices in the context of the smart grid, see S. Zeadally, A.. Pathan, C. Alcaraz, and M.. Badra, “Towards Privacy Protection in Smart Grid”, Wireless Personal Communications, vol. 73, pp. 23-50, 2012. http://doi.org/10.1007/s11277-012-0939-1.

The bottom half of Table 4-1 shows the economic sector for each facility, the average annual consumption, peak demand, percentage of facilities' average demand that the microgrid would support during a major power outage, and the hours per day, on average, that facilities would require electricity from the microgrid the outage. The data were derived from energy bills for the Proctors complex and some energy bills as well as benchmarking data for Center City.

Table 4-1 Background Information on the Facilities

Facility Name	Rate Class	Usage / Description
Proctors Arts Complex and Marquee Power DES	Large Commercial/Industrial (>50 annual MWh)	Proctors Complex includes: Theater Auditorium, GE Theater, Arcade, Community TV Station, Music Store, Cafe, Admin Offices, office spaces, Key Hall banquet hall/special event space with full kitchen The Proctors Marquee Power District Energy System service includes: Proctors Arts Complex, TransFinder HQ, Subway Restaurant, Parker Inn, Hampton Inn, and Center City.
Center City Complex	Large Commercial/Industrial (>50 annual MWh)	Proctors Complex includes: Theater Auditorium, GE Theater, Arcade, Community TV Station, Music Store, Cafe, Admin Offices, office spaces, Key Hall banquet hall/special event space with full kitchen The Proctors Marquee Power District Energy System service includes: Proctors Arts Complex, TransFinder HQ, Subway Restaurant, Parker Inn, Hampton Inn, and Center City.

Table 4-1 Contd.

Facility Name	Economic Sector Code	Annual Energy (MWh)	Peak Demand (MW)	During Major Outage	
				% Use Supported	Hours of Elect / dy
Proctors Arts Complex and Marquee Power DES	*All other industries*	2,542	.776	100%	24
Center City Complex	*All other industries*	5,186	1.517	100%	24

4.2 Characterization of Distributed Energy Resources

The principal generation resources for the microgrid are the four existing microturbines at Proctors, the proposed 2 MW of CHP, as well as 550 kW of solar PV on various rooftops. The two facilities also have a total of 400 kW of a standby gas and diesel generation. Table 4-2 below summarizes the distributed energy resources (DER) the microgrid would incorporate, including the energy/fuel source, nameplate capacity, estimated average annual production (MWh) under normal operating conditions, average daily production (MWh/day) in the event of a major power outage, fuel consumed per MWh generated. Based on the energy consumption and peak loading in Table 4-1, it is clear that there is sufficient generation capacity to serve the entire microgrid load during a major outage without the standby generators, or significant contribution from the solar PV.

Table 4-2 Summary of DER Resources

DER Name	Facility	Energy Source	Rated Capacity (MW)	Avg. Annual Production - Normal Conditions (MWh)	Avg. Daily Production - Major Power Outage (MWh)	Fuel Consumption per MWh	
						Quantity	Unit
Existing Backup Gen	Proctors	*Diesel*	0.25	0	0.0	10.0	MMBtu/MWh
Existing Backup Gen	Center City	*Natural Gas*	0.15	0	0.0	13.6	MMBtu/MWh
4 x Capstone Microturbines	Proctors	*Natural Gas*	0.26	292	1.2	11.4	MMBtu/MWh
CHP-1	Proctors	*Natural Gas*	1.00	2674	13.0	9.5	MMBtu/MWh
CHP-2	Proctors	*Natural Gas*	1.00	2674	13.0	9.5	MMBtu/MWh
Solar PV	Proctors rooftop & other locations	*Solar*	0.55	950	3.3	N/A	None

4.3 Capacity Impacts and Ancillary Services

The main generation resources for the microgrid are the existing micro turbines and the CHP units. These machines are capable of providing peak load support up to their maximum rated output. Since the solar PV is a variable resource, less than 30% of its capacity is expected to be available for peak load support.

Table 4-3 below summarizes the capacity (MW/year) available for peak load support from each DER in the microgrid. The total capacity/year available for peak from the microgrid is 2.4 MW.

Table 4-3 Provision of Peak Load Support

DER Name	Facility Name	Available Capacity (MW/year)
1 MW CHP-1	Proctors Theater	1.000
1 MW CHP-2	Proctors Theater	1.000
4 x 65 kW Microturbines	Proctors Theater	0.260
550kW Solar PV	Proctors and Elsewhere	0.150

In addition, integration of the facilities' building energy management systems into the microgrid control system and use of backup generation to meet emergency loads will facilitate approximately 690 kW of fast-load shed demand response that will be available to the market. The projected demand response available by facility after the microgrid id developed is: 390 kW at Proctors and 300 kW at Center City. However, Proctors currently provides 140 kW of demand response program, so the incremental from Proctors is 250 kW.

Based on discussions with National Grid, the Team understands there are no imminent transmission congestion issues that would be addressed by the microgrid. On the distribution side, the facilities are served by an underground secondary system that is aging. While the Utility has not expressed concerns about near term capacity issues on the network, the Team knows that the downtown area of Schenectady is undergoing revitalization. The energy density will certainly increase on the network and non-network portions of the area. The 2 MW of firm generation on the microgrid can potentially be factored into longer term plans to meet distribution load growth in the area.

Generation resources in the proposed microgrid are capable of providing ancillary services in the form of frequency regulation, reactive power support, and black start support, to the utility or the New York Independent System Operator (NYISO). Whether the project would be selected to provide these services depends on the utility's or NYISO's requirements, and the ability of the project to provide support at a cost lower than alternative sources. Based on discussions with NYISO, it is our understanding that the market for ancillary services – in particular, black start support – 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.

The Proctors Marquee Power District Energy System includes four 65 kW micro-turbines which are not yet in service, a 250-ton electric-screw chiller, two 500-ton electric centrifugal chillers, a 175-ton absorption chiller, two 8780 BTU/hour hot-water boilers, one 3,655 BTU/hour hot-water boiler, a 1,000-ton evaporative-media tower, and a 500-ton air-cooled cool tower which can be used in economizer mode during the fall and spring. In this project, the Team has proposed 2 MW of new CCHP which are expected run most of the year, servicing a portion of the heating loads in the winter months and the cooling loads (via absorption chillers) in the summer. Based on the history of the DES operation, The Team projects that the facilities can save approximately $37,950 annually on fuel costs from operation of the new CHP system at Proctors.

