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September 2016

Notice

NY Prize City of Binghamton Community Microgrid Stage 1 Feasibility Study

NYSERDA PROJECT #66639

Prepared for: **The City of Binghamton**

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GE Energy Consulting

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Foreword

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

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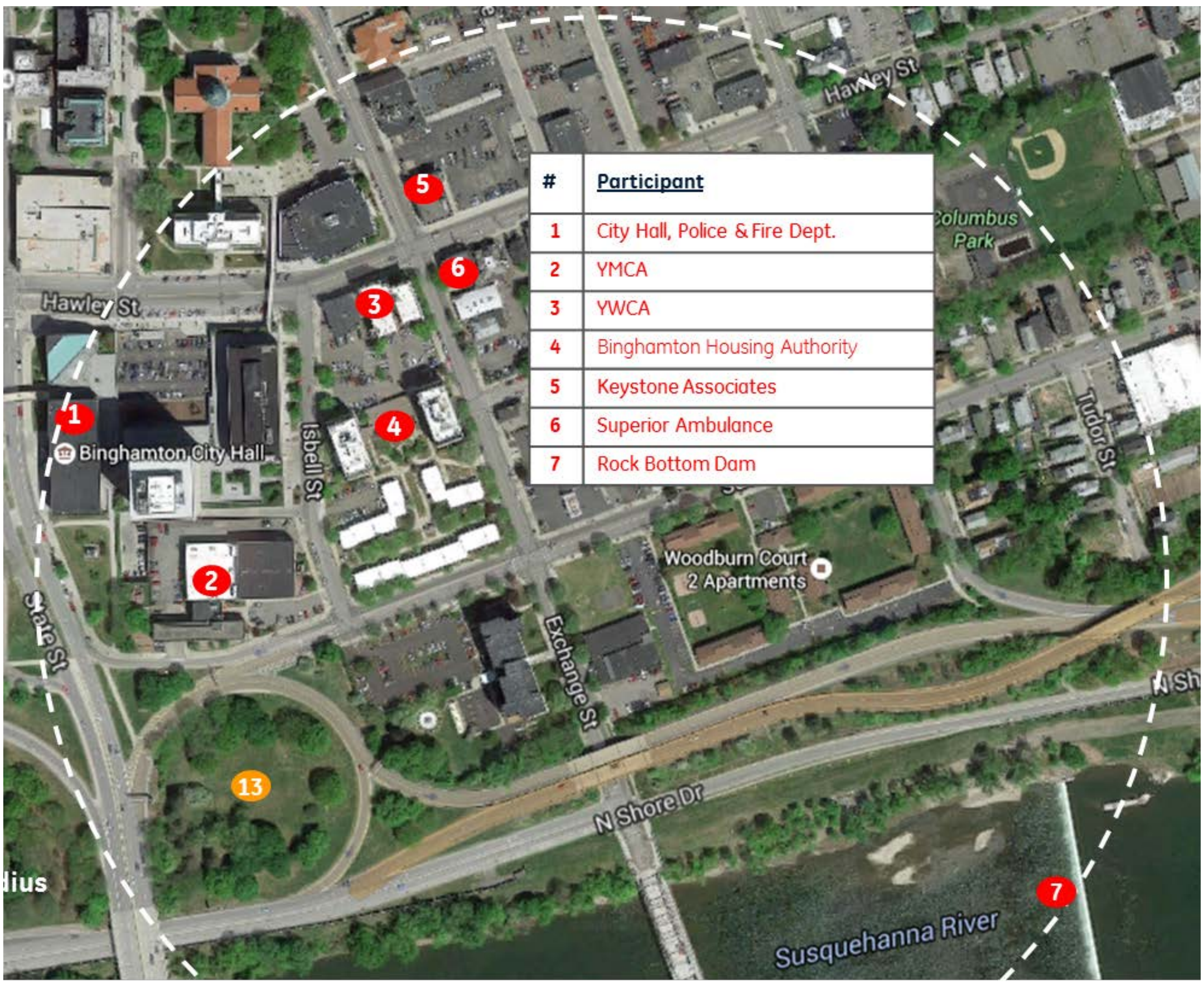
EXECUTIVE SUMMARY

This proposed City of Binghamton Community Microgrid will provide power to a number of critical and community support facilities which were affected during the two most recent major floods and allow them to maintain operations for an extended period of time. The design will greatly improve the resiliency of the surrounding area while significantly increasing the safety and well-being of residents, community organizations, public facilities and businesses in the City of Binghamton (COB).

The key stakeholders and critical facilities in the project include the City of Binghamton Police and Fire Departments, City Hall, the YMCA and YWCA, Binghamton Housing Authority (senior living apartments), Keystone Associates Architects, Engineers and Surveyors, LLC, an ambulance dispatch center, and the planned Rock Bottom Dam hydro generation facility. As shown below, these facilities are relatively near each other, clustered within a 1,000-foot radius circular area.



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

A key facility for the success of the project is the 1.95 MW hydro generation plant being planned at the Rock Bottom Dam location. This facility will be normally connected to the utility distribution system and sell power to the grid. During a grid outage precipitated by a wide-scale emergency, the facility will be connected directly to the microgrid to support the critical facilities.

Key features and benefits of the Binghamton microgrid include:

Leveraging of Clean Hydro Power: Small hydropower generation can make the power grid more resilient to climate change. When deployed with energy storage and smart grid technologies, locally-sized hydro systems can help utilities reduce or manage demand for grid-based electricity, introduce redundancy to back up the system and might be designed to keep power flowing to local users in the event of wider power interruptions.

Low Capital Expense: The proposed project includes significant enhancements to the distribution system while leveraging a significant generation source that will be externally financed, keeping capital costs extremely low while providing flexibility and a decreased risk of stranding assets.

Serves Critical Services and Facilities of Refuge: Critical loads supported during an outage include: multiple places of refuge such as the YMCA and YWCA; 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 Rock Bottom Dam facility by providing a business opportunity when the grid is down**.** The resiliency reserve mechanism is a business model option that will ensure that the capital costs of the T&D infrastructure investment required to construct the microgrid are allocated fairly between microgrid customers and non-microgrid customers.

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 Binghamton microgrid include design of rates that ensure utilities are compensated for operating costs - e.g., Active Network Management (ANM) costs - similarly to capital costs. Ancillary or grid-edge services could be an important feature of the microgrid. 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.

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

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

Findings

- Microgrids can support significant community services not related to typical energy supply and delivery services.
- Financial models exist and can be supported by these systems.
- Partnerships are necessary between utility, public, and private parties to make these systems achievable.
- Credit enhancements would assist microgrid's ability to access capital markets.
- Microgrids can provide platforms for implementing REV objectives, particularly the interface between the local balancing market and wholesale markets.
- Microgrids are a valuable test bed for implementation of NY REV LMP+D pricing schemes and DER market animation.

Recommendations

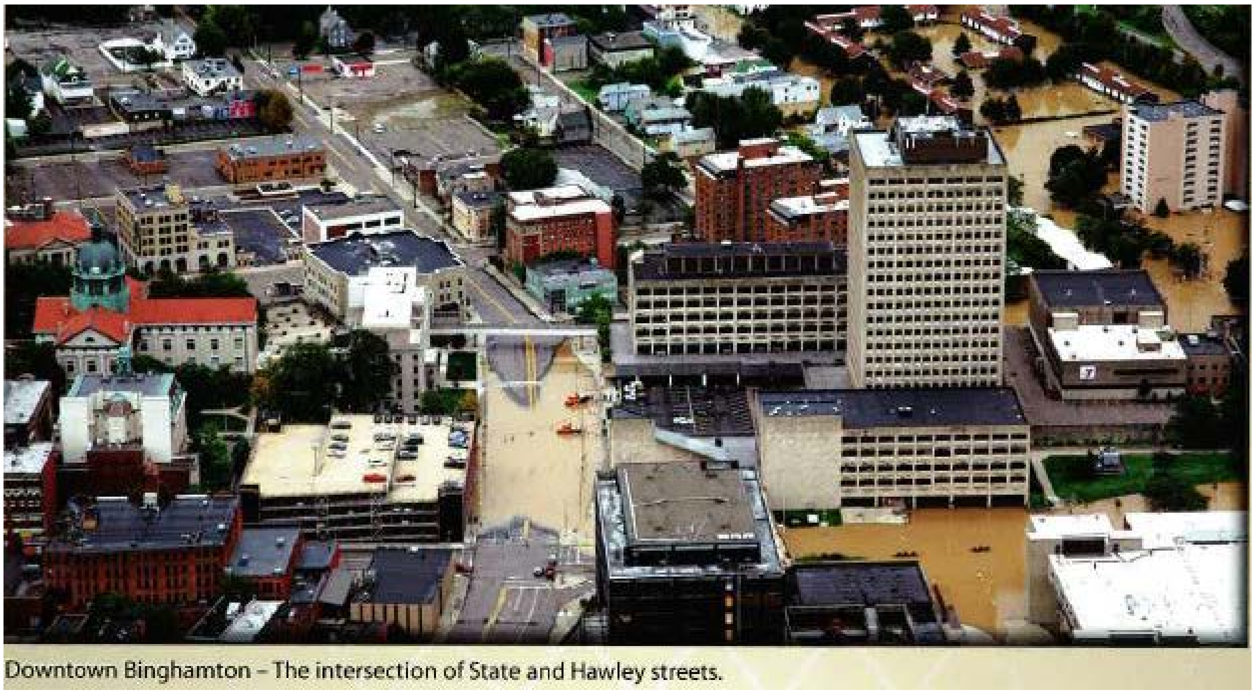
- Modification of incentives need to be developed to encourage utilities to favor capital investments over operating expenses.
- Regulatory framework is needed for defining and valuing grid-edge services.
- Resiliency should be recognized as a distinct service class.
- Service class rates should be developed for allocating infrastructure investments required for microgrid to customers equitably.

Design Overview

On September 7th of 2011, remnants of Tropical Storm Lee dropped between 8 and 12 inches of rainfall on the City of Binghamton. The combination of this heavy rainfall and the already saturated soil from Hurricane Irene caused record flooding of the Susquehanna River and its surrounding communities. The City of Binghamton's United States Geological Service ("USGS") river gauges recorded water levels as high as 17 feet above flood stage, topping the previous height record achieved in 2006. In Binghamton, 20,000 residents were ordered to evacuate their homes, and all roads in the City were closed to traffic. In Broome County alone, 6,000 homes were negatively affected, 2,365 were severely damaged, and 43 were completely destroyed. During this natural disaster, Binghamton University housed in its West Gym roughly 2,000 displaced people from within the community.

The photo below shows the aftermath of the flooding in the City in the area where the microgrid facilities are located. As seen in the photo, most of the downtown Binghamton area was underwater. The City, its businesses, public facilities and residents were all impacted by this natural disaster. Many individual residents as well as community-based housing organizations operated without water, electricity, heat and sewer services for weeks. The aftermath of this disaster still has negative impacts across major segments of the City.

The electric service in the area is via an underground secondary network that utilizes the City-owned conduit system. The local utility, New York State Electric and Gas (NYSEG) has stated that in recent storms, the network was largely energized but facilities were unable to receive power because service entrances were flooded. The microgrid will be designed to be resilient to major grid outages and shutdowns (such as those precipitated by flooding), as well as shorter blue-sky events. The new delivery infrastructure will be hardened (using submersible underground (UG) construction or selective overhead (OH) runs) and generation assets and service connections will be installed on elevated floors. The in-building circuit connections will be configured such that the microgrid generation can serve upper (livable) areas of facilities even if basements and ground-level areas are flooded. In the event of a flood basement levels could be de-energized and power maintained on the ground and upper floors, allowing the building to continue to operate as normal.



Flooding in Downtown Binghamton Community during Recent Storms

Summary of Facility Loads

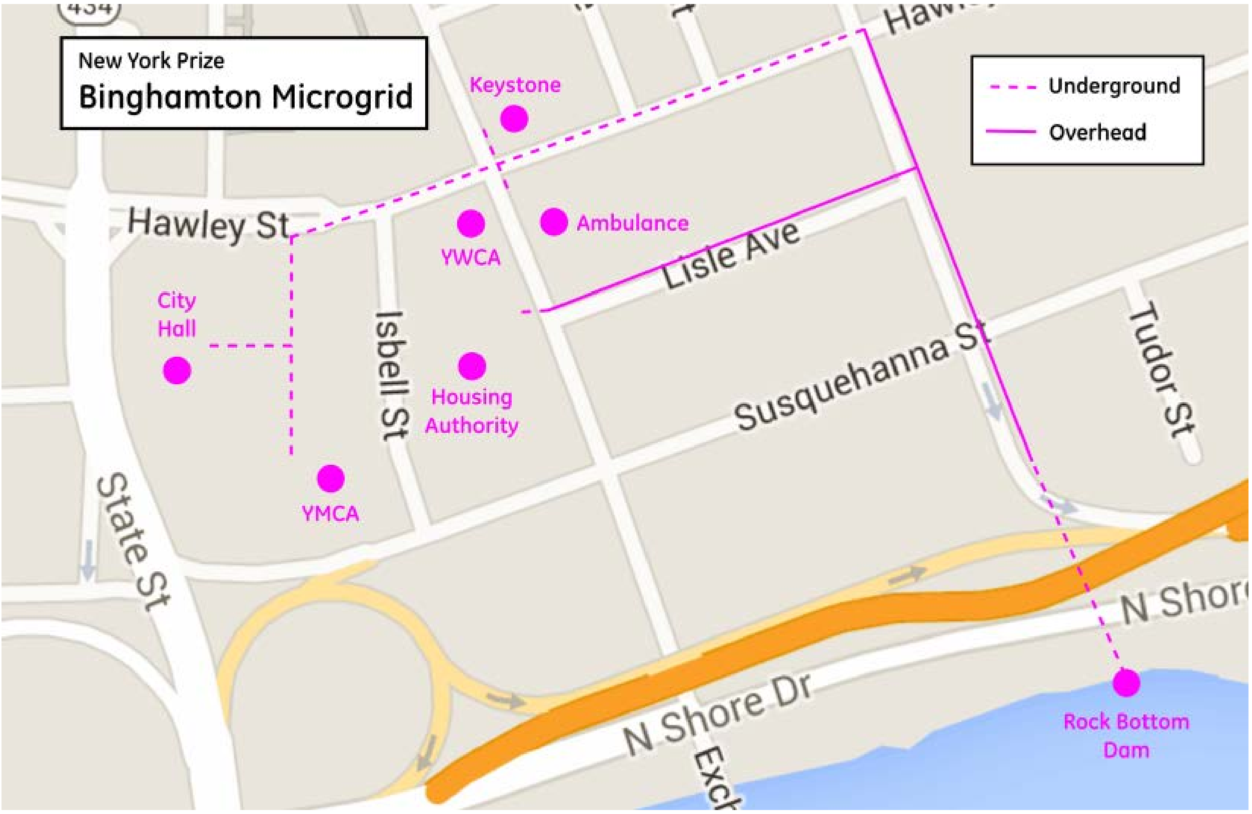
The following table lists the major facilities in the microgrid as well as the total yearly consumption and peak load for the facilities.

Summary of Binghamton Community Microgrid Loads

Facility Name	Address	Facility/Customer Description
City Hall, Police & Fire Departments	38 Hawley St	Administration, emergency management, life & safety
YMCA	61 Susquehanna St	Place of refuge, meal service
YWCA	80 Hawley St	Place of refuge, meal service
Binghamton Housing Authority	35 Exchange St	Low income and senior residences
Superior Ambulance	46 Exchange St	Emergency services
Keystone Associates	58 Exchange St	Engineering, construction, restoration services
TOTAL Microgrid Load: Yearly Energy 5,937 MWh; Yearly Peak 1.46 MW		

T&D Infrastructure

Most of the critical facilities proposed for the microgrid are served by an underground network feeder out of the Noyes Island substation. Some of the larger facilities are on dedicated vault-type transformers, while others are served off the 120/208 V street network. The close proximity of the facilities makes it possible to run new cable to interconnect the facilities through the City-owned conduit system. The proposed layout is shown in the schematic below. Only Rock Bottom Dam is connected to the overhead radial portion of NYSEG's distribution system to normally feed into the grid. Transfer switches are included in the design to move facilities from utility supply to the new microgrid infrastructure, and to connect Rock Bottom Dam to the microgrid during an emergency.

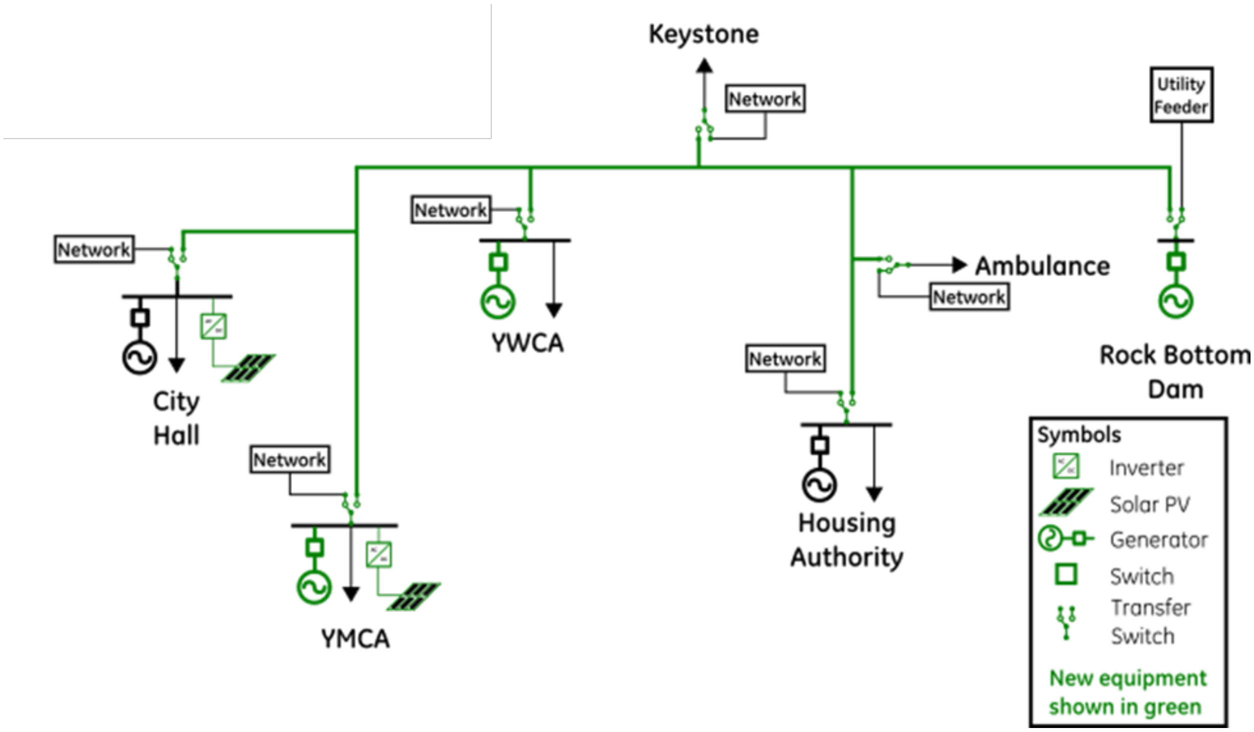


Map Showing Critical Facilities and Infrastructure for Binghamton Community Microgrid Project

Generation Resources

The proposed DERs and existing DERs that will be included in the microgrid are shown on the one-line diagram below. New equipment is shaded in green. These include a 200-kW reciprocating internal combustion engine (RICE) combined cooling, heating and power (CCHP) unit at the YMCA and two 50 kW micro-CHP units at the YWCA. 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 microgrid will also host a substantial amount of solar and hydro-based renewable resources. The principal renewable resource, and in fact, the principal emergency power resource of the microgrid is the Rock Bottom Dam Hydro with a maximum capacity of 1,950 kW. The solar resources include two sets of solar PV planned for the rooftop spaces of YMCA and the City Hall, totaling 280 kW of nameplate capacity.



Binghamton 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.