Based on the DER CAM simulation of the microgrid operation during islanded mode, emissions (above and beyond what is established) are:

- CO2 0.4966 Metric Tons/MWh
- NOx 0.0007 Metric Tons/MWh

Emission rates for SO_2 and Particulate Matter are negligible.

4.4 Project Costs

The total capital cost for the microgrid is estimated at over $7.73M. The highest capital outlay, as expected, is the installed cost of the 2 MW of CHP at Proctors, which accounts for about two-thirds of the capital outlay. However, as pointed out earlier, the CHP system would generate sufficient savings and revenue to pay for itself within several years. The next most costly items are the absorption chiller that will be part of the CHP system and the microgrid control system, including the Energy Management System, Edge Control Nodes, and integration software. Table 4-4 below summarizes the installed costs of all capital equipment planned in the microgrid. All components are assumed to have a 20-year useful life.

Table 4-4 Summary of Project Capital Costs

Capital Component	Installed Cost ($)	Component Lifespan (round to nearest year)	Description of Component
Project Management and admin	98,000	20	Turnkey install (design engineering not included)
Contract Admin and paperwork	13,000	20	Contracts, notices, PPAs
Construction Engineering	80,000	20	During build phase engineering consultation and support (submittals, RFIs)
Absorption Chiller 250T	300,000	20	Indirect fired absorption chiller
Motorized breakers x 2	40,000	20	Utility protection and island mode
Microgrid control and communications system	405,000	20	Controller, nodes, instrumentation, radios, switches, integration/configuration
2 x 1 MW CCHP engines	5,000,000	20	Supply, rig, pad, install, exhaust, duct, wire, breaching, etc.
Reinforce Proctors Roof to accommodate new machines	90,000	20	Swap membrance roof, put a super structure under the new machines.
UG Electric onnection Proctors to Center City	150,000	20	Use existing conduit and vaults for new circuits
Software	6,000	20	Billing software
Natural gas work	18,000	20	Run to new CHP
Plumbing and electrical tie-ins and utility shut downs	12,000	20	Connections made to existing head end utility gas and electric
Sub metering equipment	30,000	20	Billing Proctors tenants and Center City

Initial planning and design costs for the project are estimated at $740,000. This includes the cost for detailed analysis of steady–state, dynamic and transient interactions, engineering design and equipment specifications, engineering drawings and blueprints, energy modeling and simulation, heating, cooling and plumbing site studies, regulatory, policy and legal issues, financial modeling, cost estimations, interconnection applications and other permitting issues, project management, contract administration, governance, and other project administrative components.

Fixed operations and maintenance (O&M) costs are estimated at $47,000 per year. These include costs associated with chemicals in water, absorption chiller purging and filling, chiller maintenance, exercising machines, engineering updates and issues, computer and software licenses, insurance, contract updates, contract reviews, training, leased equipment, technical support, equipment maintenance contracts, taxes and fees.

Variable O&M costs, (excluding fuel costs) for the microgrid generation resources are shown in Table 4-5 below. These costs include part replacements, upgrades, inspections and overhauls, labor, and rentals, cost of waste disposal, pollution control costs, and utilities.

Table 4-5 Non-Fuel Variable O&M Costs

Variable O&M Costs ($/Unit of Energy Produced)	Unit	What cost components are included in this figure?
22	$/MWh	Maintenance Contract for 4 x 65 kW microturbines
19	$/MWh	Maintenance Contract for 2x 1 MW CHP

Based on the average load profiles of the facilities, the microgrid has sufficient capacity between the gas-fired CHP units, microturbines, solar PV, and demand response to supply all the critical facilities for as long as natural gas supply lasts. Table 4-6 below shows the amount of fuel that would consumed by each DER resource during a prolonged (seven-day) outage.

Table 4-6 Fuel Consumed During a Prolonged Outage

DER Name	Facility Name	Duration of Design Event (Days)	Quantity of Fuel Needed to Operate in Islanded Mode for Duration of Design Event	Unit
4 x 64 kW Microturbines	Proctors Theater	Indefinitely	96 (for 7 days)	MMBtu
2 MW CHP	Proctors Theater	Indefinitely	1729 (for 7 days)	MMBtu
550 kW PV	Proctors and Elsewhere	Indefinitely	N/A	N/A

4.5 Costs to Maintain Service during a Power Outage

Between the two facilities there is 400 kW of diesel and natural backup generation: a 250 kW diesel engine at Proctors, and a 150 kW gas engine at Center City. Neither of these existing units will be run for any significant amount of time during islanded emergency periods, due to the availability of other generation to cover the microgrid load. During grid connected blue sky days, the existing backup units (especially the diesel engine) are too expensive to run as baseload generation and so will not typically operate. However, they are available for peak load support and can be part of a demand response program, given the right market signals. For each of these backup units, Table 4-7 below summarizes the fuel/energy source, nameplate capacity, percentage of nameplate capacity during an extended power outage, average daily electricity production during a major outage, associated fuel consumption, one-time costs for connection/startup, and ongoing (non-fuel) costs for operation.

Table 4-7 Summary of Backup Generation Resources

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		
Proctors	1	Diesel	.25	50	3	30.0	MMBtu/ day	150	35
Center City	2	Natural Gas	.15	95	3.4	46.6	MMBtu/ day	150	35

During a widespread power outage (i.e., a total loss of power in the surrounding area), each of the critical facilities has emergency measures for maintaining operations, preserving property, and/or protecting the health and safety of workers, residents, or the general public. The first line of defense involves connecting and powering up the backup generation resources identified in Table 4-7 above. For some, backup systems are on automatic transfer switches with a control system that senses loss of voltage and starts up the machines to supply emergency loads. For other facilities, startup of emergency backup might be a manual process. On loss of power, there are procedures that each facility would follow to notify personnel, check on the welfare of affected persons, and evacuate certain areas if necessary. As the emergency persists, facilities might incur additional costs to maintain backup power, including equipment rental, remedial measures, administrative costs, maintenance, fuel costs, permits and fees for extended operation.

Table 4-8 below summarizes the one-time and ongoing costs for the Proctors and Center City facilities in the Schenectady project when the facilities are operating on backup power. Table 4-9 summarizes the costs for the facilities when backup power is not available.

Table 4-8 Cost of Maintaining Service while Operating on Backup Power

Facility Name	Type of Measure (One-Time or Ongoing)	Description	Costs	Units	When would these measures be required?
Proctors Complex	One-Time Measures	Turn on and check backup power, issue notifications, send non-essential personnel home	3,000	$	On loss of power any day
Proctors Complex	One-Time Measures	Hooking up and testing portable generator	1,000	$	Year round, every day

Facility Name	Type of Measure (One-Time or Ongoing)	Description	Costs	Units	When would these measures be required?
Proctors Complex	Ongoing Measures	Proctors emergency generator is only for lights and safety systems. Rental units would be bought to support shelter and lodging services, but probably not sufficient to support a show.	1,700	$/day	Daily during extended outage
Center City Complex	One-Time Measures	Hooking up and testing portable generator	1,000	$	Year round, every day
Center City Complex	One-Time Measures	Turn on and check backup power, notify multiple tenants, send non-essential personnel home.	5,000	$	On loss of power any day
Center City Complex	One-Time Measures	Center City emergency generator can only supply a fraction of the emergency load. Rental units would be bought to support shelter and lodging services.	1,700	$/day	Daily during extended outage

Table 4-9 Cost of Maintaining Service while Backup Power is Not Available

Facility Name	Type of Measure (One-Time or Ongoing)	Description	Costs	Units	When would these measures be required?
Proctors Complex	One-Time Measures	Hooking up and testing a 500kW generator	1,000	$	Year round, every day
Proctors Complex	Ongoing Measures	Renting and operating a 500kW generator	1,700	$/day	Year round, every day
Center City Complex	One-Time Measures	Hooking up and testing a 500kW generator	1,000	$	Year round, every day
Center City Complex	Ongoing Measures	Rent, hook up, and test a 500kW generator	1,700	$/day	Year round, every day
Proctors Complex	Ongoing Measures	Lost revenue from the Theater and commercial tenants, rescheduling shows, issuing refunds, compensating performers	200,000	$/day	On days Proctors has a show which is most
Center City Complex	Ongoing Measures	Lost revenue to commercial tenants	250,000	$/day	Year round, every day

Based on the data above, during power outage while operating on backup power, Proctors would experience 80% loss in services, and Center City would experience 90% loss of services. If backup generation is not available, both complexes would experience 100% loss in services.

4.6 Services Supported by the Microgrid

The microgrid includes facilities that emergency shelter and refuge for residents of the area during an emergency. Proctors is a designated Red Cross center of refuge, as is the YMCA in Center City across the street. In the event of a natural disaster, it is the only central location that has the size, resources and facility to accommodate people from multiple adjacent neighborhoods, along with the capacity to maintain life systems. Its critical facilities include two emergency relief centers, three commercial kitchens, a bank, a pharmacy, two hotels and the telecommunications and physical infrastructure to accommodate relief effort coordination on the ground. Proctors can provide shelter to 900 people and Center City can provide shelter for 1,100 people in the event of an emergency.

4.7 Summary of BCA Results

To assist with the completion of the project's NY Prize Stage 1 feasibility study, Industrial Economics, Inc. (IEc) conducted a screening-level analysis of its potential costs and benefits. IEc typically considers two scenarios for the benefit cost analysis. The first scenario assumes a 20-year operation periods with no major power outages (i.e., normal operating conditions only). The second scenario calculates the average annual duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under the first scenario.

Results of IEc's analysis (included in Appendix A) suggest that if no major power outages occur over the microgrid's assumed 20-year operating life, the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to exceed approximately 1.1 days per year (Scenario 2). The results are summarized in the table below. Figure 4-1 shows a breakdown of the benefits and costs for Scenario 1 (no power outages).

Table 4-10 BCA Results (Assuming 7 Percent Discount Rate)

	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
ECONOMIC MEASURE	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 1.1 DAYS/YEAR
Net Benefits - Present Value	-$3,450,000	$185,000
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	0.2%	6.4%