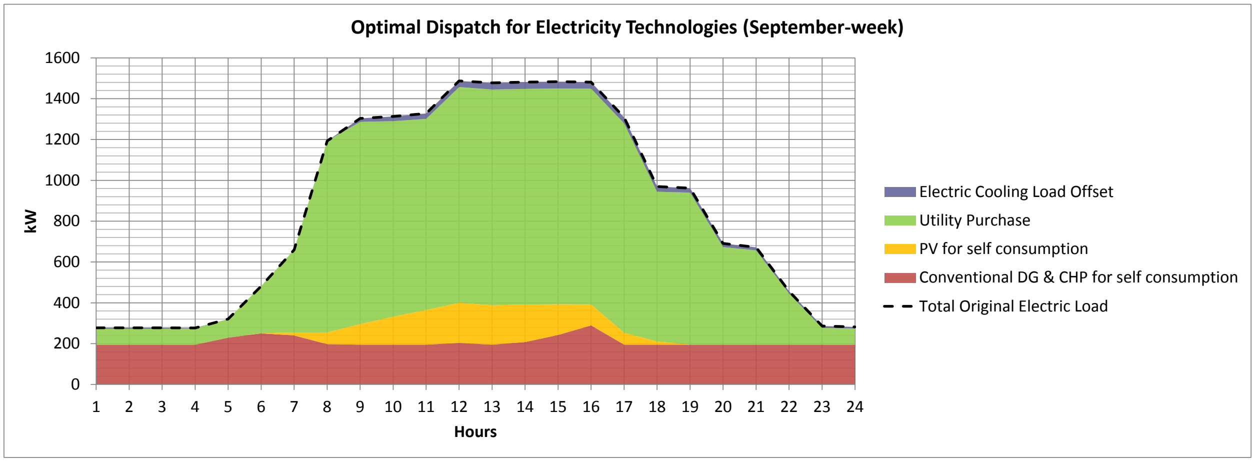
The control hierarchy will use the generation resources to maintain frequency and voltage in islanded mode. The CCHP units tend to be better suited to baseload operation than frequency control. For this reason, the majority of fast frequency regulation will come from the Rock Bottom Dam hydro unit and, if necessary, the natural gas standby generators. 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 in Stage 2, and the microgrid controller will manage assets in response to changing conditions.

Normal and Emergency Operations

Under normal conditions, the facilities that will be part of the microgrid are energized by NYSEG's distribution feeders. Rock Bottom Dam Hydro will potentially be connected to the NYSEG system via a medium voltage line along Carroll Street, and sell power to the main grid. The new 200 kW CCHP unit at YMCA, the new 50 kW micro-CHP units at YWCA, and the 280 kW of PV generation at City Hall and YMCA will generate power, allowing each facility to reduce peak demand and lower energy costs. Existing natural gas backup generation at Binghamton Housing Authority and City Hall are not expected to operate for any significant amount of time during normal conditions, but will be available to provide peak load support.

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 1.95 MW of generation from the Rock Bottom Dam Hydro unit that will be reconfigured to directly feed only the microgrid loads.

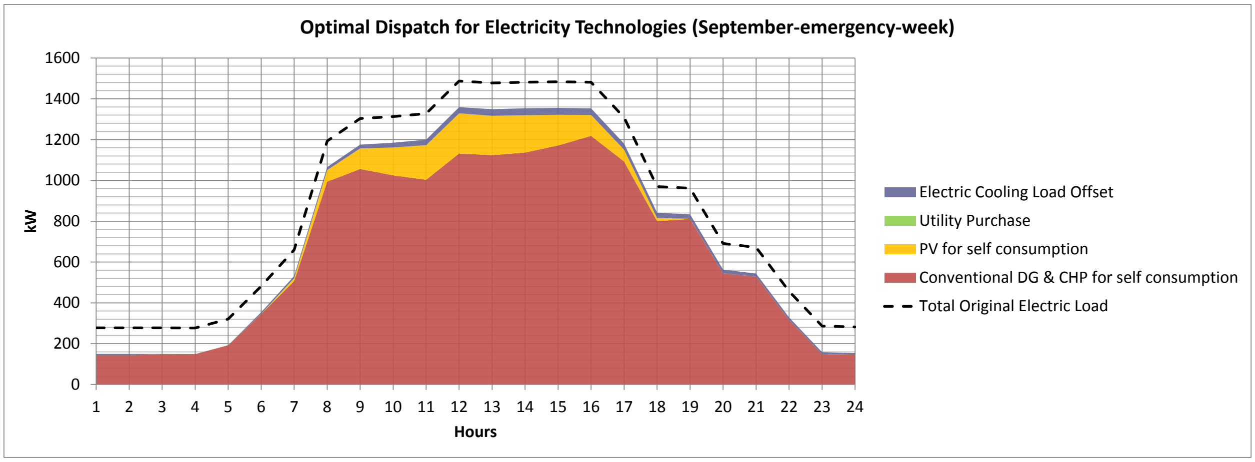
The figure below shows the load and supply balance over a weekday of operation on a normal day in September (which is the peak electrical load month based on the assumed load shapes).



Microgrid Dispatch to Meet Electrical Load – September Normal Weekday

The burgundy colored area represents the on-site generation by the microgrid CCHP units. The yellow colored area is the solar PV production. The green colored area is the additional electric energy purchased from the utility. The very narrow purple colored area at the top of the profile is the reduction in the original electrical load (i.e., the Electric Cooling Load Offset) 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.

By contrast, the figure below shows the microgrid operation during an emergency weekday in September (the month with the highest microgrid load based on the assumed load shape). As can be observed all microgrid load is met by on-site generation from Rock Bottom Dam, CCHP units and solar PV. It should be noted that due to their very small relative sizes, the solar PV and absorption chiller's cooling load offset are not discernable in the figure. The blank space between the dotted line at the top and the colored profile at is the reduction in energy consumption due to load curtailment.



Microgrid Dispatch to Meet Electrical Load – September Emergency Weekday

Microgrid Business Model

The City of Binghamton is considering a potential municipal bond offering to pay for all or a portion of the shared transmission and distribution (T&D) infrastructure required to construct the proposed Binghamton Community Microgrid project. Assuming the City issues bonds and uses the proceeds to construct the microgrid, the City of Binghamton would transfer title to and operating control over the shared T&D assets to a Special Purpose Vehicle (SPV) under a long-term lease agreement.

A subsidiary of the New York State Electric and Gas (NYSEG) would own a controlling equity stake in the SPV and would thus retain operating control over the microgrid's T&D infrastructure assets. Under the lease agreement, the SPV would maintain title to and operating control over the microgrid's T&D assets. Although the microgrid SPV would own the microgrid's T&D assets, it would not own the distributed energy resource (DER) assets connected to the microgrid. The DER assets would be owned and operated by customers and/or third parties.

The SPV would collect revenues from the following aspects of the microgrid's operations:

- Distribution network use of system (DNUoS): The microgrid's primary source of DNUoS revenues would be generated by bilateral supply contracts executed between microgrid customers but using the microgrid's T&D assets during normal operations.

- Resiliency reserve: An incentive mechanism that paid the microgrid owner a small-fixed fee for the total installed capacity connected to the microgrid and capability of operating during grid outages. Under the resiliency reserve incentive, the microgrid would also be eligible to earn performance-based payments for operating during grid outages or disruptions. The incentive would be collected by the local utility from non-microgrid customers that benefit from the microgrid during an outage.

- Wholesale capacity payments: microgrid owner could participate in wholesale capacity market on behalf of microgrid generator and receive either a portion of the proceeds from capacity payments or an administrative fee.

- Ancillary or grid-edge services: 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.

In addition to these revenue streams, the SPV would collect a resiliency surcharge from the microgrid customers which would be structured to avoid under or over-collection of revenues.

Benefit Costs Analysis

Industrial Economics, Incorporated (IEc) completed a benefit-cost analysis (BCA) 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 Binghamton Community Microgrid Project yields a benefit/cost ratio of 1.6 and an internal rate of return (IRR) of 28.4. The results indicate that *even if there were no major power outages* over the 20-year period analyzed (Scenario 1), the project's benefits would exceed its costs by roughly 60 percent. The complete IEc results are included in Appendix A.

The project team's best estimate of initial design and planning costs is approximately $550,000. The present value of the project's capital costs is estimated at approximately $5 million, including costs associated with: the total of 300 kW of new CHP 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 $626,000, or $55,200 per year.

Given the high rate of return and the significant BCA ratio, this project should be considered to be substantially financially viable, financeable, and could provide substantial benefits to the community.

Conclusion

The City of Binghamton has experienced significant growth in the years following the 2011 floods resulting from Hurricane Irene and Tropical Storm Lee. The original catalyst for this expansion was the construction of the SUNY Binghamton University Downtown Center in 2007. This development sparked a significant influx of student residents into the City. Today, in a combination of small, medium and large projects, more than 5,000 students now call downtown Binghamton their home. With these new residents came the demand for additional business services from restaurants to retail shops. Additionally, these added businesses have attracted more traffic and attention to the downtown area, which has in turn created a demand for market-rate/young-professional apartments in the Center City. Currently, there are more than one hundred of these market-rate apartment units in some stage of the planning process.

There are also other forms of development taking place in the City. The U.S. Department of Veterans Affairs plans to open a new, expanded outpatient clinic at 203 Court Street in Binghamton, replacing its existing clinic space in the Greater Binghamton Healthcare Center on Robinson Street. In addition, several industrial/manufacturing-type entities are considering moving into available sites in the City. The Broome County Industrial Development Authority, in conjunction with SUNY Binghamton University, is preparing to begin construction on a High Technology Industrial Incubator, and SUNY Broome is in the planning stages of developing a Downtown Hospitality/Hotel/Restaurant School in the vacant historic Carnegie Library building.

These developments have increased the potential for a repeat of the problems the City experienced during the past cycle of extreme weather events. This increased potential for natural disasters also increases the responsibility of all levels of Government to invest in the resources necessary to be able to prevent, mitigate and react to these events in the future. Thus, NY Prize represents an opportunity to design, develop and implement a downtown Binghamton Community Microgrid that will minimize the damages caused by these disasters and sustain the economic vitality of the downtown district. The project provides a significant opportunity to develop a replicable, scalable model that can be expanded in the region and duplicated in many New York-State communities with similar characteristics.

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1 DESCRIPTION OF MICROGRID CAPABILITIES

1.1 Minimum Required Capabilities

1.1.1 Critical Facilities

This proposed Binghamton Community Microgrid is a major opportunity for the City of Binghamton's critical facilities - which were severely impacted during the two most recent major floods - to maintain operations. It will greatly improve the resiliency of the City during another natural disaster event, while significantly increasing the safety and well-being of residents, community organizations, public facilities, and businesses in the City.

Key stakeholders and critical facility partners in the original proposal included the City of Binghamton Police and Fire Departments, City Hall and the Water Treatment Plant. The YMCA, YWCA, Holiday Inn, Binghamton Housing Authority (senior living apartments) and Newman Development Group, LLC's Twin River Commons (student apartments) also participated in initial discussions as possible generation sites and as places of refuge in the event of natural disasters. Kradjian Properties and Keystone Associates Architects, Engineers and Surveyors, LLC, two Downtown Binghamton office complexes, were also part of the initial microgrid discussions. The original critical facilities are shown on the map in Figure 1-1 below and also listed in Table 1-1.

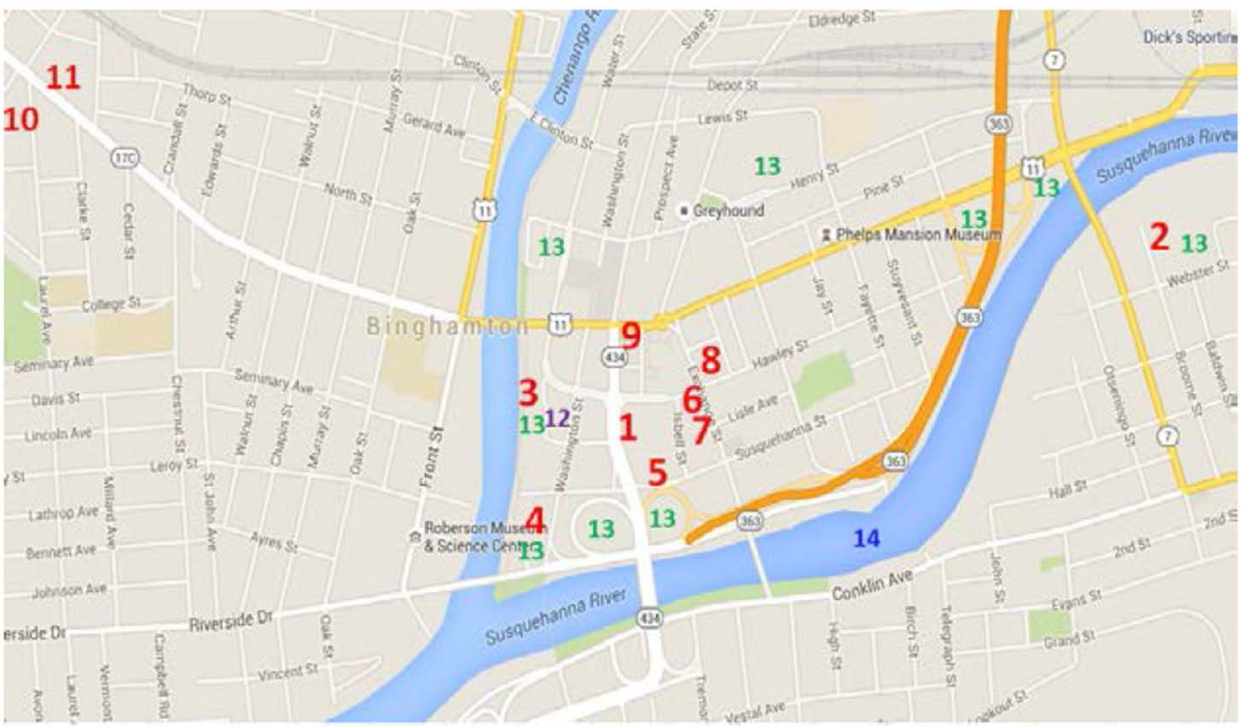

Figure 1-1 Map Showing Original Proposed Critical Facilities for Binghamton Project

Table 1-1: Listing of Original Critical Facilities Considered for the Binghamton Project

City of Binghamton Microgrid				
Map #	**Participant**	**Address**	**Municipality**	**Generation Source**
1	City Hall, Police & Fire Departments	38 Hawley St. Binghamton, NY 13901	City of Binghamton	Solar/ Battery / CCHP
2	Binghamton Water & Sewer Services	25 Broome St. Binghamton, NY 13903	City of Binghamton	Solar / Battery
3	Holiday Inn	2 Hawley St. Binghamton, NY 13901	City of Binghamton	CCHP
4	Twin River Commons	45 Washington St. Binghamton, NY 13901	City of Binghamton	Solar / Battery with existing heat pumps
5	YMCA	61 Susquehanna St. Binghamton, NY 13901	City of Binghamton	CCHP
6	YWCA	80 Hawley St. Binghamton, NY 13901	City of Binghamton	CCHP
7	Binghamton Housing Authority	35 Exchange St. Binghamton, NY 13901	City of Binghamton	CCHP
8	Keystone Associates	58 Exchange St. Binghamton, NY 13901	City of Binghamton	Solar/ Battery / CCHP
9	Kradjian Properties	84 Court St. Binghamton, NY 13901	City of Binghamton	Solar/ Battery / CCHP
10	Bates Troy	177 Main St. Binghamton, NY 13905	City of Binghamton	Current 400KW CHP
11	Binghamton Fire Station	182 Main St. Binghamton, NY 13905	City of Binghamton	CCHP
12	Electric car charging station	2 Hawley St. Binghamton, NY 13901	City of Binghamton	Solar / CCHP
13	Rooftop, ground mount, parking canopy	Approx. 13 Acre total	City of Binghamton	Solar
14	Rock Bottom Dam	Approx. 1.5MW Capable	City of Binghamton	Hydro

The relatively long distances between participating facilities and anticipated difficulties crossing the Susquehanna River and the Chenango River (electrically) are expected to present a challenge to microgrid network integration in Stage 2, and could therefore create a barrier to the project implementation in Stage 3. Consequently, in Task 1, the team decided to focus the microgrid project around the cluster of facilities between the two rivers, north of the confluence point. This excluded #2 (Binghamton Water & Sewer Services), #10 (Bates Troy), and #11 (Binghamton Fire Station). All the remaining facilities were within a 1000-foot radius of City Hall (#1 on the map). The core facilities that were down-selected for the microgrid concept in Task 1 are shown in Figure 1-2 below, along with possible sites for solar PV.

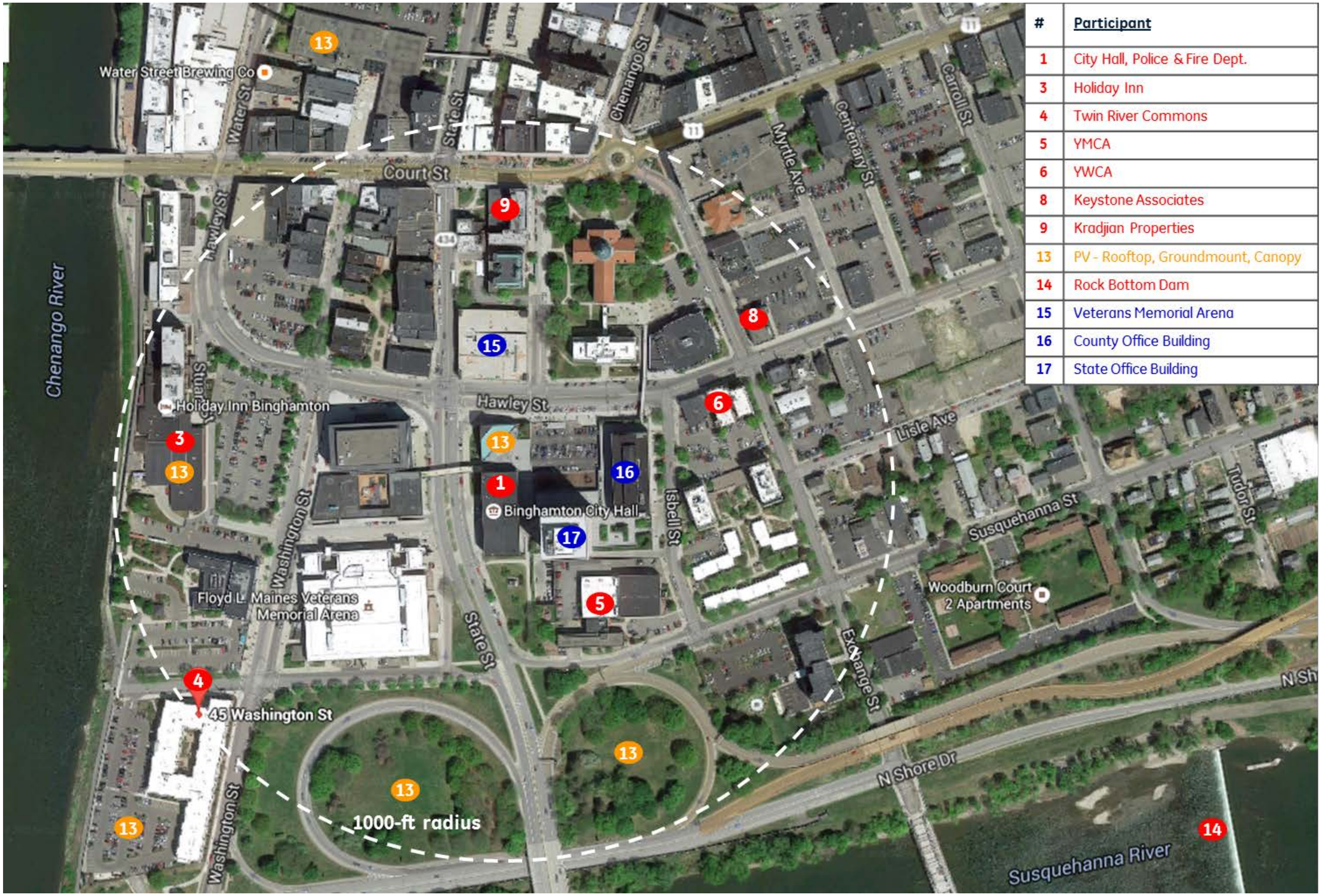

Figure 1-2: Map Showing Critical Facilities Down-Selected for Binghamton Project Located Between the Two Rivers

During Task 1, three additional facilities with existing generation were considered for inclusion. They are indicated by blue dots on the map in Figure 1-2: Floyd L. Maines Veterans Memorial Arena at 1 Stuart Street (#15 on the map); County Office Building at 60 Hawley Street (#16); and State Office Building at 44 Hawley Street (#17). However, due to time constraints, the Team has decided to not include these facilities in the Stage 1 analysis, and to seek opportunities to incorporate them at a later stage.

A key input in the decision-making process was the configuration of the existing electrical infrastructure connecting the facilities. The Team was aware that some of the facilities are served via an underground secondary network (street and spot) while some are on radial overhead lines. The mix of electric service types among the critical facilities impacted the microgrid configuration, and further excluded some facilities shown in Figure 1-2 during the Task 2 analysis, as will be described later. In addition, new facilities were added in Task 2 based on the ease of interconnection. This is further described in Section 2.2.

1.1.2 Primary Generation Source

The Team considered a number of generation and storage technologies for the proposed microgrid project. Table 1-1 lists some of the technologies that were considered at each of the original facilities. The Task 2 analysis specified the type and amount of additional generation resources for the microgrid in Section 2.3.1.

New generation sources were added to the microgrid at various sites. Some of the considerations and outcomes of the analyses are described below.