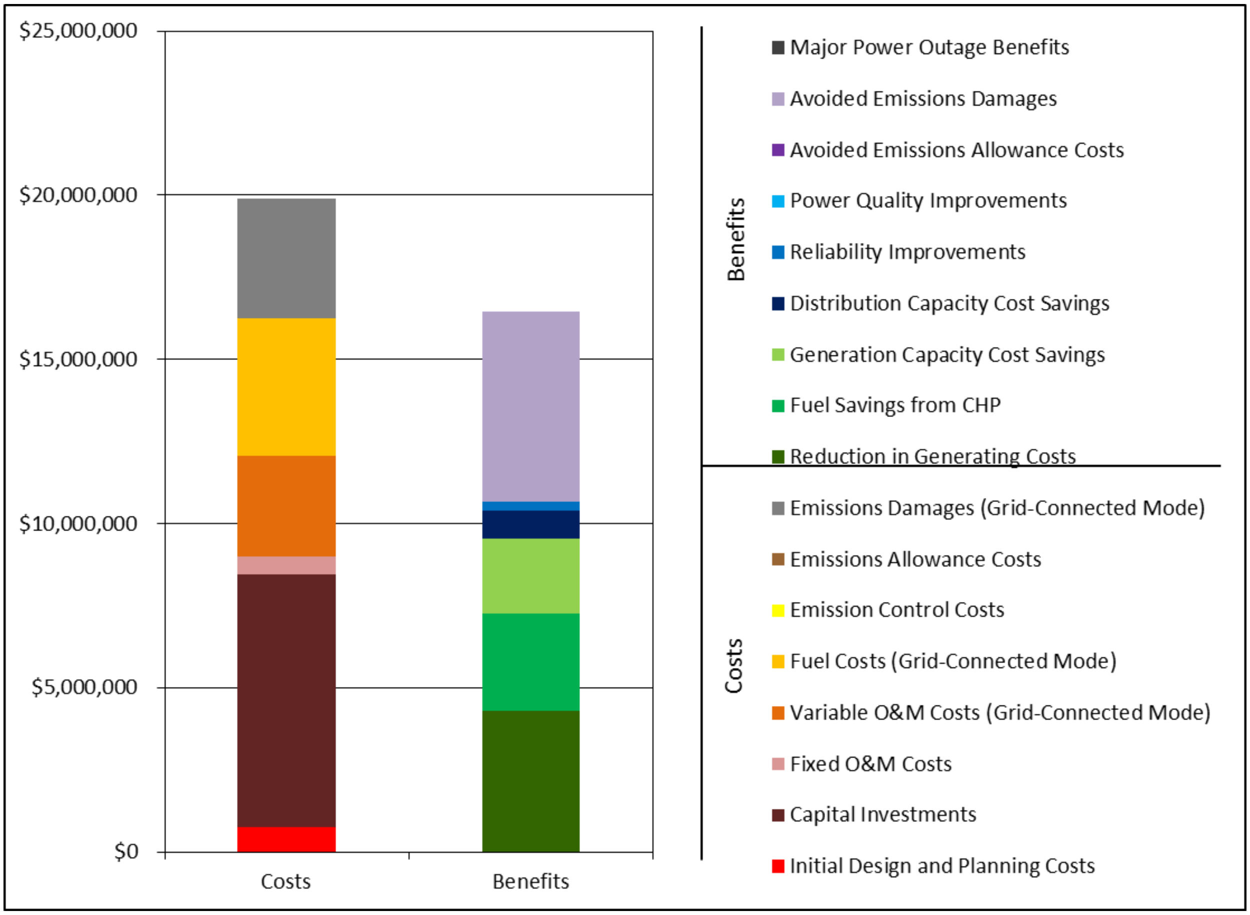

Figure 4-1: Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

As can be seen, the major cost component is the capital investment in the microgrid, particularly the CCHP units. *However, these machines provide a return on investment during normal grid operations by providing thermal services to microgrid customers, particularly established customers of Proctors Marquee Power DES. This return on sales of thermal energy during normal grid operations is not included in IEc's societal-based evaluation*. The next highest cost component is the DER fuel costs during grid connected operations. Variable O&M costs and Emission Damages of the microgrid generation resources during grid connected operations (due to the fuel consumption by the CCHP running during normal days) are also substantial cost components.

The major benefit component is the avoided emission allowance costs, attributable to clean natural gas and solar PV. The other significant benefit stream is the reduction in grid generation costs, attributable to the microgrid generation that displaces other conventional generation in the grid.

Table 4-11 below summarizes the detailed results of the Scenario 1 benefit cost analysis.

Table 4-11: 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	$740,000	$65,300
Capital Investments	$7,730,000	$670,000
Fixed O&M	$538,000	$47,500
Variable O&M (Grid-Connected Mode)	$3,060,000	$270,000
Fuel (Grid-Connected Mode)	$4,190,000	$370,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,640,000	$238,000
Total Costs	**$19,900,000**	
Benefits		
Reduction in Generating Costs	$4,300,000	$380,000
Fuel Savings from CHP	$2,940,000	$259,000
Generation Capacity Cost Savings	$2,310,000	$203,000
Distribution Capacity Cost Savings	$828,000	$73,000
Reliability Improvements	$290,000	$25,600
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$2,240	$197
Avoided Emissions Damages	$5,790,000	$378,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$16,500,000**	
Net Benefits	**-$3,450,000**	
Benefit/Cost Ratio	**0.8**	
Internal Rate of Return	**0.2%**	

APPENDIX A – BENEFIT-COST ANALYSIS SUMMARY REPORT

Site 54 – City of Schenectady

PROJECT OVERVIEW

As part of NYSERDA's NY Prize community microgrid competition, the City of Schenectady has proposed development of a microgrid that would serve two major commercial facilities prominent in the community:

- **Proctors Arts Complex**: The Proctors Arts Complex centers on a restored vaudeville playhouse that now features large-screen movies and live entertainment in three separate theater venues. Adjoining buildings house commercial tenants; non-profit organizations; the community television station; and Marquee Power, a central heating plant that serves the Arts Complex and several adjacent hotels and commercial spaces.[1]

- **Center City**: Center City is a mixed-use building complex featuring a pharmacy; a satellite campus of Schenectady Community College; technology and engineering companies; a health club; a bank; other professional offices; and a restaurant. Center City is located adjacent to the Proctors Arts Complex and is one of the facilities served by Marquee Power.

The project team notes that its long-term plan is to expand the proposed microgrid to serve the City of Schenectady City Hall, police headquarters, and library. This analysis focuses on the initial phase of the project, the scope of which is limited to the arts complex and Center City.

This microgrid builds upon the existing thermal loop between Proctors and Center City. Proctors currently has four natural gas-fueled microturbines (Capstone C65s) that have never been used. The proposed microgrid would add another two MW of CHP capability to the idle capacity at Proctors, paired with a 250-ton indirect-fired absorption chiller and cooling tower to allow for summertime use of the CHP heat. The microgrid would also feature solar generation capacity, primarily through leased PV equipment installed at Proctors; this equipment would have a nameplate capacity of 0.55 MW. Existing backup generators at Center City (natural gas, 0.15 MW) and Proctors (diesel, 0.25 MW) would supplement the microgrid's capacity.

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.

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[1] Information obtained online at https://en.wikipedia.org/wiki/Proctor%27s_Theatre_(Schenectady,_New_York) and http://www.proctors.org/ , on February 23, 2016.

- *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.[2] 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.

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[2] 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.]

The BCA considers costs and benefits for two scenarios:

- Scenario 1: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).
- Scenario 2: The average annual duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under Scenario 1.[3]

RESULTS

Table 1 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results suggest that if no major power outages occur over the microgrid's assumed 20-year operating life, the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to exceed approximately 1.1 days per year (Scenario 2). The discussion that follows provides additional detail on the findings for these two scenarios.

Table 1. BCA Results (Assuming 7 Percent Discount Rate)

	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
ECONOMIC MEASURE	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 1.1 DAYS/YEAR
Net Benefits - Present Value	-$3,450,000	$185,000
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	0.2%	6.4%

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

Scenario 1

Figure 1 and Table 2 present the detailed results of the Scenario 1 analysis.

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

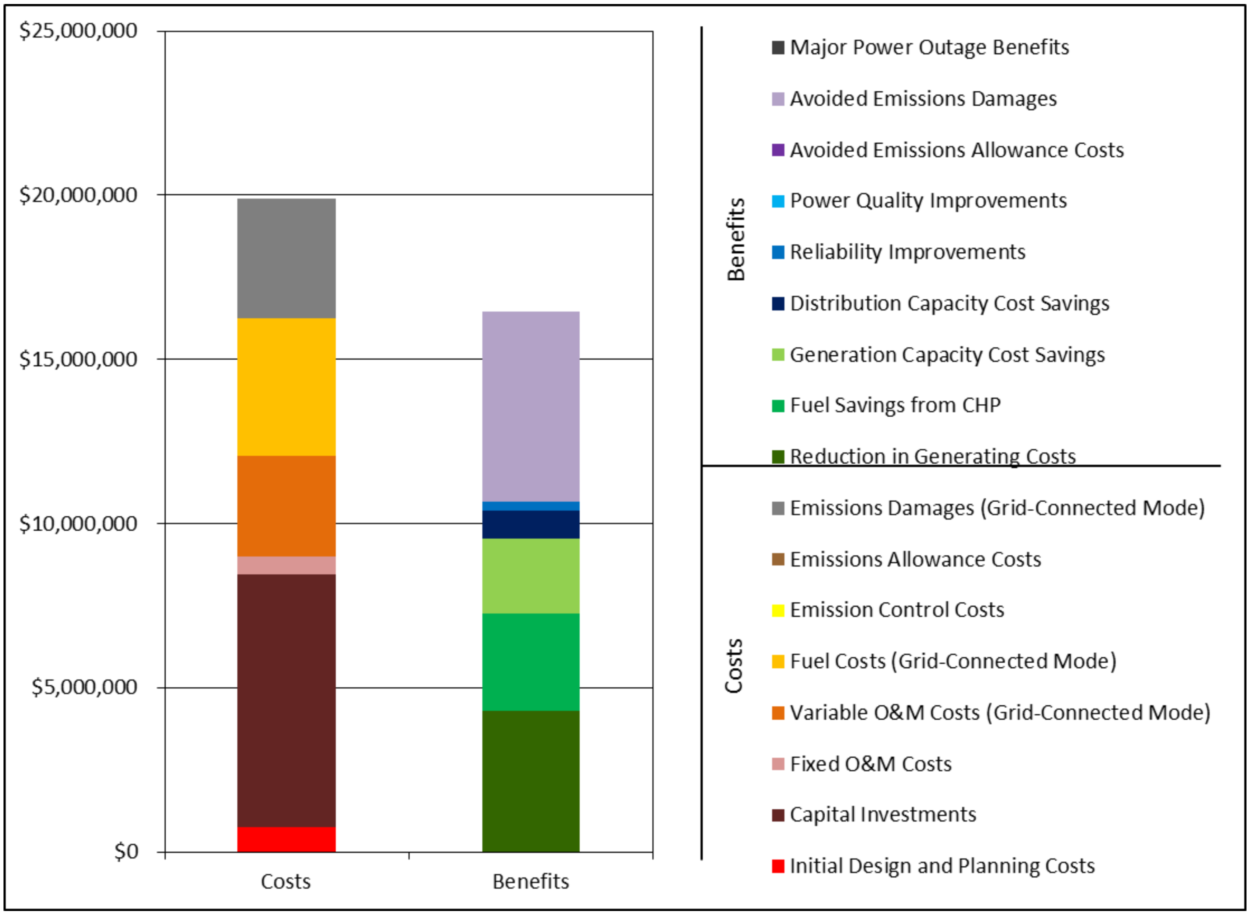

Table 2. Detailed BCA Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$740,000	$65,300
Capital Investments	$7,730,000	$670,000
Fixed O&M	$538,000	$47,500
Variable O&M (Grid-Connected Mode)	$3,060,000	$270,000
Fuel (Grid-Connected Mode)	$4,190,000	$370,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,640,000	$238,000
Total Costs	**$19,900,000**	
Benefits		
Reduction in Generating Costs	$4,300,000	$380,000
Fuel Savings from CHP	$2,940,000	$259,000
Generation Capacity Cost Savings	$2,310,000	$203,000
Distribution Capacity Cost Savings	$828,000	$73,000
Reliability Improvements	$290,000	$25,600
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$2,240	$197
Avoided Emissions Damages	$5,790,000	$378,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$16,500,000**	
Net Benefits	**-$3,450,000**	
Benefit/Cost Ratio	**0.8**	
Internal Rate of Return	**0.2%**	

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 $740,000. The present value of the project's capital costs is estimated at approximately $7.7 million. These costs are dominated by the two one-megawatt Ener-g CHP units that would supply the majority of the microgrid's production; these units account for roughly 65 percent of all capital costs. Other major capital cost elements include the absorption chiller for the CHP system; the underground power lines connecting Proctors to Center City; and the microgrid control and communication system.

In addition, the analysis incorporates an estimate of the capital cost associated with PV equipment. The project team indicated that the PV equipment would be leased at zero out-of-pocket cost. While a zero-cost lease is relevant when assessing the financial viability of the microgrid, the current analysis focuses on societal benefits and costs. Since the PV equipment is an element of the project, its capital costs are included. The analysis estimates these costs based on a survey of NYSERDA's 2014-2015 costs for small, non-residential solar projects in upstate New York; this study suggests a value of $2.70 per watt. Applied to the nameplate capacity of the two proposed solar units, this figure yields a total capital cost estimate of approximately $1.5 million. The analysis assumes a 25-year lifespan for this equipment.[4]

Finally, 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 $538,000, or $47,500 annually.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas and diesel fuel. 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.[5] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $4.2 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 $3.1 million.

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 fuel-based generators are estimated at approximately $238,000 annually. These damages are primarily attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $3.6 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 $4.3 million. Cost savings would also result from fuel savings due to the combined heat and power systems. The BCA estimates the present value of fuel savings over the 20-year operating period to be approximately $2.9 million. These reductions in demand for electricity

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[4] Excluding the capital costs of the PV equipment would raise Scenario 1's benefit-cost ratio to 0.9; hence, the inclusion of the costs has only a modest impact on the overall conclusions of the analysis.

[5] 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.

from bulk energy suppliers and heating fuel would also avoid emissions of CO_2, SO_2, NO_x, and particulate matter, yielding avoided emissions damages with a present value of approximately $5.8 million.[6]

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.[7] The analysis estimates the impact on available generating capacity to be approximately 2.41 MW per year, based primarily on estimates of output from the new CHP units. In addition, the project team expects development of the microgrid to reduce the conventional grid's demand for generating capacity by an additional 0.3 MW as a result of new demand response capabilities.[8] Based on these figures, the BCA estimates the present value of the project's generating capacity benefits to be approximately $2.3 million over a 20-year operating period. The present value of the project's potential distribution capacity benefits is estimated to be approximately $828,000.

The project team has indicated that the proposed microgrid would be designed to provide ancillary services, in the form of frequency regulation, reactive power support, and black start support, to the New York Independent System Operator (NYISO). Whether NYISO would select the project to provide these services depends on NYISO's requirements and the ability of the project to provide support at a cost lower than that of alternative sources. Based on discussions with NYISO, it is our understanding that the 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 $26,000 per year, with a present value of $290,000 over a 20-year operating period. This estimate is calculated using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[9]

- System Average Interruption Frequency Index (SAIFI) – 0.96 events per year.