- Natural Gas-fired CCHP units were considered and proposed for YMCA (#5 on the map) and YWCA (#6 on the map). During blue-sky conditions, the co-gen units will provide hot water and thermal-driven cooling, while reducing kW demand and kWh energy usage. During emergency grid events, the CCHP will provide heat and electricity for the host sites, with a portion of their electricity production allocated to maintain the City's Fire and Police operations through the crisis. These safety and emergency services are centrally located to the facilities where the CCHP units are being considered to allow for efficient distribution of electric power to these critical facilities. The general configuration of the power delivery infrastructure is described in Section 2.1.1.
- About 2 MW of Community Solar PV can be installed on 13 acres of open space, rooftops and parking lot canopies in the downtown area. Potential locations were identified and are shown on Figure 1-1. Figure 1-2 shows the locations that are near the critical facilities between the rivers. These locations alone have a potential of about 1 MW. During task 2, solar PV production was limited to 280 kW on the rooftops of City Hall and the YMCA
- Electric Vehicles charged by Combined Solar-Energy Storage Systems to systematically replace the 385 vehicles in the City's aging fleet that cost over $700,000 in fuel in 2014. With the City as an "anchor tenant," the goal is to begin to electrify the local transportation system with solar-powered EV charging stations. The first commercial market analysis will also explore electric-vehicle commuting models that will initiate the City's EV market with faculty and students traveling between downtown and the main SUNY Binghamton Campus - where 1/3 of the carbon emissions are from vehicles. This option was not pursued in Stage 1 due to the reduced configuration, but it will be discussed in Stage 2.
- Energy-efficiency and demand-reduction technologies were evaluated at each participant's site. These include LED lighting, motors, and HVAC upgrades including thermal cooling, as well as air

and ground source heat pumps. The City also has a number of energy efficiency initiatives at City Hall and elsewhere that will be explored in Stage 2.

- An evaluation was performed to determine the cost effectiveness of converting the Rock Bottom Dam to a micro hydro generating station for about 2 MW of base load generation for the microgrid facilities. This is the major source of generation for the proposed microgrid during a grid emergency.
- Absorption Chillers that will use CCHP-produced steam and hot water during the cooling season to drive the air conditioning in buildings, while consuming a small amount of electricity to run the circulation pumps. Absorption chillers allow CCHP to be used to provide a year-round thermal source for hot water as well as heat and air conditioning. The proposed CCHP systems at YMCA and YWCA are paired with absorption chillers improve overall efficiency and reduce the electrical load on the facilities.

The existing aggregate 250-kW standby gas engine at City Hall will remain in-place to back up individual facilities in the event of a microgrid failure. In addition, BHA (which was later added to the project) has a 205 kW natural gas standby generator. These machines will be evaluated for their potential to provide load following and black-start services in Stage 2.

1.1.3 Operational Variability

The inclusion of a micro-hydro facility at Rock Bottom Dam improves the economic prospects of the microgrid. During normal operation, the electricity produced by the plant will be exported to the larger grid. CHP units at the YMCA and YWCA run for most of the year and generate electricity that will offset the demand of those facilities, and possibly supply other facilities in the microgrid (in addition to thermal energy). The Solar PV resources produce as much power as possible (given irradiance) and feed into the connected loads. Curtailment of PV resources is not anticipated during connected mode. City Hall and YMCA are both on spot networks, but they are connected electrically. Considering the limited size of the PV and the combined load of both facilities, the risk of backfeed is judged to be minimal. However, the power flow in the network at the POIs will be monitored and controlled by the microgrid controller to ensure that network protectors do not trip on reverse flow.

In islanded mode, the same generation sources are expected to be available to support the microgrid load. The CHP units and/or the Rock Bottom Dam micro-hydro unit are expected to provide a strong voltage reference that would allow the PV inverters to function in islanded mode. To avoid a collapse of the island: some generators would switch from baseload to frequency control; some voltage regulators would switch from power factor control to bus voltage regulation; and excess (curtailable) load would 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. This would require appropriate sensors to monitor electric properties (voltage, phase angle, frequency, and real and reactive power flow) at the points of interconnection (POI). This capability can also be used in connected mode to modify generation and load in a feedback loop to prevent backfeed. In addition, the CHP units will incorporate microprocessor-based Intertie protection relays (such as Beckwith 3520 or 3410) with synch check, undervoltage functions, and the ability to mitigate backfeed by modulating output.

A number of commercial microgrid control system platforms are available as candidate solutions, in addition to advanced control systems being developed by GE, 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 NYSEG 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 Binghamton is provided in Section 2.5.

1.1.4 Intentional **Islanding**

Islanding is the situation where distributed energy resources continue 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. Without active voltage and frequency regulation controls providing stabilization, an island is not likely to remain in continuous operation for long. The Team considered switching technologies (transfer switches and isolation switches) that would allow the microgrid to seamlessly and quickly transition to islanded mode, and also incorporated 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 microgrid concept includes several points of interconnection with the main grid, spot networks and the street grid. After reviewing infrastructure details and discussing with NYSEG, the Team minimized the number of connection points so as to make transition manageable. When the points of connection to the main grid are severed via transfer switches and/or isolation switches, 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 of the machines will operate as base load generation (such as the CHP units and Rock Bottom Dam micro-hydro), and others (like the gas engines at City Hall and BHA) 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. The team will study this further in Stage 2, but if the CHP units and Rock Bottom Dam operate as base load during normal operation, this might not be a significant issue.

1.1.5 Automated Separation from Grid

As currently configured, the Binghamton microgrid will have several 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. This could include switching operations to redirect Rock Bottom Dam generation toward only the microgrid facilities, switching non-critical loads off (where it makes sense) and isolating portions of the network that do not serve critical loads.

The steps for transition are generally described later in Section 2.1.2. The design includes power and communication equipment necessary to facilitate the transition.

1.1.6 Renewable Options and Requirement for Scheduled Maintenance

The Team explored the possibility of installing ground-mount, roof-top, and parking lot canopy PV at various locations within the microgrid footprint. These potential locations were identified in Figure 1-2, and total about 1 MW in aggregate within the circle, and 2 MW in the larger area. In subsequent analysis during Task 2, the amount of PV was reduced to 280 kV on rooftops of City Hall and the YMCA. This PV capacity 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. As mentioned earlier, some of the installed backup gas engines could be well suited for load-following. In addition, hydro units tend to have extremely good ramp and range capability. The proposed 1.95 MW micro-hydro at Rock Bottom Dam would be able to follow load and mitigate aggregate PV variability if needed. Energy storage was considered as an option for accommodating high penetration of renewables. However, considering the economics of storage in this size range, the Team elected to focus on other options such as controllable loads and flexible generation before recommending batteries. The project also includes sufficient base load resources from Rock Bottom Dam, and proposed CHP units to ensure that the system can provide reliable output on a 24/7 basis.

Some of the facilities such as City Hall, have dedicated operations and maintenance personnel, and documented procedures to keep their thermal and electrical systems running. Proposed CHP units will be on a contracted 5-year manufacturer's maintenance plan. The maintenance plan will adhere to and comply with manufacturer's requirements for scheduled maintenance intervals for all generation in the microgrid. In Stage 2, the Team may 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. Longer duration maintenance 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 in the microgrid includes a 250 kW back up gas engine at City Hall and a 205-kW gas engine at BHA. Additional fossil-fueled co-generation resources are proposed at the YMCA and the YWCA. In addition, there is a micro-hydro unit planned at Rock Bottom Dam, as well as about 280 kW of rooftop solar PV. The ultimate determination of "how much and where" was made during the load and supply analysis described in Section 2.3.

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 base load 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). To avoid a collapse of the island, some generators would switch from base load to frequency control; some voltage regulators would switch from power factor control to bus voltage regulation; and excess loads should 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 further explored these operational issues in the Task 2 analysis.

1.1.8 Two-Way Communication

The existing building automated system at City Hall was considered for integration in the microgrid control system. The facility has a Siemens SCADA system to that can control building-wide heating and cooling systems. 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 (or lack thereof) was identified the Team recommended 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 resulting from 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 most-costly option. 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. 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 Customer Type Connectivity

The proposed microgrid will serve facilities identified in Figure 1-2 based on the cost of providing service, importance of providing power to the critical facility, and alternatives for connection to the microgrid. The

Team evaluated these considerations during subsequent tasks in the feasibility study. The short list of these facilities evaluated in Task 1 includes the following:

- Binghamton City Hall, Police & Fire Dept.; 38 Hawley St.
- Holiday Inn; 2 Hawley St.
- Twin River Commons; 45 Washington St.
- YMCA; 61 Susquehanna St.
- YWCA; 80 Hawley St.
- Keystone Associates; 58 Exchange St.
- Kradjian Properties; 84 Court St.
- Rock Bottom Dam; Susquehanna River

Several of these facilities (Holiday Inn, Twin River, and Kradjian) were ultimately eliminated due to infrastructure concerns. Subsequent to the Task 1 analysis, BHA and Superior Ambulance were added to the project. Additional facilities that could be considered for inclusion at a later stage include:

- Floyd L. Maines Veterans Memorial Arena; 1 Stuart Street
- County Office Building; 60 Hawley St.
- State Office Building; 44 Hawley St.

This proposed Binghamton Community Microgrid is a major opportunity for the City of Binghamton's critical facilities - which were affected 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 Binghamton. In the event of future natural disasters leading to electric outages and a loss of thermal support within the City, the microgrid would allow the Police Department, Fire Department, and City Hall to operate and aid City residents and businesses. The proposed combined heat and power ("CHP") units will improve overall system efficiency and reduce the environmental impacts of energy production.

1.1.10 Uninterruptable Fuel Supply

The main source of generation for the microgrid is the micro-hydro unit at Rock Bottom Dam. Natural gas was considered as the primary source of fuel for the fossil-fueled generation sources. This includes new natural gas-fired CHP units at the YMCA and the YWCA as well as the currently installed 250 kW natural gas generator at City Hall and the 205-kW engine at BHA. The Team discussed the reliability and resiliency of the natural gas supply with NYSEG. The team is aware that there were numerous natural gas outages in the aftermath of Hurricane Lee, but still need to confirm the cause and duration of the impacts in the microgrid area. Information was requested from the utility on the availability of gas supply for new units and the history of outages in the area. This will be further explored in Stage 2.

1.1.11 Resiliency to Forces of Nature

On September 7th, 2011, remnants of Tropical Storm Lee dropped between 8 and 12 inches of rainfall onto the City of Binghamton. The combination of this heavy rainfall and the already saturated soil from Hurricane Irene caused record flooding of the Susquehanna River and its surrounding communities with water levels rising as high as 17 feet above flood stage, topping the previous record. In Binghamton, 20,000 residents were ordered to evacuate their homes, and all roads in the city were closed to traffic.

The downtown region around the proposed microgrid was hit extremely hard due to the fact that it sits at the confluence of the Chenango and Susquehanna Rivers. These storms left 39 square miles of Broome County underwater. It was reported that flooding and washouts from this storm caused a total of 68,000 electric customers and 11,500 natural gas customers to lose service. Six of NYSEG's electric substations had to be de-energized for safety reasons because of the extreme flooding.

Facilities in downtown Binghamton affected by the flooding included City Hall, the Police and Fire Departments, Holiday Inn, YMCA, YWCA, and Binghamton Housing Authority. The customers in this prospective microgrid are on an underground secondary network system, with larger facilities on spot networks. This naturally results in a high level of day-to-day reliability. However, when interruptions occur in the network, they tend to be significant and take longer to restore than events on overhead radial systems – mostly due to difficulty locating and repairing underground faults, and the complexity inherent in restoring networks.

The New York Department of Public Service 2013 Electric Reliability Performance Report shows that the average customer in NYSEG's territory experienced 132 minutes of interruption as a result of non-storm events in 2013, and more than 50% of these interruptions resulted from tree contact and weather events on the overhead portions of the system – events that would likely be mitigated by siting generation sources closer to the load. The downtown Binghamton network is likely served by feeders with some overhead exposure, so the reliability of the downtown grid could still plausibly be affected by common-mode failures of overhead lines, particularly during severe weather events such as ice storms and windstorms. Moreover, the substation(s) serving the underground network are affected by major events, as the experience with Tropical Storm Lee (noted above) shows. Therefore, it is conceivable that a district-energy microgrid could significantly reduce the number of customer interruptions precipitated by major events on the main grid. Customers on a CHP-based microgrid would also experience less momentary interruptions and sags as a result of events (such as tree/animal contact and lightning) that typically lead to voltage/power quality issues for customers supplied by overhead radial lines.

CHP 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 having diesel backup generators. 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 CHP unit was designed to operate during grid outage, there was not a single site that lost power. As long as the natural gas supply is resilient, CHP systems will continue to supply power to critical loads such as Fire, Police and Emergency Operations. As mentioned above, if gas supply fails, the team will consider the use of backup diesel generation for a subset of super-critical loads.

In Stage 2, the Team will work with NYSEG and stakeholders to develop a resilient design that incorporates hardening strategies commonly practiced by systems engineers in areas exposed to storms and outage events. GE worked with the State of New Jersey post-Hurricane Sandy to review utility storm hardening measures, and some of these findings will be applied here. These include 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, undergrounding where possible, use of spacer cable and extreme wind and ice-loading construction for overhead, and a host 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. In addition, smart distribution design elements can be used to ensure flexible, reliable operation.

1.1.12 Black-Start Capability

As discussed later in Task 2, the standby natural gas generators located at City Hall and the Housing Authority are capable of operating without the presence of the distribution system which makes them ideal for black-start application. 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 2.3).

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 in Stage 2. 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.

Innovative characteristics of the envisioned Binghamton Community Microgrid include: integration within a microgrid system of a large DER that normally provides power to the larger grid; 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.

1.2.2 Network Control System

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.

Furthermore, 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

The Team has considered all opportunities to incorporate clean power and renewable resources into the generation mix for the microgrid. The planned hydro plant at Rock Bottom Dam is an excellent example of clean renewable power supply.

There is currently 250 kW of natural gas generation at City Hall and a 205-kW gas engine at BHA. The Team explored locating CHP gas units at additional sites to supply electrical, heating and cooling loads for most of the facilities in the footprint.

As the map in Figure 1-2 shows, facility buildings and some open spaces may be good candidate sites for rooftop, canopy and ground-mounted solar PV arrays which could be integrated into the microgrid. In total, about 1 to 2 MW of Community Solar PV could be installed on 13 acres of open space, rooftops and parking lot canopies in the downtown area. The Team elected to include 280 kW at this stage and explore other options as the project moves forward.

Electric Vehicles charged by Combined Solar-Energy Storage Systems are planned to systematically replace the 385 vehicles in the City's aging fleet that cost over $700,000 in fuel in 2014. With the City as an "anchor tenant," the goal is to begin to electrify the local transportation system with solar-powered EV charging stations. The first commercial market analysis will also explore electric-vehicle commuting models that will initiate the City's EV market with faculty and students traveling between downtown and the main SUNY Binghamton Campus - where 1/3 of the carbon emissions are from vehicles.

As the project moves into Stage 2, the analysis will focus on the applicability of various clean distributed energy resource technologies, energy efficiency and demand reduction initiatives that are aligned with the City's sustainability goals.

1.2.4 Energy efficiency and Demand Response Options

As the project moves forward into Stage 2, the facilities, which represent more than $1 Million of annual electricity expenditures, and 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. The boilers at the YMCA were all installed within the last seven years; the steam boilers at the YWCA are four years; and facilities have had lighting upgrades in the last five years.

The microgrid has the ability to provide generation/load reduction to support a substation during critical periods as an alternative to distribution-system reinforcement and potentially receive payments for islanding as a demand response ("DR") service, payments for exporting power as a generation service, and payments for maintaining critical loads during a larger system outage. A contract could call for immediate response in local crises, not just to reduce peak system demand. Short-term markets for local service could be local voltage/VAR support, short-term substation relief, and emergency services (e.g., agreements to make agreed-upon energy exports or to assume prescribed load shapes). Through distribution support services, the microgrid could provide grid restoration services that are more flexible than typical black-start capabilities and ultimately, ensure local reliability, circuit by circuit, across the larger grid. All of these different market constructs need to be further discussed with NYSEG, and an appropriate mix of services agreed to in order to support both NYSEG and microgrid participant requirements.

This study considered demand response options, both within the utility programs and also in NYISO markets, 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.

The GE Team met with NYISO representatives to discuss the potential for NYISO market participation by microgrids and behind the meter DG. NYISO is still working on the applicable market rules. The GE Team will maintain the relationship with NYISO and monitor on-going developments and impact on the Binghamton Community Microgrid. Based on the latest information, the team will explore ways for the proposed microgrid to actively participate in the NYISO's energy, capacity, and ancillary services markets.

1.2.5 Electrical System Interconnection

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 can be electrically connected using the existing City-owned conduit system and portions of the electrical infrastructure. As the Team developed the parameters of the microgrid in Task 2, the need for isolation switches, transfer switches, motor operated breakers and other switchgear, relays, transformers and other equipment became clearer. The installation requirements and resulting cost for additional equipment are examined in subsequent tasks.

The microgrid has several points of interconnection (POI) to the larger grid. In connected mode, network protectors at the POI 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. In Stage 2, the Team will also consider 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 NYSEG, the team developed the operation strategy for the microgrid, which is discussed in Section 2.1.

The Team worked with NYSEG to develop an understanding of the relevant features of the electric distribution system and 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 need to be considered in the functional design of the microgrid electrical infrastructure. A very important consideration will be the overall cost of various grid type options.

Based on the selected grid, 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. The Team will take into account the latest REV developments in considering various business models and operational modes of the microgrid within the REV framework. In particular, the Team will describe the options for 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 buy and sell of power and demand resources) both at retail/distribution system level and also at NYISO/transmission system level. We understand that details of REV framework will keep evolving, which we will take into account in our development of the microgrid functionalities. This project is unique in that it involves possible incorporation of a micro-hydro plant into a downtown microgrid served by a secondary network.

The Team is working collaboratively with NYSEG as well as community stakeholders to develop mutually beneficial approaches to the implementation of the proposed energy ecosystem. There are opportunities to begin to test and validate certain key REV market constructs and associated new potential revenue streams and profits moving bi-directionally between consumers and the Utility through a phased-in, utility-as-distributed-services-platform-provider ("DSPP") business model. Team members have been actively involved with, and are highly knowledgeable about, all aspects of the REV proceedings and believes that, through working together over the coming months, we will be able to put in place a naturally evolving plan, which will demonstrate that NYSEG will be one of the utility leaders in New York State in implementing the REV vision.

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. The Team will work closely with the NYSEG 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 complete evaluation of our projects 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.

Facilities in the project area are served primarily by an underground secondary network. These types of systems date back to the early to mid-twentieth century and, while extremely reliable, tend to be very expensive to operate and maintain. There is very little visibility into events on these systems, when an event occurs it is usually widespread and catastrophic. In addition, these systems can pose public safety hazards from stray voltages, arcing faults and manhole explosions. Many utilities with underground secondary systems are trying to find ways to move away from those systems, or improve O&M without sacrificing the inherent reliability. A community microgrid in the location has the potential to take some stress off the aging network system, and reduce the O&M cost for NYSEG while maintaining or improving overall reliability for the end customers.

1.2.8 Private Capital Options

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 CHP, 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: Property Assessed Clean Energy (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 structured 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) includes 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 includes 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.

The feasibility study has determined options for the ownership structure of microgrid. It is expected that NYSEG will continue to own and operate electric distribution lines as part of a Special Purpose Entity. Microgrids are unique from a financing perspective because of the diversity of kinds of assets, with very different "financeability" profiles and perceived levels of risk. This translates into complexity in terms of how a financing package is put together, particularly one that needs to be standardized, transparent, and based on a methodology which investors will understand. It would also be uncommon if a microgrid is implemented as one project with one common investment vehicle. Instead, the value proposition of microgrids includes multiple components, centered on demand and consumption reduction, on-site generation and storage, advanced control systems and automated grid independence. Development phases can also overlap, leading to additional complexity. In addition, not all phases or asset components will qualify for incentives or grants, and the overall capital investment could be substantial. As a result, the Team believes that the financing of microgrids in general and in New York State in particular will require a creative approach to bundling every source into an integrated package, which will effectively reduce risks for all investor..

Another critical component of microgrid financing in New York State will be to creatively package a variety of these resources with the credit-enhancement products of the Green Bank. As the project moves forward into Stage 2, we will need to work with NYSEG to develop NYS PSC driven compensation mechanisms that will support microgrids in a standardized, transparent manner with no "hidden" costs found in tariffs today.

It should be noted that the most significant barriers to this microgrid are utility regulations and cost, and expense of electrical and information network to connect multiple customers to one or more power generation resources. The study identifies opportunities for NYSEG and the anchor facilities to establish economic relationships (higher rate for exported power, lower rate for standby power, capacity payments, payments for kWh's they don't have to provide, etc.) that results in a better financial pro forma for this project. These learnings can be utilized in other microgrid applications (of all sizes) throughout New York State.

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. The ultimate goal of the Binghamton Community Microgrid is to implement a microgrid that does not lead to grid defection but rather to enhance grid efficiency, reliability and resiliency and provide microgrid participants with benefits not available otherwise or more economically. Given expected load growth in downtown Binghamton, with the current increase in student population and additional student housing projects under consideration, the implementation of a Community Microgrid could delay or eliminate the need for certain utility transmission and distribution upgrades which would be required otherwise.