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[6] 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.

[7] 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.

[8] The project team designated an additional 0.39 MW to demand response based on output from the new CHP units at Proctors. However, since production from these units was already designated for peak load support, the analysis excludes them from demand response.

[9] www.icecalculator.com.

- Customer Average Interruption Duration Index (CAIDI) – 116.4 minutes.[10]

The estimate takes into account the number of small and large commercial or industrial customers the project would serve; the distribution of these customers by economic sector; average annual electricity usage per customer, as provided by the project team; and the prevalence of backup generation among these customers. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.[11] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

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

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.8; i.e., the estimate of project benefits is about 80 percent 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

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.[12,13]

As noted above, the microgrid project would serve two major facilities: the Proctors Art Complex and Center City, both of which house multiple tenants. The project's consultants indicate that at present, both

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[10] SAIFI and CAIDI values were provided by the project team for National Grid.

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

[12] 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.

[13] 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.

facilities have modest backup generation capability. Proctors has a 0.25 MW diesel generator, while Center City has a 0.15 MW natural gas generator. At Proctors, however, the backup generation is only sufficient to provide 10 percent of the normal level of service; likewise, backup generation would allow Center City to maintain only 20 percent of its normal level of service. Should the backup generator units fail, the team indicates that both facilities would rent portable generators, each at a cost of approximately $1,700 per day. In the absence of backup power – i.e., if the backup generator failed and no replacement was available – both facilities would experience a total loss in service capabilities.

For the Schenectady microgrid, the primary economic consequences of a major power outage depend on the value of the services the facilities of interest provide. For both Proctors and Center City, the analysis values a loss of service based on an estimate of the cost of power interruption at large commercial and industrial facilities using the Department of Energy's ICE Calculator. Consistent with the information provided by the project team, the analysis assumes that both facilities require a full 24 hours of service per day. The ICE Calculator estimates a total value of service of $139,000 per day for Proctors and $189,000 per day for Center City.

Two other options for valuing services exist:

- First, in characterizing the potential costs incurred during a total loss of power, the consultant estimated a revenue loss of $200,000 per day on days when Proctors is screening a film, and $250,000 in lost revenue per day for Center City. Note that these figures are reasonably consistent with the ICE Calculator estimates. However, simple revenue losses are likely to overstate economic welfare losses, making them less accurate in the context of the benefit-cost analysis.
- Second, the project consultant notes that if the Red Cross requested use of either facility as an emergency shelter, that request would be granted. The consultant estimates that together, the facilities would house approximately 2,000 people. Applying standard Red Cross estimates of $50 per day per person suggests a value of service $100,000 per day for both facilities combined. This figure likely understates the losses that would be incurred in routine power outages.

Overall, the ICE Calculator estimates appear to be the most analytically appropriate. Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage is approximately $292,000 per day.

Summary

Figure 2 and Table 3 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 1.1 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 2. Present Value Results, Scenario 2 (Major Power Outages Averaging 1.1 Days/Year; 7 Percent Discount Rate)