The City of Binghamton has experienced significant growth in the years following the 2011 floods resulting from Hurricane Irene and Tropical Storm Lee. The original catalyst for this expansion was the construction of the SUNY Binghamton University Downtown Center in 2007. This development sparked a significant influx of student residents into the City. Today, in a combination of small, medium and large projects, there are in excess of 5,000 students who now call downtown Binghamton their home. With these new residents came the demand for additional business services such as restaurants to retail shops. The once-over-stocked supply of vacant real estate within the City has all but disappeared, and available downtown buildings are now selling at a premium. Additionally, these added businesses have attracted more traffic and attention to the downtown area, which has in turn created a demand for market-rate/young-professional apartments in the city center. Currently, there are more than one hundred of these market-rate apartment units in some stage of the planning process.

All of this growth and development has significantly expanded the occupied square footage of property within the City as well as increased the demand for more energy. These developments have also expanded the potential to increase exponentially the significant problems the City experienced during the past cycle of extreme weather events. This greatly expanded potential for natural disasters also increases the responsibility of all levels of Government to invest in the resources necessary to be able to prevent, mitigate and react to these events in the future. Thus, the NY Prize represents an opportunity to design, develop and implement a downtown Binghamton Community Microgrid that will minimize the damages caused by these disasters.

Key participants and critical facility partners include the City of Binghamton, its Police and Fire Departments, and City Hall, the YMCA and the YWCA. Collectively, the participants annually spend in excess of $1,000,000 on more than 10 GWh of electricity, and have an average peak load of 1-2 MW. These facilities will benefit from improved energy surety and security, as well as reduced cost of thermal and electrical service.

Microgrids and district energy systems can contribute to the transition to a green economy through cost savings from avoided or deferred investment in power generation infrastructure, an elimination of line losses and a reduction in peak capacity; wealth creation through reduced fossil fuel expenditures and generation of local tax revenue; and employment from jobs created in system design, construction, equipment manufacturing and operations and maintenance. The Team expects energy savings to increase the economic strength of Binghamton as these savings are likely to be reinvested in the local economy.

1.2.10 Innovations that Strengthens Surrounding Grid

Currently, there are no rooftop solar installations in the microgrid area. As far as the Team is aware, no DERs are currently allowed to operate in parallel with the secondary network due to the risk of back-feeding. City Hall has a 250 kW gas engine that is used as backup generation. The potential Rock Bottom Dam hydro facility and the proposed CHP units at microgrid facilities will be designed to run as base load generation, and will therefore be parallel to the main grid for long periods during normal operation. The microgrid will introduce a significant block of electrical load to the CHP units that would minimize the risk of backfeed. 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 and developers to interact with the grid, participate in the market, and define new streams of revenue and value. This will also allow the utility to define new services that can be provided to microgrids and DERs behind or beyond the meter.

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.

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. As the project moves forward, 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 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 be 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

Figure 2-1 below shows a simplified layout of the Binghamton microgrid. The microgrid is formed by connecting a number of adjacent facilities as shown in Figure 2-1. The microgrid is composed of the Binghamton City Hall (which includes the police bureau and fire headquarters), the Binghamton Housing Authority, the YMCA, the YWCA, an ambulance station and the Keystone Associates building. The majority of the power will come from Rock Bottom Dam.

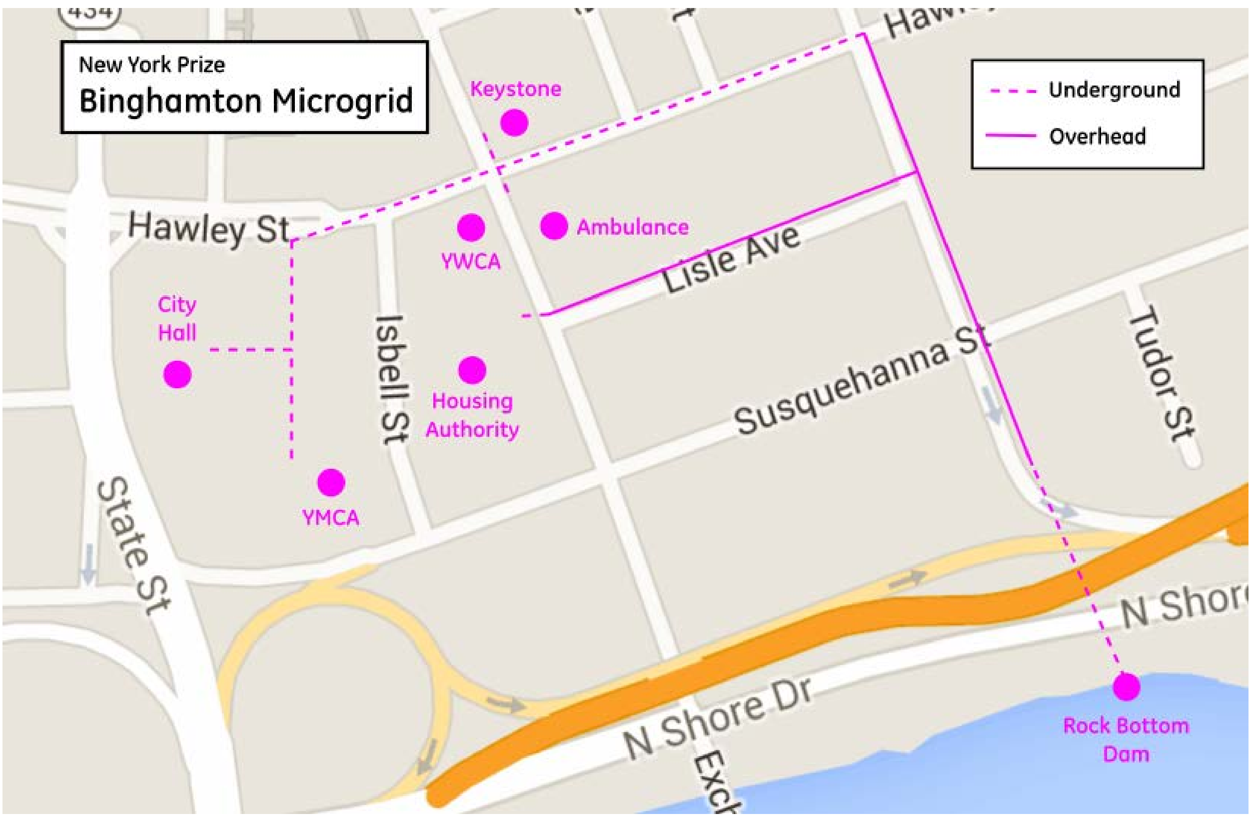

Figure 2-1: Simplified Layout of Binghamton Microgrid Showing Routing of Electrical Connections and Select Facilities

Figure 2-2 below shows a simplified one-line diagram with the location of the distributed energy resources (DER). Because the electrical infrastructure at this location is primarily networked, new conductor and transfer switches will be installed to connect the facilities together and to the Rock Bottom Dam facility. Additionally, CHP will be added at the YMCA and YWCA.

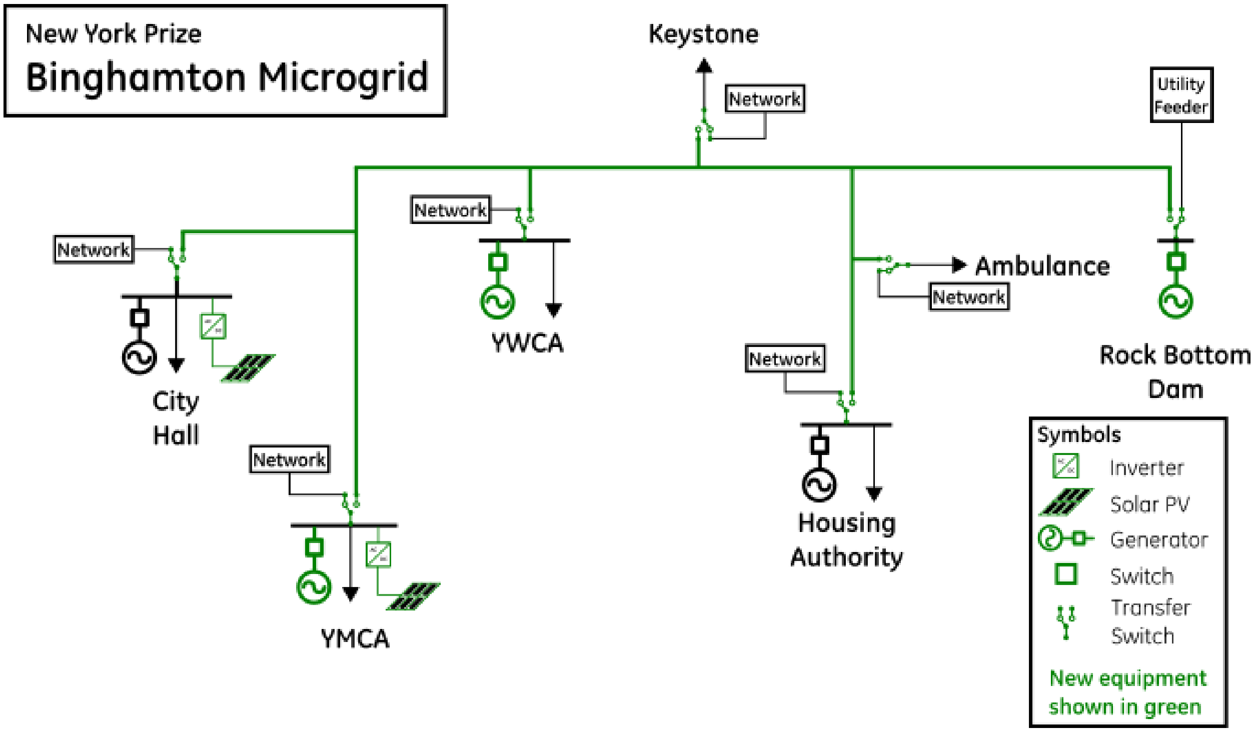

Figure 2-2: Binghamton Microgrid One-Line Diagram Showing Generation Sources and Major Equipment

2.1.2 Normal and Emergency Operations

Normal Conditions

Under normal conditions, most the facilities that will be part of the microgrid are primarily fed by the New York State Electric and Gas (NYSEG) network. The YMCA and the YWCA can offset their consumption with CHP generation, and City Hall can offset its consumption with the onsite PV generation. Production from DERs at networked facilities is not expected to be large enough to cause problems with the network (back-feeding). The Rock Bottom Dam will connect to the NYSEG network through a radial feeder (likely NOYES Island 278) to provide electricity to the larger grid and participate in available electricity markets.

The electrical tie between the facilities may or may not be connected during normal operation. If the electrical tie-line is active, the total load of all facilities provides a larger sink for the CHP and PV generation. This will allow all facilities to reduce peak demand on the grid and lower their energy cost.

Emergency Conditions

When power is lost to the critical facilities due to, for example, a catastrophic event on the bulk power system, loads in the 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 frequency, and the CHP 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 natural gas backup generators at City Hall and BHA will start up to supply critical facility loads. Once the facilities are isolated from the utility system and each other, the CHP generators at YMCA and YWCA will restart in islanded mode (self-synchronized). When the CHP generation is stabilized, the microgrid tie-line is closed in and the Rock Bottom Dam facility will transfer from its normal feed to the microgrid and synchronize with the online generation. The City Hall and BHA emergency generators can then be ramped down as load at all locations is sequentially picked up by the CHP and Hydro. 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 CHP 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.

Figure 2-3 shows the interconnection of the microgrid facilities.

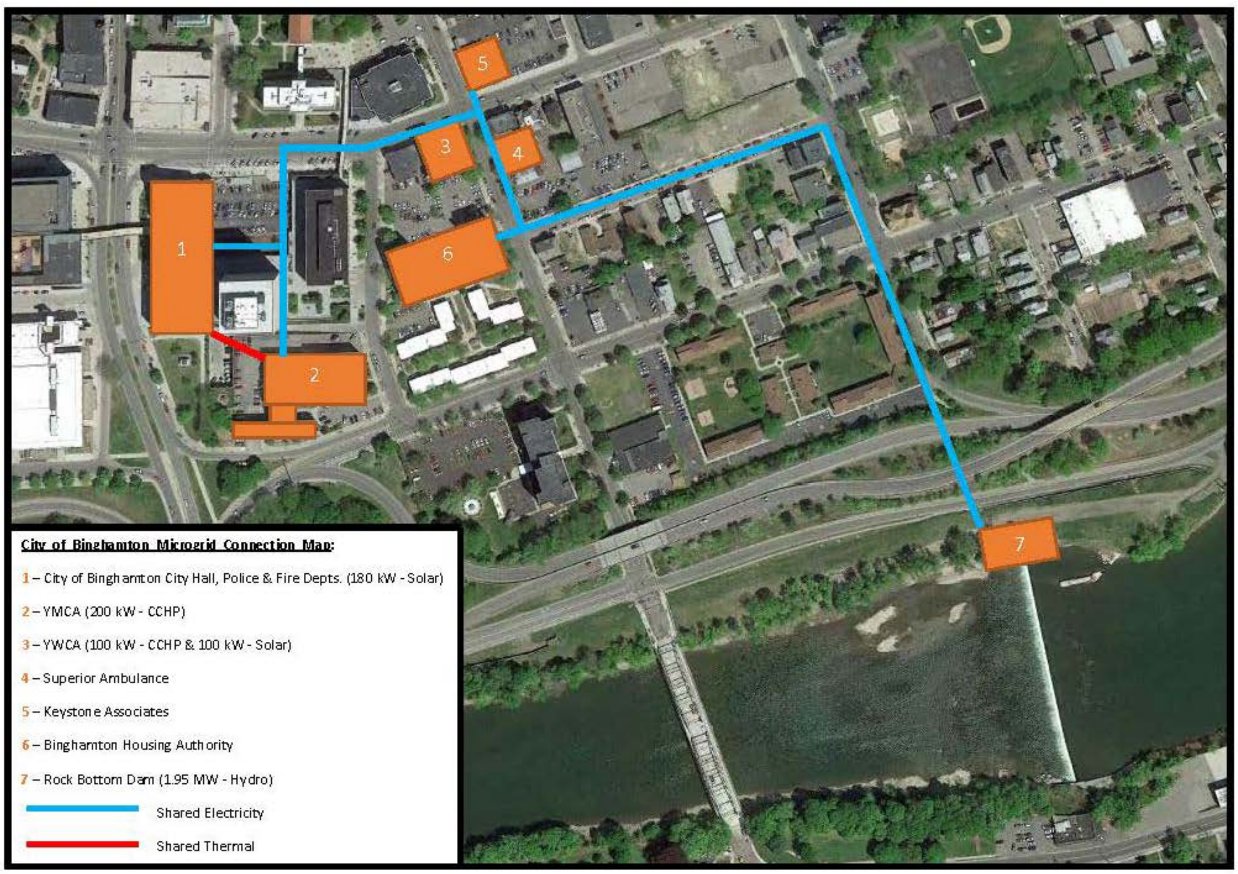

Figure 2-3: City of Binghamton Microgrid Connection Map

2.2 Load Characterization

The Contractor shall:

2.2.1 Electric and Thermal Loads

In grid connected mode (and also in islanded mode), CHP Units will be running at almost 100% maximum capacity (except when the facility loads drop below the available capacity of the CHP units). In grid connected model power will be imported from the grid to make up any shortfall over the load cycle. The Rock Bottom Dam will generate power for the larger grid and sell energy and ancillary services to the utility and/or participate in NYISO energy, capacity, and ancillary markets.

In islanded mode, there will be more than sufficient power to meet the load of the microgrid by the Rock Bottom Dam. The Dam and the CHP units will modulate output to match the electrical demand of the island. There will be about 10% of peak load available for load curtailment during emergency periods on a need basis or offered as demand response during grid connected mode.

There are also additional 250 kW and 205 kW natural gas backup units available within the microgrid that will be used if needed and subject to economics of onsite generation versus power purchase from utility, or as peak load support during system peak hours.

The table below summarizes the microgrid electrical, heating, and cooling loads:

Table 2-1: Monthly Electrical, Heating, and Cooling Load

	Electrical Load			Heating Load			Cooling Load	
	Energy (kWh)	Peak (kW)		Energy (kWh)	Peak (kW)		Energy (kWh)	Peak (kW)
JAN	491,469	1,259		850,892	2,041		0	0
FEB	497,384	1,402		739,017	1,959		0	0
MAR	537,648	1,401		637,370	1,529		1,688	5
APR	455,518	1,212		394,441	1,531		6,753	19
MAY	422,705	1,099		186,672	706		38,829	106
JUN	502,585	1,341		57,536	223		123,240	345
JUL	528,395	1,365		14,064	53		258,297	703
AUG	550,924	1,438		27,489	104		182,327	497
SEP	548,401	1,457		129,136	501		54,023	151
OCT	425,953	1,105		328,594	788		3,376	10
NOV	439,791	1,150		519,102	1,277		0	0
DEC	536,882	1,370		742,213	1,780		0	0
YEAR	**5,937,654**	**1,457**		**4,626,525**	**2,041**		**668,533**	**703**

2.2.2 Hourly Load Profile

The sources of data are the electric and fuel billing statements. Project partners collected and provided utility statements for the facilities in the microgrid. We did not have utility statements for the Superior Ambulance, and therefore, we estimated its electric load based on the square footage area of the facility.

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.

The electrical, heating, and cooling load profiles can be improved if and when hourly data for each facility becomes available.

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

The resulting total microgrid 12 x 24 electrical load profile is based on the combination of individual facility load shapes, mainly from DER-CAM database for similar buildings (or closet building or facility type). The load shapes were scaled to result in the reported annual energy and come close as possible to the reported annual peak load of the facilities, i.e., with approximate, if not exact, average annual load factor.

The figures that follow the tables present the weekday and weekend profiles of microgrid electrical, heating, and cooling loads.

Table 2-2: 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
weekday	JAN	269	254	268	250	268	400	429	587	1118	1117	1121	1259	1240	1240	1242	1236	1242	958	819	729	578	573	300	254
weekday	FEB	305	277	303	283	306	444	479	656	1245	1241	1248	1402	1380	1384	1384	1385	1392	1069	908	810	643	635	331	278
weekday	MAR	267	263	269	269	298	443	565	964	1243	1243	1247	1401	1377	1384	1384	1383	1283	957	898	694	627	493	278	257
weekday	APR	231	233	234	235	270	397	542	980	1075	1080	1081	1212	1186	1198	1202	1197	1052	783	785	554	543	377	233	231
weekday	MAY	207	208	206	208	241	357	488	889	972	980	985	1099	1079	1087	1089	1086	967	714	719	512	501	340	215	213
weekday	JUN	244	243	242	241	285	431	598	1093	1185	1191	1205	1341	1320	1333	1336	1335	1177	866	870	618	604	411	253	247
weekday	JUL	262	260	260	262	305	456	612	1105	1201	1207	1219	1359	1348	1358	1359	1365	1212	889	892	635	614	421	265	264
weekday	AUG	260	262	261	260	308	465	640	1181	1276	1284	1288	1438	1422	1432	1437	1434	1265	926	928	655	638	431	268	265
weekday	SEP	272	272	272	271	314	474	649	1179	1285	1290	1301	1457	1445	1448	1450	1449	1279	944	940	673	657	445	277	274
weekday	OCT	207	209	211	213	246	359	492	904	986	981	992	1105	1082	1094	1092	1091	966	712	717	510	496	337	206	202
weekday	NOV	229	225	232	227	236	361	389	546	1021	1020	1029	1150	1133	1138	1137	1136	1141	875	747	663	517	511	261	223
weekday	DEC	283	272	284	273	284	435	464	641	1205	1208	1219	1370	1348	1356	1352	1348	1355	1044	893	787	619	612	312	272
weekend	JAN	264	251	264	253	277	372	411	407	651	636	643	775	766	764	647	638	651	471	472	370	372	359	260	245
weekend	FEB	293	275	293	283	313	422	468	460	746	728	738	882	870	873	728	719	730	529	536	417	424	399	297	278
weekend	MAR	268	264	270	270	290	420	440	525	711	705	705	856	836	769	694	697	678	501	497	398	384	386	266	268
weekend	APR	224	221	226	225	242	371	383	524	621	604	612	739	721	608	607	598	571	436	438	344	334	329	230	226
weekend	MAY	198	199	205	202	217	341	344	489	564	552	564	672	663	556	547	549	514	381	380	310	292	286	197	197
weekend	JUN	243	240	239	238	254	400	410	575	668	675	680	814	801	676	674	669	641	487	488	396	365	361	247	245
weekend	JUL	258	255	254	255	272	431	443	615	710	696	704	842	828	689	693	690	656	491	493	400	386	374	257	256
weekend	AUG	262	260	260	261	285	439	451	631	723	719	722	868	846	710	710	711	663	510	513	414	390	386	269	267
weekend	SEP	272	269	268	264	265	433	440	655	760	761	766	921	904	741	745	734	694	524	521	412	400	394	269	264
weekend	OCT	216	215	215	217	216	335	336	476	549	554	557	680	658	564	562	557	534	408	409	332	315	311	222	218
weekend	NOV	241	230	244	236	266	352	392	429	634	610	624	739	727	695	602	591	594	435	439	344	341	329	245	231
weekend	DEC	282	271	284	277	310	420	461	458	745	720	735	880	870	865	734	718	734	530	535	416	421	395	296	269

Table 2-3: 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
weekday	JAN	1044	1044	1031	1106	1290	1564	1855	2041	2019	1803	1519	1281	1126	1037	997	997	1017	1032	1034	1028	1022	1019	1017	1018
weekday	FEB	1003	1003	990	1062	1238	1502	1782	1959	1938	1732	1458	1230	1081	996	958	958	976	991	993	987	982	978	977	978
weekday	MAR	782	782	772	829	966	1172	1390	1529	1512	1351	1138	960	844	777	747	747	762	773	775	770	766	763	762	763
weekday	APR	766	766	906	1158	1403	1531	1465	1207	856	545	342	226	158	116	95	94	114	154	206	264	326	391	457	514
weekday	MAY	353	353	417	533	647	706	675	556	394	251	157	104	73	53	44	43	53	71	95	122	150	180	211	237
weekday	JUN	112	112	132	169	205	223	214	176	125	80	50	33	23	17	14	14	17	22	30	39	47	57	67	75
weekday	JUL	27	27	31	40	49	53	51	42	30	19	12	8	5	4	3	3	4	5	7	9	11	14	16	18
weekday	AUG	52	52	61	79	95	104	99	82	58	37	23	15	11	8	6	6	8	10	14	18	22	27	31	35
weekday	SEP	251	251	297	379	459	501	480	395	280	179	112	74	52	38	31	31	37	50	67	86	107	128	150	168
weekday	OCT	403	403	398	427	498	604	717	788	780	696	587	495	435	400	385	385	393	399	399	397	395	394	393	393
weekday	NOV	653	653	645	692	807	979	1161	1277	1263	1128	950	802	705	649	624	624	636	646	647	643	640	638	637	637
weekday	DEC	911	911	900	965	1125	1364	1618	1780	1761	1573	1325	1118	982	905	870	870	887	900	902	897	892	889	887	888
weekend	JAN	743	743	746	745	771	850	986	1143	1248	1244	1146	1017	909	832	782	760	767	792	820	842	858	870	874	860
weekend	FEB	714	714	716	716	740	816	946	1097	1198	1194	1100	977	872	799	751	730	736	761	787	808	824	836	839	826
weekend	MAR	557	557	559	558	578	636	738	856	935	932	858	762	681	623	586	569	575	593	614	630	643	652	655	644
weekend	APR	425	425	466	522	585	645	685	687	644	569	490	423	372	331	300	279	270	273	288	316	354	397	435	459
weekend	MAY	196	196	215	240	270	297	316	317	297	262	226	195	171	153	138	129	125	126	133	146	163	183	200	212
weekend	JUN	62	62	68	76	85	94	100	100	94	83	71	62	54	48	44	41	39	40	42	46	52	58	63	67
weekend	JUL	15	15	16	18	20	22	24	24	22	20	17	15	13	11	10	10	9	9	10	11	12	14	15	16
weekend	AUG	29	29	32	35	40	44	46	47	44	39	33	29	25	22	20	19	18	19	20	21	24	27	29	31
weekend	SEP	139	139	153	171	192	211	224	225	211	186	160	139	122	108	98	91	88	89	94	104	116	130	142	150
weekend	OCT	287	287	288	288	298	328	381	441	482	480	442	393	351	321	302	294	296	306	317	325	331	336	338	332
weekend	NOV	465	465	467	466	483	532	617	715	781	778	717	636	569	520	489	476	480	496	513	527	537	545	547	538
weekend	DEC	649	649	651	650	673	741	860	997	1088	1085	999	887	793	726	682	663	669	691	715	734	749	759	762	750

Table 2-4: 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
weekday	JAN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
weekday	FEB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
weekday	MAR	1	1	1	1	1	1	1	2	2	3	3	4	4	5	5	5	4	4	3	3	2	2	1	1
weekday	APR	3	3	3	3	4	4	6	8	10	13	15	17	18	19	19	18	16	14	12	10	8	7	5	4
weekday	MAY	18	18	18	18	20	25	33	45	58	72	84	94	102	106	106	101	92	81	68	57	46	37	29	24
weekday	JUN	59	59	57	58	66	82	109	146	190	234	274	307	331	345	344	329	301	263	223	184	150	120	95	78
weekday	JUL	121	121	117	119	134	167	222	298	387	477	559	626	676	703	703	673	614	537	455	376	306	244	194	159
weekday	AUG	85	85	82	84	95	118	157	210	273	337	394	442	477	497	496	475	433	379	321	266	216	173	137	112
weekday	SEP	26	26	25	26	29	36	48	64	83	103	120	134	145	151	151	144	132	115	98	81	66	52	42	34
weekday	OCT	2	2	2	2	2	2	3	3	4	5	7	8	9	10	10	10	9	8	6	5	4	3	3	2
weekday	NOV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
weekday	DEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
weekend	JAN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
weekend	FEB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
weekend	MAR	1	1	1	1	1	1	1	1	1	2	2	2	2	3	3	3	2	2	2	2	2	1	1	1
weekend	APR	3	3	3	3	3	4	5	6	7	9	10	11	12	13	13	12	11	10	9	8	7	6	5	4
weekend	MAY	19	19	19	19	19	22	26	33	42	51	58	64	68	70	70	68	64	59	53	46	40	33	27	23
weekend	JUN	62	62	61	60	62	70	85	108	137	165	189	208	221	228	228	221	208	191	171	151	129	109	90	74
weekend	JUL	127	127	125	123	128	143	174	221	279	337	387	425	452	466	466	452	425	390	350	307	264	222	183	151
weekend	AUG	90	90	88	87	90	101	123	156	197	238	273	300	319	329	329	319	300	275	247	217	186	156	129	107
weekend	SEP	27	27	27	26	27	31	37	48	60	72	83	91	97	100	100	97	91	84	75	66	57	48	39	33
weekend	OCT	2	2	2	2	2	2	2	2	3	3	4	4	5	5	5	5	5	5	4	4	3	3	3	2
weekend	NOV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
weekend	DEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

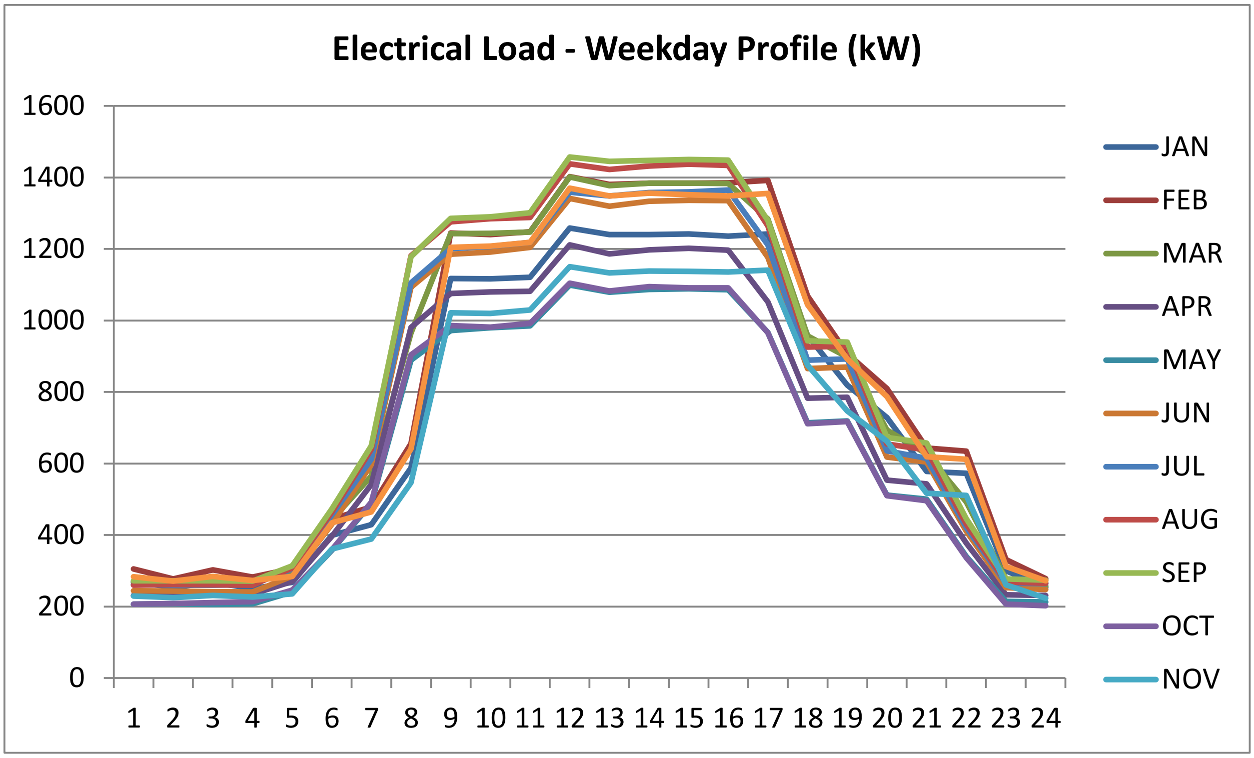

Figure 2-4: Microgrid Electrical Load Weekday Profile (kW)

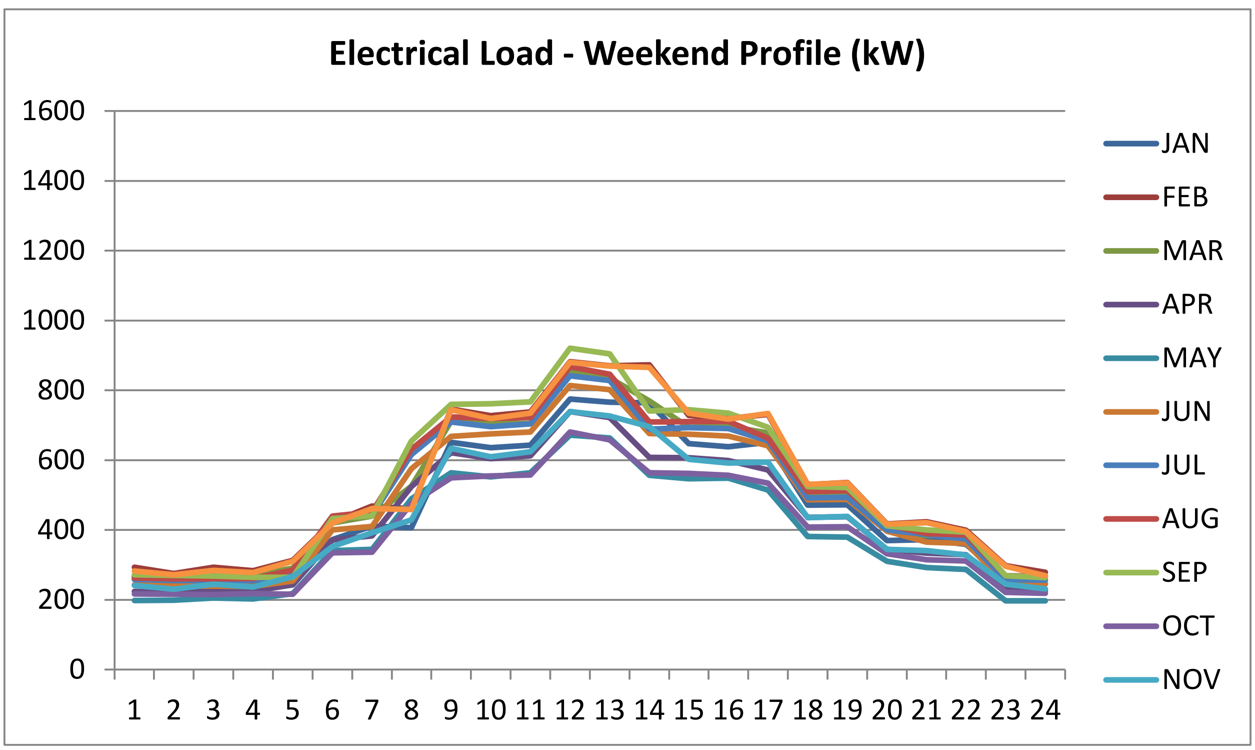

Figure 2-5: Microgrid Electrical Load Weekend Profile (kW)

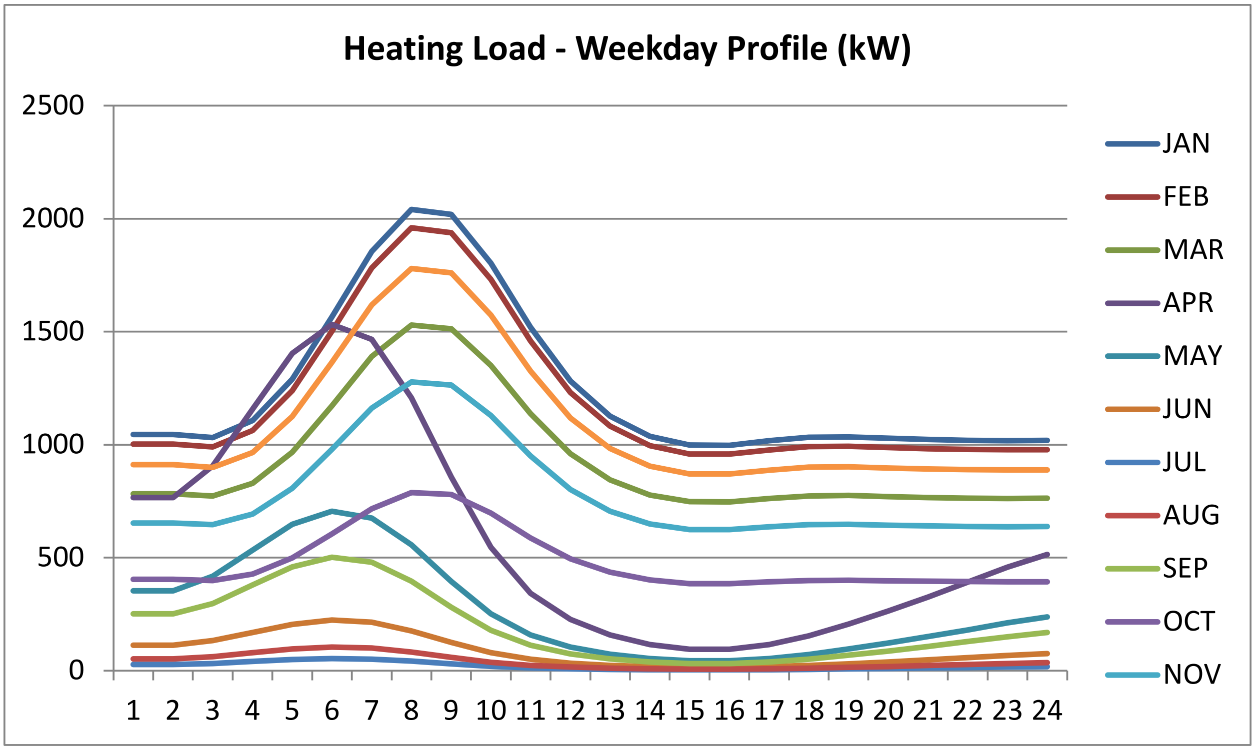

Figure 2-6: Microgrid Heating Load Weekday Profile (kW)

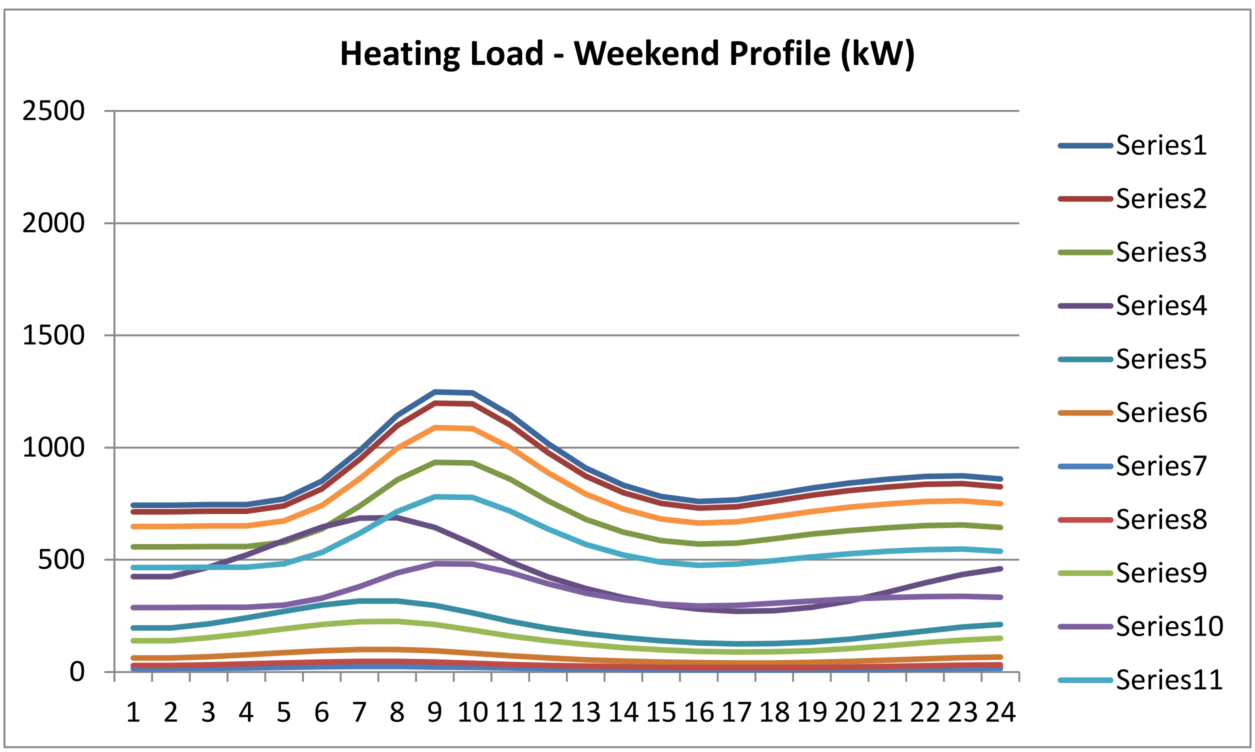

Figure 2-7: Microgrid Heating Load Weekend Profile (kW)

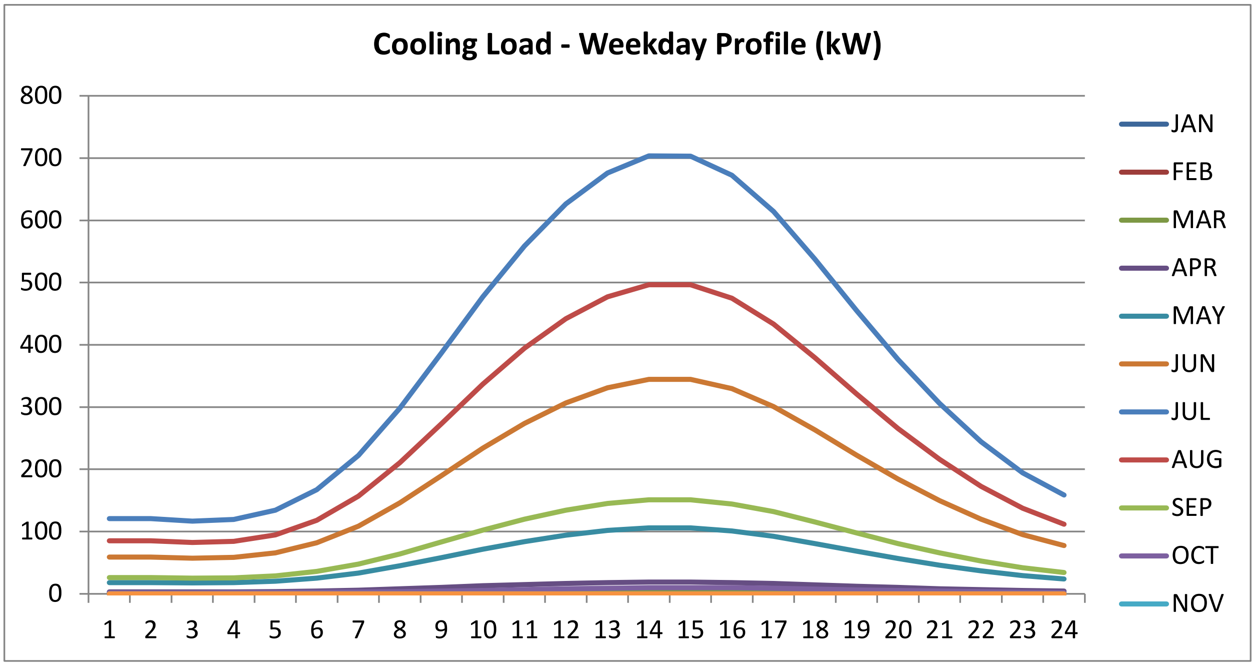

Figure 2-8: Microgrid Cooling Load Weekday Profile (kW)