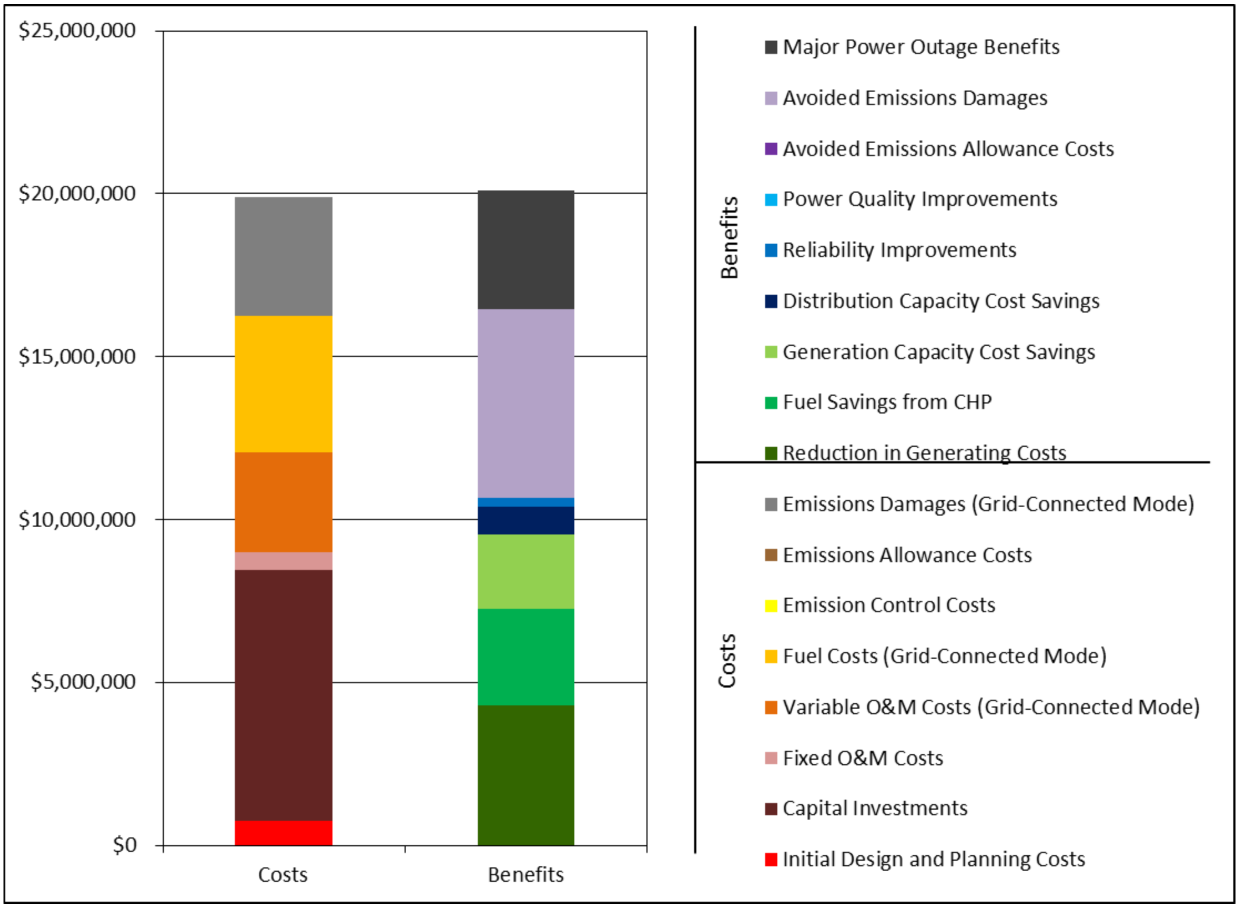

Table 3. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 1.1 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$740,000	$65,300
Capital Investments	$7,730,000	$670,000
Fixed O&M	$538,000	$47,500
Variable O&M (Grid-Connected Mode)	$3,060,000	$270,000
Fuel (Grid-Connected Mode)	$4,190,000	$370,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,640,000	$238,000
Total Costs	**$19,900,000**	
Benefits		
Reduction in Generating Costs	$4,300,000	$380,000
Fuel Savings from CHP	$2,940,000	$259,000
Generation Capacity Cost Savings	$2,310,000	$203,000
Distribution Capacity Cost Savings	$828,000	$73,000
Reliability Improvements	$290,000	$25,600
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$2,240	$197
Avoided Emissions Damages	$5,790,000	$378,000
Major Power Outage Benefits	$3,630,000	$321,000
Total Benefits	**$20,100,000**	
Net Benefits	**$185,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.4%**	

APPENDIX B - FACILITY QUESTIONNAIRE AND MICROGRID QUESTIONNAIRE

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: 54. City of Schenectady54. City of Schenectady

Point of contact for this questionnaire:

Name: Herbert Dwyer

Address: 950 Danby Road, Suite 100F, Ithaca, NY 14850

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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 outage.

   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.

   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	Fuel Consumption per Day		One-Time Operating Costs ($)	Ongoing Operating Costs ($/Day)
						Quantity	Unit		
Proctors	1	Diesel	.25	50	3	30.0	MMBtu/ day	150	35
Center City	2	Natural Gas	.15	95	3.4	46.6	MMBtu/ day	150	35

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.

A. Cost of Maintaining Service while Operating on Backup Power

3. Please provide information in the table below 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)

    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?
Proctors Complex	One-Time Measures	Turn on and check backup power, issue notifications, send non-essential personnel home	3,000	$	On loss of power any day
Proctors Complex	One-Time Measures	Hooking up and testing portable generator	1,000	$	Year round, every day
Proctors Complex	Ongoing Measures	Proctors emergency generator is only for lights and safety systems. Rental units would be bought to support shelter and lodging services, but probably not sufficient to support a show.	1,700	$/day	Daily during extended outage
Center City Complex	One-Time Measures	Hooking up and testing portable generator	1,000	$	Year round, every day
Center City Complex	One-Time Measures	Turn on and check backup power, notify multiple tenants, send non-essential personnel home.	5,000	$	On loss of power any day
Center City Complex	Ongoing Measures	Center City emergency generator can only supply a fraction of the emergency load. Rental units would be bought to support shelter and lodging services.	1,700	$/day	Daily during extended outage

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

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)

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?
Proctors Complex	One-Time Measures	Hooking up and testing a 500kW generator	1,000	$	Year round, every day
Proctors Complex	Ongoing Measures	Renting and operating a 500kW generator	1,700	$/day	Year round, every day
Center City Complex	One-Time Measures	Hooking up and testing a 500kW generator	1,000	$	Year round, every day
Center City Complex	Ongoing Measures	Rent, hook up, and test a 500kW generator	1,700	$/day	Year round, every day
Proctors Complex	Ongoing Measures	Lost revenue from the Theater and commercial tenants, rescheduling shows, issuing refunds, compensating performers	200,000	$/day	On days Proctors has a show which is most
Center City Complex	Ongoing Measures	Lost revenue to commercial tenants	250,000	$/day	Year round, every day

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)).

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

5. 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.
Center City	80%
Proctors	90%

6. During a power outage, <u>if backup generation is not available</u>, 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
Center City	100%
Proctors	100%

B. Questions for facilities that provide: Fire Services

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

N/A

8. Please estimate the <u>percent increase</u> in average response time for this facility during a power outage:

N/A

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

N/A

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

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

N/A

11. Is the area served by the facility primarily (check one):

☐ Urban

☐ Suburban

☐ Rural

☐ Wilderness

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

N/A

13. What is the distance (in miles) to the next nearest alternative EMS provider?

N/A

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

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

N/A

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

N/A

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

N/A

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

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

N/A

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

☐ Metropolitan Statistical Area

☐ Non-Metropolitan City

☐ Non-Metropolitan County

19. Please estimate:

a. The number of police officers working at the station under normal operations.

N/A

b. The number of police officers working at the station during a power outage.

N/A

c. The percent reduction in service effectiveness during an outage.

N/A

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

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

N/A

21. Does the facility support (check one):

☐ Residential customers

☐ Businesses

☐ Both

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

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

N/A

23. Does the facility support (check one):

☐ Residential customers

☐ Businesses

☐ Both

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

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

Proctors Theater and Center City are both designated Centers of Refuge. Proctors can provide shelter to 900 people and Center City can provide shelter for 1,100 people in the event of an emergency. This assumes that during an emergency the facilities would not function as they normally would.

25. 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).

None.

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: 54. City of Schenectady54. City of Schenectady

Point of contact for this questionnaire:

Name: Herbert Dwyer

Address: 950 Danby roads Suite 100F Ithaca NY 14850

Telephone: 607-330-1203

Email: herbert.dwyer@asienergy.com Name: Herbert Dwyer

Address: 950 Danby roads Suite 100F Ithaca NY 14850

Telephone: 607-330-1203

Email: herbert.dwyer@asienergy.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
Proctors Arts Complex and Marquee Power DES	Large Commercial/Industrial (>50 annual MWh)	Proctors Complex includes: Theater Auditorium, GE Theater, Arcade, Community TV Station, Music Store, Cafe, Admin Offices, office spaces, Key Hall banquet hall/special event space with full kitchen The Proctors Marquee Power District Energy System service includes: Proctors Arts Complex, TransFinder HQ, Subway Restaurant, Parker Inn, Hampton Inn, and Center City.	*All other industries*	2,542	.776	100%	24
Center City Complex	Large Commercial/Industrial (>50 annual MWh)	CVS Pharmacy, Schenectady County Community College Classrooms, Quirky, WiseLabs – Tech incubator, NBT Bank, Metroplex – County development authority, M/E Engineering Offices, YMCA (Designated Center of Refuge), Johnny's Italian restaurant, other offices	*All other industries*	5,186	1.517	100%	24