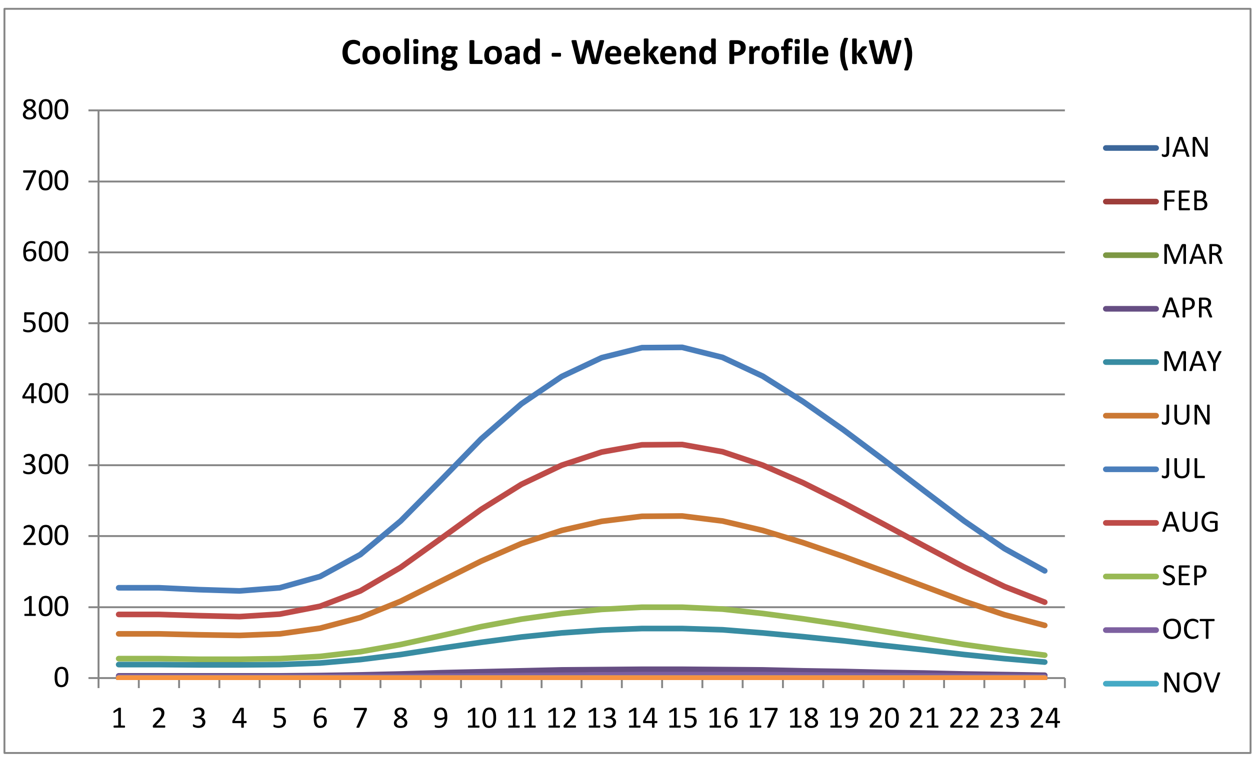

Figure 2-9: Microgrid Cooling Load Weekend Profile (kW)

2.2.3 Description of Loads

The microgrid total electrical load is based on sum of all the loads of individual critical facilities to be served by the microgrid as listed in Table 2-5 below.

The estimated microgrid non-coincidental electrical peak load is 1,457 kW. The Rock Bottom Dam's maximum capacity is 1,950 kW. However, the actual available capacity will fluctuate from month to month.

However, with the existing 250-kW and 205-kW backup generation, and the proposed total of 300 kW of CHP units, a total of 280 kW nameplate capacity solar PV, and 128 kW of curtailable load (about 10% of the peak load of the three largest facilities), there are more than enough supply and demand side resources to fully meet microgrid's peak electrical load during periods of emergency.

Table 2-5: Summary of Microgrid Electrical, Heating, and Cooling Loads

	Electrical Load			Heating Load			Cooling Load	
	Energy (kWh)	Peak (kW)		Energy (kWh)	Peak (kW)		Energy (kWh)	Peak (kW)
JAN	491,469	1,259		850,892	2,041		0	0
FEB	497,384	1,402		739,017	1,959		0	0
MAR	537,648	1,401		637,370	1,529		1,688	5
APR	455,518	1,212		394,441	1,531		6,753	19
MAY	422,705	1,099		186,672	706		38,829	106
JUN	502,585	1,341		57,536	223		123,240	345
JUL	528,395	1,365		14,064	53		258,297	703
AUG	550,924	1,438		27,489	104		182,327	497
SEP	548,401	1,457		129,136	501		54,023	151
OCT	425,953	1,105		328,594	788		3,376	10
NOV	439,791	1,150		519,102	1,277		0	0
DEC	536,882	1,370		742,213	1,780		0	0
YEAR	5,937,654	1,457		4,626,525	2,041		668,533	703

The total electrical load includes all the loads of individual facilities within the microgrid. However, only the heating and cooling loads of the City Hall, YMCA, and YWCA are serviced by the proposed CHP units. The reason is that the CHP units are meant to meet the thermal loads of the facilities they will be installed in or which share thermal conduits/networks. To meet the thermal load of all the facilities in the microgrid will entail substantial cost in development of the physical thermal network connecting all the facilities, and hence, it was considered not to be an economic option.

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 natural gas based backup generation that will continue to function as backup resources. The proposed new elements are shaded in grey. These include a 200 kW Rice CHP and a 2x50 micro-CHP (basically engines of Toyota Camry configured with CHP capability). The CHP 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.

This microgrid will also host a substantial amount of solar and hydro based renewable resources. The principal renewable resource, and in fact, the principal emergency power resource of the microgrid is the Rock Bottom Dam with a maximum capacity of 1,950 kW. The solar resources include two sets of solar PV planned for the rooftop spaces of YMCA and the City Hall, totaling 280 kW of nameplate capacity.

Table 2-6 Microgrid Generation Resources

Distributed Energy Resource Name	Facility Name	Energy Source	Nameplate Capacity (MW)
Existing Backup Generator	Binghamton City Hall, Police Bureau & Fire Headquarters	*Natural Gas*	0.250
Existing Backup Generator	Binghamton Housing Authority	*Natural Gas*	0.205
200 kW CHP	YMCA (sells City Hall Heat)	Natural Gas	0.200
2 x 50 kW micro CHP	YWCA	Natural Gas	0.100
100 kW Solar PV	YMCA	Solar	0.100
180 kW Solar PV	City Hall	Solar	0.180
Storm Hardened Hydro Plant	Rock Bottom Dam	Hydro	1.950

2.3.2 New DER and Thermal Generation Resources

The principal generation resource is the 1.95 MW of hydro power at Rock Bottom Dam. Additionally, 200 kW of CHP will be installed at the YMCA, and 100 kW of CHP will be installed at the YWCA. Also included in the microgrid are 100 kW of solar PV proposed for the YMCA facility, and 180 kW of solar proposed for the City Hall building.

The YMCA PV space requirement is about 7,036 square feet. The City Hall PV space requirement is about 12,665 square feet (area requirements are calculated by the DER-CAM model based on the PV nameplate capacity sizes and the annual solar irradiance characteristic of the Binghamton region based on the NREL PVWatt database).

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, heating, and cooling load profiles of the aggregate loads of the microgrid facilities.

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

Figure 2-10 below provides a view of the "theoretical" load and supply balance over a weekday of operation on a normal day in the month of September (the month of annual peak load based on the assumed load profiles).

It should be noted that the during the normal operation, it is assumed that the Rock Bottom Dam will operate independently from the microgrid and sell power and other services to the utility or NYISO.

Hence, the DER-CAM model only dispatches the remaining generation units in the microgrid based on the comparative economics of on-site generation versus purchase from the utility. As can be seen, due to having insufficient power in normal days, in addition to the on-site generation, power is also purchased from the utility. We have imposed a requirement that the CHP's run every hour during normal days in order to provide for the thermal needs of their facilities.

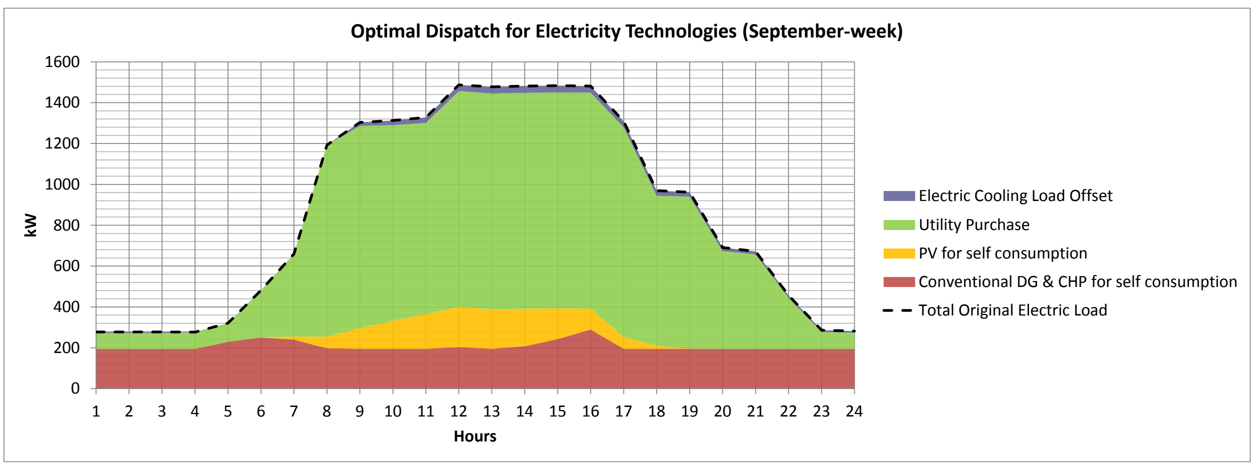

Figure 2-10: Microgrid Optimal Electrical Dispatch – September Normal Weekday

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 CHP units. The yellow colored area is the solar PV production. The green colored area is the additional electric energy purchased from the utility. The very narrow purple colored area on the top is the reduction in the original electrical load (i.e., the Electric Cooling Load Offset) 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.

Figure 2-11 shows the microgrid operation during an emergency weekday in September (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. The bulk of onsite generation (the burgundy colored area) is actually the energy provided by the Rock Bottom Dam. There blank space between the dotted line and the colored area is the load reduction due to Load Curtailment.

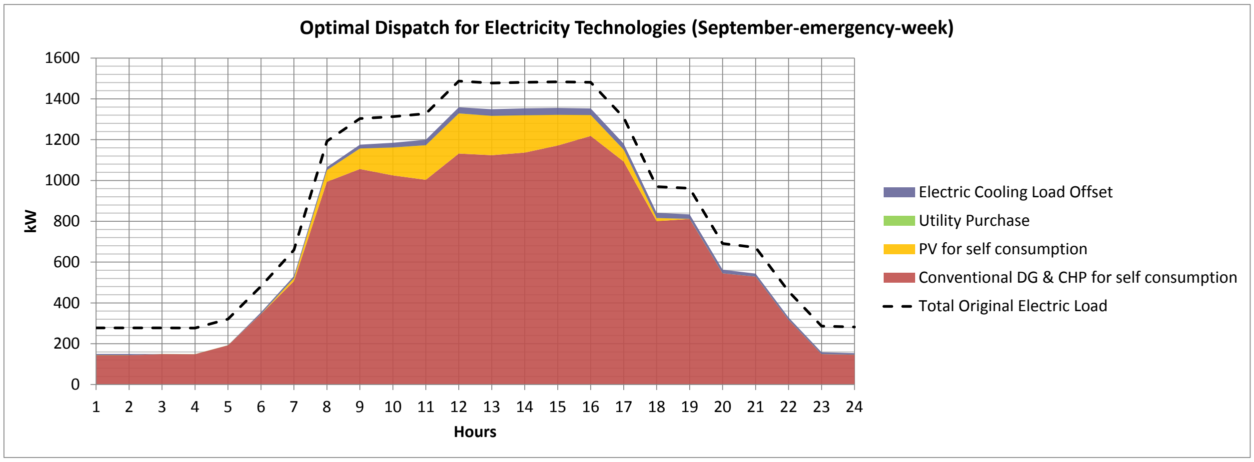

Figure 2-11: Microgrid Optimal Electrical Dispatch – September Emergency Weekday

Figure 2-12 shows the thermal dispatch for heat load during a normal weekday in September. 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 CHP thermal energy that is used to run the absorption chiller, shown in the next figure. As can be seen, at hour 6, all the recovered CHP thermal energy is used to meet the heating load, and as such, not much would be left to be used by the absorption chiller at that hour, whereas, at hours 15 and 16, there is plenty of CHP recovered thermal energy is left after meeting the heating load, which can be used by the absorption chiller.

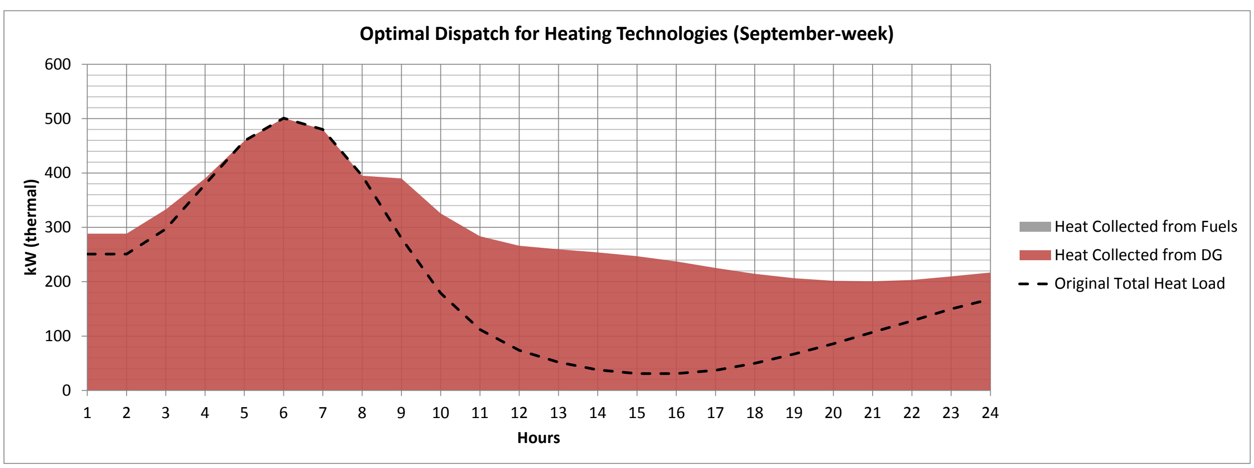

Figure 2-12: Microgrid Optimal Heating Dispatch – September Normal Weekday

Figure 2-13 shows thermal dispatch for cooling load during a normal weekday in September. 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).

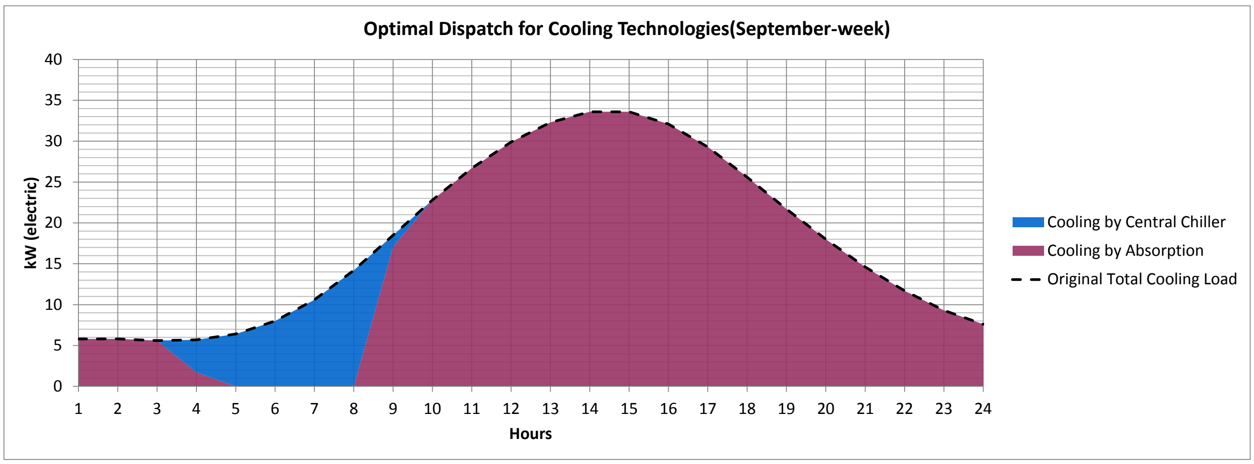

Figure 2-13: Microgrid Optimal Heating Dispatch – September Normal Weekday

2.3.4 Resiliency of DERs and Thermal Generation Resources

The CHP units will be installed above the flood plain of the City Hall and YMCA and are therefore protected from severe weather and flooding. According to the EPA Catalog of CHP technologies[2], reciprocating engine based CHPs have a high availability of 96-98% with hours-to-overhaul period of 30,000 to 60,000 hours, and very fast start time of 10 seconds.

These CHP units, along with the 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. Therefore, supply to the CHP units is not expected to be interrupted in most emergencies (barring seismic activity or sabotage). However, 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 during 4-5 months of the year. However, the 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 existing backup generation at both sites is more than enough to compensate for any energy lost due to

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

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.

2.3.5 Fuel Sources for DERs

The primary source of energy for the Binghamton microgrid is the 1.95 MW of hydro power from the Rock Bottom Dam. Solar PV will supply 280 kW of power, and natural gas will supply 300 kW of power for CHP operations (and if need be, for the operations of the 250 kW and 205 kW backup units).

2.3.6 Capabilities of DERs

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.

New York State and NYSEG 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 fault recovery. This action can be coordinated with the utility operations center if needed.

Connecting DER to a networked system can have many challenges. However, control, communication and protection technologies exist that can allow DER to integrate safely into networks. *IEEE Std. 1547.6-2011 Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Networks* provides a number of options such as load / generation ratio assessment and reverse power monitoring and control to allow integration of DER into networks. For this application, the ratio of load to generation (without the generation from Rock Bottom Dam) is expected to be sufficiently large to minimize impact of DER on the Binghamton network.

The standby natural gas generators located at City Hall and the Housing Authority are capable of operating without the presence of the distribution system which makes them ideal for black-start application. As such, these generators have the ability to maintain real and reactive power balance and can maintain frequency and voltage. Most have the capacity for partial load operation within a range (minimum / maximum capacity ratings). However, upgrades to control and protection equipment may be necessary to allow the generators to feed the larger grid.

Some types of generators are more capable of providing frequency control than others. For the Binghamton microgrid, some assets will provide baseload power while other assets would switch to frequency control mode. The CHP units tend to be better suited to baseload operation than frequency control. For this reason, the majority of fast frequency regulation will come from the Rock Bottom Dam hydro unit and, if necessary, the standby generators. To augment this fast 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 Binghamton microgrid, some combination of these modes will be employed depending on the asset type. For example, the hydro 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 CHP units 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.

While the PV will likely have some advanced functionality such as Volt/VAR control, the dispatchable generation will likely be used to perform the majority of frequency / voltage control. Further study will indicate if the PV will need to be curtailed to maintain stability in islanded operation.

2.4 Electrical and Thermal Infrastructure Characterization

2.4.1 Electrical and Thermal Infrastructure

Due to the microgrid facilities being fed from a network and because of how difficult it would be to isolate critical loads from non-critical loads in an emergency, relying on existing utility infrastructure for the Binghamton microgrid is not feasible. To connect the microgrid facilities together, transfer switches will be installed at each facility which will isolate the facilities from the network during a network outage. The facilities will be transferred to a radial system consisting of newly installed lines/cables that connect only the microgrid facilities/generation sources together. This new infrastructure will be installed in existing conduits which are owned by the city. The proposed new infrastructure is shown in Figure 2-1.

To detect abnormal conditions, and to detect when the grid has returned to normal, CTs/PTs will be installed at several isolations points. To achieve the appropriate selectivity/sensitivity, it is likely some combination of direct instrumentation of isolation points and transfer trip will be used. The appropriate configuration will be determined through further study.

2.4.2 Resiliency of Electrical and Thermal Infrastructure

The primary fuel source for the Binghamton microgrid will be a hardened hydro station located in the nearby Susquehanna River.

To help protect the electrical infrastructure from the elements, the majority of the cables and electrical equipment will be underground. Where the cables are above ground (Figure 2-1), they will be hardened and protected against weather and damage.

The largest risks to the electrical infrastructure are: 1) a widespread transmission outage, such as the 2003 Northeast blackout, 2) failure of the connecting substations, such as during a catastrophic weather event or transformer failure, 3) network collapse from multiple feeder failures, and 4) flooding during server rainstorms.

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 natural gas supply line is also resilient, and will allow the microgrid to be operational for as long as capacity exists. The natural gas distribution system can significantly enhance energy security at domestic military installations during electric grid failures, according to a 2013 study by the MIT Lincoln Laboratory commissioned by the U.S. Department of Defense (DoD).[3] The study assessed the reliability of the natural gas supply system during electric power grid outages and concluded that it is highly resilient to the loss of electricity provided by the conventional power grid. More specifically, natural gas supplies would continue to flow with minimal risk of interrupted deliveries during electric power grid outages of three months or longer.

2.4.3 Microgrid Interconnection to the Grid

Figure 2-2 shows the points of interconnection with the Binghamton network. When not in islanded mode, the microgrid will be fed normally through the network, and the hydro unit will feed into a radial feeder. When entering islanded mode, the microgrid will isolate from the network / utility system via the transfer switches shown in Figure 2-2 and use a dedicated, newly constructed medium voltage system.

Since the hydro unit will be a rotating machine, traditional protection systems based on high currents under faulted conditions may be used. Additionally, since the microgrid infrastructure will not be used in conjunction with utility infrastructure under normal conditions, the need for protection system elements to have multiple set-points / configurations will be minimized.

In addition to overcurrent protection (Functions 50/51), the microgrid protection scheme will likely 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

2.5 Microgrid and Building Controls Characterization

2.5.1 System Control Architecture

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.

[3] http://www.forbes.com/sites/williampentland/2013/06/15/natural-gas-grid-is-key-enabler-for-u-s-energy-security-says-dod-study/#238b14ae669f

- **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 2-14 shows control devices for the proposed Binghamton microgrid as an overlay on the electrical one-line diagram.

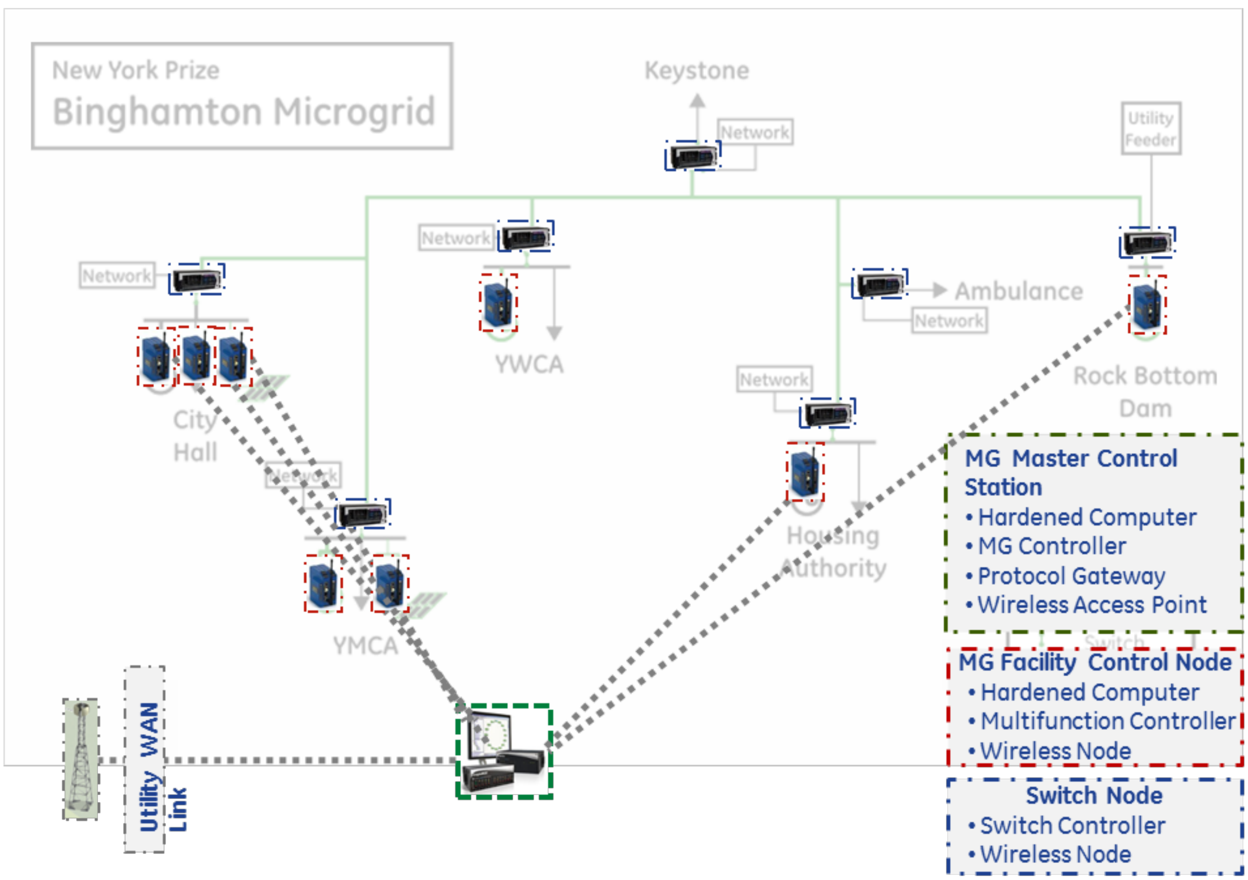

Figure 2-14 Binghamton Microgrid Electrical One-Line Diagram with Control and Communications Overlay

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 CHP gas engines, the solar PV units, and even the backup generation, which will 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. In addition to regulating the generation units a primary task of the Microgrid Master Control Station is to coordinate the switching devices at the boundary of the microgrid. To simplify Figure 2-14 these communication links are not shown.

Some existing generation and new generation units are expected to be equipped with microprocessor-based controllers that can regulate either the natural-gas engines or the inverter-based power conditioning systems. 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.

The local controller devices can interface with the 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 in the economic optimization of microgrid assets. In such cases, it will communicate with building energy management systems to determine and set load set points. At this point it is not clear the energy management systems of which facilities will be included in microgrid optimization. In terms of peak demand, the primary candidate is the City Hall. 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 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. Seamless transition during an unplanned event is not foreseen due to current interconnection rules governing DER operation. However, it is conceivable that a planned seamless transition can be achieved.

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: 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. Using the transfer switches (shown in Figure 2-2), the microgrid facilities will connect to the dedicated microgrid infrastructure. Further study will determine if the individual isolation points will determine the need to disconnect, or if a signal will be sent from the microgrid controller. To achieve the appropriate selectivity/sensitivity, a combination of direct detection of abnormal conditions and transfer trip will be used.

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 will likely be shed to allow seamless transition for the uninterruptable loads on the microgrid. Once the microgrid is established, controllable loads may be used in much the same was spinning reserve generation.

We are proposing to include 10% of the largest three loads in the load shedding scheme, particularly as load curtailment resources during emergency (about 128 kW). Since such demand side resources will be integrated to the microgrid system with metering, monitoring, and control & communications capabilities, they will also be available as demand response resources during normal days.

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.

Any of the standby generators located at City Hall or the Housing Authority are good candidates for black-start. As standby units, these generators are generally capable of operating without a grid connection (maintaining voltage and frequency); however, some upgrades to protection / control equipment may be necessary to allow connection to the larger grid. Additionally, the hydro unit may be capable of black-starting given the prime mover will be available. Using the hydro unit to black-start may simplify configuration since the hydro capacity will allow microgrid load to come online using fewer controls.

Once black-start power is provided via the standby generators, CHP units at the YMCA and YWCA can come online and provide power to the larger microgrid. Finally, if the grid stability is sufficient, the PV units located at City Hall and the YMCA can connect to the grid.

Performing economic dispatch and load following

The Binghamton microgrid will provide load following during emergency periods utilizing the both the flexible Rock Bottom Dam and the new CHP units.

The economic dispatch of the microgrid resources 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 hydro and solar generation), and the microgrid generation unit efficiencies and constraints, fuel prices, and variable operations and maintenance (VOM) costs. However, under most circumstances, the hydro generation alone may be sufficient to meet all the microgrid loads and there may be no need for economic dispatch in most periods.

During normal days, each individual facility will be on its own. Those with onsite generation can meet some or most of their electrical and thermal needs by the CHP units. Surplus energy can be sold back to the grid. Others facilities lacking onsite generation, will be purchasers of power from the utility.

It is plausible to assume that at some future point in time, a more complex decision process will determine the microgrid generation 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 Figure 2-10 for example). However, because there is only a small amount of microgrid generation resources relative to the original microgrid load during normal days - due to Rock Bottom Dam operating outside the microgrid) - Figure 2-10 cannot show the full extent of interplay of onsite generation versus utility purchase).

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 128 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 is a critical requirement, then storage may be option. At this stage of analysis, the cost vs benefit analysis is not definitive enough for the stakeholders to request this feature be incorporated into the microgrid.

The team does not believe NYSEG has established a definitive value for energy 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

For the Binghamton microgrid, a large portion of the generation will be hydro (roughly 1.95 MW). This will provide a lot of base-load generation, but it will also be able to respond to changes in load. If study shows that additional fast acting generator is needed, the natural gas standby units located at City Hall and the Housing Authority will 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. The CHP located at the YMCA and YWCA will be used primarily as base load generation.

For reactive power / voltage control, all 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 2-14. The total nameplate capacity of PV installations is 280 kW, close to 19% of the peak load.

Given the relative size of the Rock Bottom Dam generation, and other generation and load curtailment resources, forecasting of solar power 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 online microgrid 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 Team may consider another layer of protection that 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 City of Binghamton 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 a facility control node regulates, 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

Standard industrial-grade control and communication devices can withstand extreme operational temperatures (-40º C to +70º C) and 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 (e.g. fiber optic network), for the microgrid communications backbone a wireless field network is proposed as shown in the Figure 2-14.

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 with or without BEMS integration. At least the control node at the City Hall will integrate with the existing building management system. Communication with the master control station is achieved through 900 MHz or WiMax field network. The wireless communication links to the switchgear devices are not shown in the figure.

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, IEC61850, and Ethernet 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.

If the utility communications network is considered external to the microgrid communications network, an interposing server will be utilized to provide for controlled information flow. Firewalls will be utilized between the microgrid network and the interposing server and between the external link and the interposing server to provide enhanced cyber security for this link.

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.

3 ASSESSMENT OF MICROGRID'S COMMERCIAL AND FINANCIAL FEASIBILITY

The City of Binghamton is considering a potential municipal bond offering to pay for all or a portion of the shared transmission and distribution (T&D) infrastructure required to construct the proposed Binghamton Community Microgrid project. Assuming the City issues bonds and uses the proceeds to construct the microgrid, the City of Binghamton would transfer title to and operating control over the shared T&D assets to a Special Purpose Vehicle (SPV) under a long-term lease agreement.

A subsidiary of the New York State Electric and Gas (NYSEG) would own a controlling equity stake in the SPV and would thus retain operating control over the microgrid's T&D infrastructure assets. Under the lease agreement, the SPV would maintain title to and operating control over the microgrid's T&D assets. Although the microgrid SPV would own the microgrid's T&D assets, it would not own the distributed energy resource (DER) assets connected to the microgrid. The DER assets would be owned and operated by customers and/or third parties.

The SPV would collect revenues from the following aspects of the microgrid's operations:

- Distribution network use of system (DNUoS): The microgrid's primary source of DNUoS revenues would be generated by bilateral supply contracts executed between microgrid customers but using the microgrid's T&D assets during normal operations.
- Resiliency reserve: An incentive mechanism that paid the microgrid owner a small-fixed fee for the total installed capacity connected to the microgrid and capability of operating during grid outages. Under the resiliency reserve incentive, the microgrid would also be eligible to earn performance-based payments for operating during grid outages or disruptions. The incentive would be collected by the local utility from non-microgrid customers that benefit from the microgrid during an outage.
- Wholesale capacity payments: microgrid owner could participate in wholesale capacity market on behalf of microgrid generator and receive either a portion of the proceeds from capacity payments or an administrative fee.
- Ancillary or grid-edge services: 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.

In addition to these revenue streams, the SPV would collect a resiliency surcharge from the microgrid customers which would be structured to avoid under or over-collection of revenues.

3.1 Commercial Viability - Customers

3.1.1 Individuals Affected

The proposed microgrid will serve a mixed group of large commercial and municipal customers, many of which would experience some loss of power outage without the proposed microgrid. In the event the critical loads served by the microgrid went unserved, at least 50,000 individuals would potentially be affected, which is the estimated population served by the facilities owned by the Binghamton Police and Fires Department and served by the microgrid during a grid outage.

3.1.2 Direct/Paid Services

The microgrid SPV would provide the following potential services to customers:

- Facilitate peer-to-peer transactions in the form of bilateral supply contracts executed between microgrid customers but using the microgrid's T&D assets during normal operations.
- Demand response, including Energy Capacity Reserves Regulation
- In NYISO, there are certain restrictions on the use of on-site generation for reliability programs, such as the ICAP/SCR program. A Local generator that is normally operating to partially serve its Load may participate in the program with incremental capacity that is available to operate at the direction of the NYISO in order to reduce the remaining Load being supplied from the transmission or distribution system. Any incremental capacity in excess of the total host load is not eligible to sell into the NYISO markets. However, excess energy may be eligible to be sold to the local distribution utility through a retail tariff. The resource with a local generator should have an integrated hourly meter that is either installed to measure the output of the generator or interval metering of the total net load.[1]
- Wholesale capacity payments: microgrid owner could participate in wholesale capacity market on behalf of microgrid generator and receive either a portion of the proceeds from capacity payments or an administrative fee.
- Ancillary or grid-edge services: 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.

The operation of the microgrid would provide the following potential *indirect benefits* to the NYISO and/or local utility:

- Optionality value for future T&D planning: In many markets, demand side resources are successfully being used to provide resource adequacy and meet reliability criteria.

The operation of the microgrid would provide the following potential *indirect benefits* to the NYISO:

- Greater visibility into the distribution grid.

[1] DNV GL,

3.1.3 Microgrid's Expected Customers

The microgrid will provide power to the following facilities during a grid outage: Binghamton Housing Authority; Binghamton City Hall; Binghamton Police Bureau; Binghamton Fire Headquarters; YWCA; YMCA; Superior Ambulance; and, Keystone Associates.

The microgrid customers listed below are expected to purchase electric and/or thermal services from other microgrid customers using the microgrid's network assets for delivery.

- YMCA has 200 kW of CCHP and will sell hot water (summer and winter) and chilled water (summer) and electricity to City of Binghamton City Hall.
- YWCA has 100 kW of micro-CHP and will sell electricity to other microgrid facilities.
- Gravity Renewables is planning to acquire Rock Bottom Dam and install a 1.95 MW storm hardened hydroelectric plant at the site, which will be connected to the microgrid. The Rock Bottom hydro facility will sell power to the City of Binghamton at rates projected to deliver an estimated $200,000 in annual electricity savings.

3.1.4 Microgrid's Stakeholders

Key participants and critical facility partners in the project include the City of Binghamton Police and Fire Departments, City Hall, Superior Ambulance, both the YMCA and YWCA, Binghamton Housing Authority (senior living apartments) and Keystone Associates. The proximity of additional facilities to the microgrid network, including the Twin Rivers Student Housing Complex and the Holiday Inn, as well as senior housing and low-income apartments, will augment the project's value as a place of refuge for the community. Many of those facilities may be considered for connection to the microgrid in the future, as well as other nearby government-owned facilities. The County and State Building, which are both located near City Hall, are also potential candidates for expanding the microgrid project.

3.1.5 Relationship between Microgrid Owner and Customers

The owner of the microgrid – or, the microgrid SPV – will only have legal title and operating control over the microgrid's T&D assets. The power generating assets and any related behind the meter equipment will be owned directly by the customers or third-party entities partnering with the customer.

3.1.6 Customers During Normal Operation vs. Island Operation

The microgrid will provide power to the following facilities during a grid outage: Binghamton Housing Authority; Binghamton City Hall; Binghamton Police Bureau; Binghamton Fire Headquarters; YWCA; YMCA; Superior Ambulance; and, Keystone Associates.

The microgrid customers listed above in Section 3.1.3 are expected to purchase electric and/or thermal services from other microgrid customers using the microgrid's network assets for delivery.

During normal operation ("grid-connected mode"), individual facilities with CHP units will be supplying the majority of their own electrical and thermal needs, subject to daily and seasonal variation. The 200-kW CHP unit at the YMCA can supply most of the YMCA's electric demand, most of the YMCA's thermal demand, as well as portion of the thermal and electric demand for City Hall (via a contractual arrangement). The 100 kW of CHP at the YWCA can supply most of its electrical and thermal needs, depending on the time-of-day and season. The YWCA will also export electricity to other facilities (such as Superior Ambulance) pursuant to a Power Purchase Agreement. The 280 kW of solar PV located at City

Hall and YMCA will partially offset the electric demand of those individual facilities. Any shortfall in electrical supply is made up by the grid. Any shortfall in thermal supply is made up by existing thermal equipment.

During emergency operation ("island mode"), the microgrid facilities will be able to collectively share the CHP generation, solar PV, any backup generation that is brought online, and the 1.95 MW from the Rock Bottom Hydro Dam. The microgrid customers without microgrid generation assets would purchase power from Rock Bottom Dam under a contractual arrangement. The microgrid customers with generation assets would supply some or all of their own demand, and either purchase power from Rock Bottom Dam (if there is a shortfall) or sell excess to other microgrid facilities. The microgrid customers with CHP units will continue to supply all or a portion of their own thermal needs; YMCA would continue to provide thermal services to City Hall.

3.1.7 Contractual Agreements

Grid-connected Mode Contracts: The microgrid SPV will be assigned legal title to the capacity payments associated with any power generating assets connected to the microgrid. In addition, the microgrid SPV will have contracts in place for wheeling any power supplied by one microgrid customer to another microgrid customer, including the DNUoS charges paid by the parties to a bilateral supply contract.

Island Mode Contracts: During a black out event, the CHP, and solar PV will be dispatched first and if needed the backup generators of Binghamton Housing Authority and City of Binghamton will come online to satisfy any remaining loads.

3.1.8 Customer Solicitation and Registration

The microgrid has already recruited the following facilities as customers for power during a grid outage: Binghamton Housing Authority; Binghamton City Hall; Binghamton Police Bureau; Binghamton Fire Headquarters; YWCA; YMCA; Superior Ambulance; and, Keystone Associates.

The microgrid will solicit additional customers by issuing Request for Proposals for procuring power and demand side resources from existing and potential customers of the microgrid. Potential customers include nearby County and State office buildings.

3.1.9 Other Energy Commodities

Hot water, chilled water, and electricity are the commodities that will be sold to the microgrid customers, as described earlier in Section 3.1.3.

3.2 Commercial Viability – Value Proposition

3.2.1 Community Benefits and Costs

Community Benefits: The primary benefit provided by the proposed Binghamton Community Microgrid is the enhanced resiliency of City of Binghamton's critical facilities during emergencies. The project will greatly improve the availability of critical services during emergencies and grid outages.

Community Costs: The cost of the microgrid can be divided into two components: (1) the cost of constructing the microgrid's T&D infrastructure and (2) power generating and associated costs. For this project, the T&D assets are estimated to cost about $ 1.6 million and the generating assets are estimated to cost about $ 5.4 million. Under the proposed resiliency reserve mechanism, community members that would be served by critical facilities during a grid outage would pay the microgrid owner a small-fixed fee for the total installed capacity connected to the microgrid and capability of operating during grid outages. The same community members would be required to pay performance-based incentives to the microgrid owner for operating during grid outages or disruptions. The resiliency reserve incentive would be collected by the local utility from non-microgrid customers that benefit from the microgrid during an outage.

3.2.2 Benefits to the Utility

The proposed microgrid is expected to provide the utility with peak load support. In the immediate future, the microgrid is not expected to defer any specific transmission or distribution investments or upgrades since the two network feeders serving microgrid facilities are loaded to less than 3 MW at peak. However, the microgrid will provide the utility with additional flexibility for managing the electric system in the future.

3.2.3 Proposed Business Model

The City of Binghamton is considering a potential municipal bond offering to pay for all or a portion of the shared transmission and distribution (T&D) infrastructure required to construct the proposed Binghamton Community Microgrid project. Assuming the City of Binghamton issues bonds and uses the proceeds to construct the microgrid, the City of Binghamton would transfer title to and operating control over the shared T&D assets to a Special Purpose Vehicle (SPV) under a long-term lease agreement.

A subsidiary of the New York State Electric and Gas (NYSEG) would own a controlling equity stake in the SPV and would thus retain operating control over the microgrid's T&D infrastructure assets. Under the lease agreement, the SPV would maintain title to and operating control over the microgrid's T&D assets. Although the microgrid SPV would own the microgrid's T&D assets, it would not own the distributed energy resource (DER) assets connected to the microgrid. The DER assets would be owned and operated by customers and/or third parties.