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
Existing Backup Generator	Proctors	*Diesel*	.25	0	0	10	MMBtu/MWh
Existing Backup Generator	Center City	*Natural Gas*	.15	0	0	13.6	MMBtu/MWh
4 x Capstone Microturbines	Proctors	*Natural Gas*	.26	292	1.2	11.4	MMBtu/MWh
CHP-1	Proctors	*Natural Gas*	1.0	2674	13.0	9.5	MMBtu/MWh
CHP-2	Proctors	*Natural Gas*	1.0	2674	13.0	9.5	MMBtu/MWh
Solar PV	Proctors rooftop and other locations	*Solar*	.550	950	3.3	N/A	None

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?
1 MW CHP-1	Proctors	1.000	☐ Yes
1 MW CHP-2	Proctors	1.000	☐ Yes
4 x 65 kW Microturbines	Proctors	0.260	☐ Yes
550 kW PV	Proctors and Elsewhere	0.150	☐ 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
Proctors CHP	.390	.140
Center City	.302	None

* Load curtailment plus existing backup generation.

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
N/A	MW/year

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

Impact of Microgrid on Utility Distribution Capacity	Unit
2	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
Project Management and admin	98,000	20	Turnkey install (design engineering not included)
Contract Admin and paperwork	13,000	20	Contracts, notices, PPAs
Construction Engineering	80,000	20	During build phase engineering consultation and support (submittals, RFIs)
Absorption Chiller 250T	300,000	20	Indirect fired absorption chiller
Motorized breakers x 2	40,000	20	Utility protection and island mode
Microgrid control and communications system	405,000	20	Controller, nodes, instrumentation, radios, switches, integration/configuration
2 x 1 MW CCHP engines	5,000,000	20	Supply, rig, pad, install, exhaust, duct, wire, breaching, etc.
Reinforce Proctors Roof to accommodate new machines	90,000	20	Swap membrance roof, put a super structure under the new machines.
UG Electric connection Proctors to Center City	150,000	20	Use existing conduit and vaults for new circuits
Software	6,000	20	Billing software
Natural gas work	18,000	20	Run to new CHP
Plumbing and electrical tie-ins and utility shut downs	12,000	20	Connections made to existing head end utility gas and electric
Sub metering equipment	30,000	20	Billing Proctors tenants and Center City

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?
740,000	Engineering analysis, engineering design, project management, permitting, initial interconnect, legal, meetings.

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?
$47,500	Yearly maintenance mostly associated with chemicals in water, absorption chiller purging and filling, chiller maintenance, exercising machines, engineering updates and issues, updating software licenses

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	N/A	N/A
2		

Year	Fixed O&M Cost ($)	What cost components are included in this figure?
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?
22	$/MWh$/MWh	Maintenance Contract for 4 x 65 kW microturbines
19	$/MWh$/MWh	Maintenance Contract for 2x 1 MW CHP

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
4 x 64 kW Microturbines	Proctors	Indefinitely	96 (for 7 days)	MMBtu
2 MW CHP	Proctors	Indefinitely	1729 (for 7 days)	MMBtu
550 kW PV	Proctors and Elsewhere	Indefinitely	N/A	N/A

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	37,950	MMBtu

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 ($)	Description of Component(s)	Component Lifespan(s) (round to nearest year)
Capital Costs ($)	0		
Annual O&M Costs ($/MWh)	0		▨
Other Annual Costs ($/Year)	0		▨

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	0.4966	Metric Tons/MWh
SO_2	0.0000	Metric Tons/MWh
NO_x	0.0007	Metric Tons/MWh
PM	0.0000	Metric 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. [22]

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[22] 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;

Estimated SAIFI	**Estimated CAIDI**
1.17	2.87

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.		

G. Other Information

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

This microgrid is using the existing thermal loop between Proctors and Center City and building upon it. There are 4 x Capstone C65s existing in Proctors that have never run. This project is to add another 2 megawatts of CHP to Proctors. Pair that with a 250 ton indirect fired absorption chiller and companion cooling tower to allow for summer time use of the CHP heat. National Grid is currently in a project with Proctors to swap out the NG network protection relays which prevent export power in the “other” direction. REV is currently underway and we believe we will be allowed to reverse-net-meter electricity upon REV’s final outcome. Those 2 assumptions, coupled with the energy savings of the CHP we believe to offset microgrid expenses, thus repaying loans

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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.

needed to expand this microgrid. We believe that we will be able to sell the thermal hot/chilled water and electricity created by the CCHP to Center City and Proctors tenants. Any remaining electricity would be net metered to National Grid or as very often we will have 1 megawatt over demand we can participate in the ISO and capacity markets. The yearly net profit from these operations should be about eight hundred thousand dollars to be used to pay the cost of installing the microgrid off. We are hoping to see a 7 year simple payback. The 5-year plan for this microgrid would be to connect the City of Schenectady City Hall, Police HQ, and the County owned Library. These facilities are located 2 blocks north east of the Center City complex. City Hall has aging infrastructure that needs replacement and this microgrid would be a fantastic what to offset those capital expenses. Currently we did not model this but could to show more benefit to this project. 50 ton indirect fired absorption chiller and companion cooling tower to allow for summer time use of the CHP heat. National Grid is currently in a project with Proctors to swap out the NG network protection relays which prevent export power in the “other” direction. REV is currently underway and we believe we will be allowed to reverse-net-meter electricity upon REV’s final outcome. Those 2 assumptions, coupled with the energy savings of the CHP we believe to offset microgrid expenses, thus repaying loans needed to expand this microgrid. We believe that we will be able to sell the thermal hot/chilled water and electricity created by the CCHP to Center City and Proctors tenants. Any remaining electricity would be net metered to National Grid or as very often we will have 1 megawatt over demand we can participate in the ISO and capacity markets. The yearly net profit from these operations should be about eight hundred thousand dollars to be used to pay the cost of installing the microgrid off. We are hoping to see a 7-year simple payback. The 5-year plan for this microgrid would be to connect the City of Schenectady City Hall, Police HQ, and the County owned Library. These facilities are located 2 blocks north east of the Center City complex. City Hall has aging infrastructure that needs replacement and this microgrid would be a fantastic what to offset those capital expenses. Currently we did not model this but could to show more benefit to this project. This microgrid is using the existing thermal loop between Proctors and Center City and building upon it. There are 4 x Capstone C65s existing in Proctors that have never run. This project is to add another 2 megawatts of CHP to Proctors. Pair that with a 2