The SPV would collect revenues from the following aspects of the microgrid's operations:

- Distribution network use of system (DNUoS): The microgrid's primary source of DNUoS revenues would be generated by bilateral supply contracts executed between microgrid customers but using the microgrid's T&D assets during normal operations.
- Resiliency reserve: An incentive mechanism that paid the microgrid owner a small-fixed fee for the total installed capacity connected to the microgrid and capability of operating during grid outages. Under the resiliency reserve incentive, the microgrid would also be eligible to earn performance-based payments for operating during grid outages or disruptions. The incentive would be collected by the local utility from non-microgrid customers that benefit from the microgrid during an outage.

- Wholesale capacity payments: microgrid owner could participate in wholesale capacity market on behalf of microgrid generator and receive either a portion of the proceeds from capacity payments or an administrative fee.
- Ancillary or grid-edge services: 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.

In addition to these revenue streams, the SPV would collect a resiliency surcharge from the microgrid customers which would be structured to avoid under or over-collection of revenues.

The business model envisions the microgrid owner serving as a “network coordinator” or “microgrid coordinator” that incentivizes customers to provide the highest value energy supply, load management, or ancillary services to the microgrid system by providing differentiated price signals. The Microgrid Coordinator’s role would closely resemble that of a wholesale grid operator and would provide highly differentiated price signals to direct investments by other service providers.

Table 3-1 Microgrid SWOT

Strengths	Opportunities
Modular	Expand generating capacity
Heterogeneous power quality	Expanding renewables market
Reliable power (even during grid outage)	Avoided T&D investments
Flexible architecture	Inverter and storage innovation
Multiple ownership models	Interconnect with additional customers
Diverse applications	Plug in hybrids
Weaknesses	**Threats**
Incentives diffuse	Technical obsolescence
Unclear road map	Lack of clear standards
Fragmented regulation	Competing business models
Utility safety concerns	Stranded assets

3.2.4 Site Characteristics

The inclusion of a micro-hydro facility at Rock Bottom Dam is another unique element of this project, and should improve the economic prospects of the microgrid. In islanded mode, the hydro generation is expected to be available to support the microgrid load (or at least a critical subset of the load). If there was an event whereas natural gas supply stopped, Rock Bottom dam could power the entire microgrid.

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.

3.2.5 Replicability/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. In addition, there is an extensive city-owned conduit system in the downtown area. Duct space is leased to NYSEG, but the city also has the capacity to run its own lines. Besides the facilities included in the project, there are number of other critical facilities within a 1000-foot radius of City Hall. These include the nearby State and County Office buildings, a Holiday Inn with a significant thermal load, the Twin River Commons Student Housing Complex, and Veterans Memorial Arena that is capable of sheltering thousands of residents in an emergency. There are also a number of other student residencies and senior apartments nearby that are reachable via the city-owned conduit system.

The microgrid site is in an area of down-town Binghamton served by a secondary network system. There are many of these types of systems across New York State, particularly in upstate New York and New York City. These systems typically employ network protectors to prevent reverse flow onto the primary feeders (back-feed). Behind-the-meter DERs on the network system may be prevented from exporting power to the grid, particularly if they are on a dedicated spot network or on a small secondary network. This project allows the utility and the stakeholders to identify and deploy designs, technologies, and operating rules that would allow it to be replicated on other network systems.

3.2.6 Purpose and Need for Project

In the event of future natural disasters leading to electric outages and a loss of thermal support within the City of Binghamton, this proposed microgrid would allow the Police Department, Fire Department, City Hall and Superior Ambulance to operate and aid City residents and businesses. The proposed CHP 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 extremely reliable and is un*likely* to be compromised by anything other than a transmission system failure, substation failure, or network collapse. NYSEG has stated that in the most recent major flood their network system was still energized, but individual facilities had to be taken off the network because their ground or basement level service connections were compromised. Even though the network in general is very reliable, individual facilities on dedicated transformers served by a single feeder, such as YMCA and BHA, can experience lengthy outages due to faults on individual feeders. In fact, the operating history provided by NYSEG shows several lengthy outages over the last six years that interrupted hundreds of customers on the network feeders.

The microgrid is designed to be resilient to major grid outages and shutdowns (such as those precipitated by flooding), as well as shorter blue-sky events. The new delivery infrastructure will be hardened (using submersible underground (UG) construction or selective overhead (OH) runs) and generation assets and service connections will be installed on elevated floors. The in-building circuit connections will be configured such that the microgrid generation can serve upper (livable) areas of facilities even if basements and ground-level areas are flooded.

An important part of this project is the storm hardening of the buildings. In the event of a flood a transfer switch would de-energize the basement levels and maintain power on the ground and upper floors, allowing the building to continue to operate as normal. The buildings' boilers are located on the upper floor, except for those with CHP. CHP was installed in buildings with basement boiler systems so that the CHP will provide heat when those boilers are under water.

3.2.7 Value Propositions

Electricity purchaser:

Community: The City of Binghamton Police and Fire Departments, located at City Hall, are key participants in the Community Microgrid project and have a key role in providing emergency-management services to the City of Binghamton. In the event of a natural disaster, both the Police and Fire departments will be able to provide these services. Providing these departments with the capability to operate in the event of a natural disaster is extremely critical to the resiliency and safety of the City of Binghamton. The City Hall, YMCA, YWCA, Superior Ambulance, BHA, Keystone Associates and are all business participants in the Binghamton Community Microgrid. The YMCA, YWCA, and Binghamton Housing Authority provide subsidized housing to the City. Superior Ambulance is a for profit company that delivers key services during all weather and emergency events. These facilities are critical for ensuring public safety. These businesses are participating to provide services to aid in the resiliency of the City and to create efficiency in the proposed microgrid.

Suppliers and partners: The microgrid will accelerate and potentially facilitate the installation of several distributed generation projects. It will also create opportunities for distributed generating assets to pursue bilateral supply contracts.

Utility: 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.

NY State: 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 provide a platform for implementing the REV framework.

3.2.8 Added Revenue Streams, Savings and Costs

The cost of the microgrid can be divided into two components: (1) the cost of constructing the microgrid's T&D infrastructure and (2) power generating and associated costs. For this project, the T&D assets are estimated to cost about $1.6 million and the generating assets are estimated to cost about $5.4 million. The energy cost savings will be used to pay for the cost of the generating equipment. The primary revenues streams used to pay for the T&D costs will be capacity payments, program administration fees and DNUoS charges collected in connection with bilateral supply contracts.

T&D Infrastructure: Assuming a 20-year life of the investment and a discount rate of 12%, the annual levelized payment on the initial combined $7 million investment is estimated to be about $840,000 per year.[2]

[2] These estimates do not reflect the potential impact of accounting rules associated with capital cost recovery.

Capacity payment: there are various capacity auctions in NY and the clearing prices can vary from one auction to another, from one locality to another. Based on the recent (historical) monthly spot market weighted average clearing prices, a reasonable assumption for Binghamton would be in the range of ~$3/kW-month escalating with inflation (2% annual is a reasonable planning assumption): multiply $3.00 by the kW of capacity to be bid into the market by 12 months per year [$3.00 x total kW x 12 months]. This also assumes that the microgrid's capacity bids would clear the auction and receive the market clearing price.

DNUoS: NYSEG's Distribution charges typically vary by voltage level by customer class and often include multiple charges and fees. Also, if these DNUoS charges are intended to recover the costs associated with use of the microgrid, a more detailed analysis is required to understand the costs before an allocation mechanism or rate structure can be determined.

Program administration: This charge would be collected to recover the general and administrative expenses of the microgrid itself (staffing, software, accounting, billing, etc.), so those costs would need to be estimated.

In addition to these revenue streams, the Project Team will identify 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 include estimation of avoided costs of power interruptions for different facilities within the microgrid.

3.2.9 State Policy Objectives

NY REV Framework: Microgrid will potentially enable the active and dynamic scheduling of local generating assets so as to maximize the economic efficiency and technical reliability of the microgrid and the surrounding system. The microgrid will also serve as a platform for communicating 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.

NYS Renewable Portfolio Standards: The distributed hydro facility at Rock Bottom Dam as well as other generating assets connected to the microgrid will increase renewable energy used in New York State and reduce greenhouse gas emission.

3.2.10 New Technology

Innovative characteristics of the envisioned Binghamton Community 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. By leveraging the microgrid controller, the microgrid SPV 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 Current Status and Securing Support

The microgrid has already recruited the following facilities as customers for power during a grid outage: Binghamton Housing Authority; Binghamton City Hall; Binghamton Police Bureau; Binghamton Fire Headquarters; YWCA; YMCA; Superior Ambulance; and, Keystone Associates.

The Project Team has relied on the following engagement strategies for managing stakeholders in connection with the proposed microgrid:

- 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.

3.3.2 Team Members Roles

The project developers include Keystone Associates, 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.

The effective customer will become the City of Binghamton. They will be the champion of this microgrid. City of Binghamton owns most of the underground T&D conduits and wires we will be using for this project. City of Binghamton will be one of the main faces of this project. City of Binghamton can also assist in the financing endeavors of this project.

An Engineering firm or Developer (ASI Energy or other) will operate as the Prime Contractor and Project Manager. The Project Manager contractor will manage communications, bid out the project, establish a project management plan and fill any resource gaps for this project as appropriate. The Project Manager will also execute the financial model for this project.

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.

A project engineer will be Keystone Associates, having first right of refusal to execute all appropriate engineering services, given Keystone Associates is on a cost share for Stage 1 they will be allowed to bid 15% higher than the competition to recoup those expenses in the effort of being awarded the Engineering

RFP. In the event Keystone Associates cannot compete here, Keystone Associates will be retained as a project engineering consultant.

A third party commissioning engineering agent may be selected via RFP process to commission the system. The mechanical, electrical, plumbing, carpentry, structural, rigging, controls, HVAC, tin knocking, masonry, and other associated "trade" contractors will be selected on a basis of most qualified and within the bidding amounts of the remaining contractors. This will be a formal bidding process including sealed bids, measures taken to reduce bid-rigging, Pugh matrix selection, and other bidding best practices. Special inspectors, City Building Department Officials NYSEG officials, NYSERDA and other stakeholders will be managed and contracts administered by the Project Manager. Major technology such as controls, CHP, chillers, cooling towers, will be selected by submittal process, RFP, and a Pugh decision matrix similar to that of selecting trade contractors. All vendors will be under contract with the Project Manager except the third party commissioning agent which will be under contract with YMCA and YWCA, to prevent conflict of interest. Rock Bottom dam will have a contract with City of Binghamton for supplying energy likely through MEGA, and also a contract with the Project Manager to facilitate physical connection of Rock Bottom Hydro to the microgrid.

3.3.3 Public/Private Partnerships

Public/private partnerships are a possibility with the proposed microgrid. As a governmental entity, the City of Binghamton has bonding authority that could be used to access financing on more favorable terms than would otherwise be available to a purely private applicant. The City is also installing solar PV on government-owned buildings, which will be connected to the microgrid.

3.3.4 Letter of Commitment

The applicant does have a letter of commitment from the utility and it was submitted as part of the initial proposal to NYSERDA.

3.3.5 Applicants Financial Strength

Moody's Investors Service recently assigned an A2 credit rating to Binghamton, NY's $10.3 million Public Improvement Serial Bonds - 2016. The A2 rating reflects the City of Binghamton's moderately-sized tax base with significant institutional presence and lower than average wealth levels. The rating also reflects adequate General Fund reserves, ongoing negative net assets in the enterprise funds and a high debt burden. The stable outlook reflects the likelihood that the City of Binghamton's General Fund financials will remain stable, and the negative position reported in the enterprise funds will continue to improve.[3]

3.3.6 Qualification and Performance Record(s)

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

[3] https://www.moodys.com/credit-ratings/Binghamton-City-of-NY-credit-rating-600025520

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.

Keystone Associates Architects, Engineers and Surveyors, LLC ("Keystone") is a multi-disciplinary design firm headquartered in Binghamton, New York, the heart of the Upstate Region. Keystone was established in 1993 and has provided professional design services for a region encompassing all of Upstate New York, as well as Northeastern Pennsylvania. Keystone provides an extensive menu of professional services such as: Architecture, Civil Engineering, Surveying, MEP, Structural Engineering, Geotechnical Engineering, Environmental Engineering, Pavement Management, Construction Management, Sustainability Management, Interior Design, Material Testing to a broad range of clients including municipalities, private developers, school districts, housing authorities, college and universities, utility companies and various other commercial and industrial enterprises.

3.3.7 Contractors and Suppliers

The project developers include Keystone Associates, ASI Energy and GE Energy Consulting. These are the only selected project vendors at this time. Additional vendors will be filtered through a RFI process. The project team will select the most qualified CHP 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.

CHP vendors will be selected to build and operate the CHP 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 Project Financers or Investors

The City of Binghamton is evaluating a potential bond offering to finance all or a portion of the shared T&D assets required to construct the proposed microgrid project.

3.3.9 Legal and Regulatory Advisors

ASI Energy has engaged Brookside Strategies, LLC as a legal and regulatory advisory services firm based in Kennebunk, Maine in connection with the proposed project. ASI Energy and GE Energy Consulting have an on-going relationship with the NYS PSC.

3.4 Commercial Viability – Creating and Delivering Value

3.4.1 Microgrid Technologies

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 CHPs, then CHP options were selected. In such cases, the recovered CHP thermal energy would replace the boiler thermal energy production.

The absorption chiller option was added for the potential to supply 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 & maintenance costs, and variable operations & 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 CHP 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.

3.4.2 Applicant or Microgrid Owner Assets

Rock Bottom dam should be in service about the time the microgrid is complete. The City of Binghamton owns the underground conduit system that can be leveraged for this project. The YMCA likely has a cooling tower that could be used to reject heat from the (future) absorption chiller, although this remains to be seen. Other than the two existing backup generators, the microgrid does not intend to use any additional incumbent generating equipment.

3.4.3 Balanced Generation vs. Load

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.

Both City Hall and BHA have backup 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.

For the Binghamton microgrid, the hydro plant would likely provide baseload power but it is also capable of fast frequency regulation and load following. The CHP units tend to be better suited to baseload operation than frequency control. If needed fast frequency regulation can also come from the standby generation at City Hall and BHA. To augment this fast frequency regulation, load must also be controlled. The microgrid controller will be integrated with the City Hall BEMS as well as control systems at the YMCA and YWCA to enable fast load shedding. Additionally, it may be necessary for solar production to be curtailed under some circumstances.

3.4.4 Permits/Permissions

In general, the projects proposed as part of this microgrid projects are not likely to pose unique permitting or related challenges. Solar PV and CHP have been deployed widely across New York State. The project development cycle for solar and CHP projects is well understood and the permitting procedures are generally well established. Since the City owns the underground conduit system, the Project Team does not anticipate any unique permits required to construct the microgrid.

3.4.5 Project Development, Construction and Operations

The microgrid would be organized as an SPV for designing, building, owning, operating and transferring (DBOOT) the microgrid assets for microgrid customers. Individual generating projects would also likely be constructed under a DBOOT model.

In each project, 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. At the end of the ESA, ownership of the microgrid assets would transfer and vest to the customers.

3.4.6 Benefits Passed to Community

Community members will benefit from the microgrid by receiving essential services during emergencies and grid outages, when those essential services would otherwise be adversely impacted.

3.4.7 Utility Requirements

The utility may need to operate the T&D assets used by the microgrid SPV during normal and critical/emergency days. The utility may also need to maintain the T&D assets.

3.4.8 Demonstrated Technologies

The technologies proposed in this microgrid project are technologically mature. CHP 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. CHP and solar PV have been deployed together in microgrid systems. 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.

In 2014, a case study of the Sendai microgrid in Japan prepared by the NEDO organization, emphasized the critical role of fuel diversity for supporting microgrid operations during a prolonged outage. The study stated that: "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."[4]

The Microgrid Control design in Stage 2 might 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 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 is currently being tested at NREL and will be applied at a microgrid site in Potsdam, NY. The U90Plus algorithm is being incorporated into the D400 controller, and this solution will be deployed in mid-2016 in 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 200 ms to 400 ms 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 in 2015.

3.4.9 Operational Scheme

The business model envisions the microgrid SPV serving as a "network" or "microgrid" coordinator that incentivizes customers to provide the highest value energy supply, load management, or ancillary services

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

to the microgrid system by providing differentiated price signals. The SPV would potentially play the role of the wholesale grid operator, providing highly differentiated price signals to direct investments by other service providers.

The corporate governance system used by the SPV would reflect all legal and regulatory requirements, including state and federal standards of conducts for utility-affiliate transactions, Generally Accepted Accounting Principles and any financing covenants.

3.4.10 Customer Metering and Charges

Under the unbundled utility microgrid model, the Microgrid Coordinator only owns the microgrid's distribution infrastructure. It does not own the distributed energy resources assets. As a result, it would not receive revenues generated by the DER assets participation in demand response, energy sales and so forth. However, in lieu of these revenue streams, the Microgrid would be able to recover its capital investment in three ways.

- The microgrid could also expand customer choice and enable more efficient end-use by providing networked smart devices together with web access to real-time energy data.
- The Operations (OPS) Center would also facilitate integration of distributed back-up and renewable generation and energy storage technologies to reduce reliance on peaking power plants and reliability must run contracts, to lower emission, and avoid the cost of relieving grid restraints.
- The Microgrid Coordinator could also generate revenues by offering a suite of ancillary and distribution grid support services, including revenues from the following potential *grid edge services*: Network Voltage Data Service; Synchrophasor 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.[5]

3.4.11 Replication Plans

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.

3.4.12 Barriers to Market Entry

The proposed barriers to entry for microgrid participants are primarily financial. Microgrid customers must pay for the shared T&D assets required to construct and operate the microgrid. To the extent that the microgrid does not generate sufficient revenue to pay the costs of the additional T&D assets, the customers must pay those costs.

3.4.13 Overcoming 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. The Project Team will work with the Utility to prioritize and

[5] See Appendix 7 to 2015 Boothbay Harbor Pilot Filing.

develop markets which use resources that improve system efficiency and utilization, support consumer engagement, provide dynamic load management and ensure environmental benefits. These may include: 1) price-responsive resources that reduce or shift usage from the utility grid in response to price signals in order to avoid demand charges; 2) operating resources that provide energy or grid services in response to price signals for services provided; and 3) delivery resources that provide energy or grid services based on utility dispatch.

3.4.14 Market Identification

Please refer to the following provision 3.5 – Financial Viability

3.5 Financial Viability

3.5.1 Categories of Revenue Streams

The Community Microgrid is able to provide generation/load reduction to support a substation during critical periods (alternative to distribution-system reinforcement); to island or reduce peak demand as a DR service; to export power as a generation service; to provide grid-restoration (black-start) services; to maintain critical loads during an extended outage; to provide local voltage/VAR support, reactive power, short-term substation relief, and emergency services.

Revenues from DNUoS Charges

The incremental capital investment in T&D infrastructure could be recovered through DNUoS charges paid by microgrid customers. DNUoS charges are used by some distribution utilities to recover their infrastructure investments in network operation and maintenance. The additional costs associated with the microgrid could be compared to the costs associated with upgrading the physical assets on the network by increasing capacity of existing lines or adding new circuits. DNUoS charges provide a framework for allocating the incremental cost of establishing a microgrid based on how each of the microgrid's customers use of the microgrid's distribution assets affects the total system cost.[6]

Revenues from Program Administration

The Microgrid Coordinator could collect administrative fees for managing market transactions, including bilateral contracts between specific microgrid customers and transactions between DER assets and grid operators, including participation in demand response programs. Similar to aggregators, the Microgrid Coordinator could issue a Request for Proposals (RFP) to solicit bids from demand and supply-side energy resources in the market, evaluate the bids, and, subject to the PSC's review, execute contracts for resources. The Microgrid Coordinator would also monitor and enforce the performance of those resources.

Revenues from Active Network Management (ANM)

The Microgrid Coordinator could substantially augment the potential value the microgrids provided to the electric system. For example, the OPS Center would facilitate geo-targeted investments in distributed energy resources to avoid or defer the cost of future transmission upgrades and expansions, and to reduce the need for more generation resources by enabling greater use of non-transmission alternatives (NTA) resources to avoid or defer major capital expenditures. The OPS Center could be equipped with the

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[6] See Ignacio Perez-Arriaga and Ashwini Bharatkumary, *A Framework for Redesigning Distribution Network Use-of-System Charges Under High Penetration of Distributed Energy Resources* (2014).

requisite network interfaces and communications protocols to receive status updates from utility grid operators with respect to loads on key circuits in those regions where NTA resources are deployed and, when the loads begin to approach critical levels, orders demanding specific levels of load reductions. Based on region-specific dispatch algorithms, the OPS Center will dispatch NTA resources that can be actively controlled.

3.5.2 Other Incentives

- Renewable Portfolio Standards
- Greenhouse gas emissions credits
- PON 2568 CHP Acceleration Program
- NYSERDA's Consolidated Funding Application (CFA) program
- Federal, state and local incentives for solar
- Federal investment tax credits
- Bonus depreciation rules

3.5.3 Capital and Operating Costs

There are two categories of capital costs: T&D assets and the power generating assets. The estimated capital cost of the T&D assets is $1.635 million. The estimated capital cost of the power generating assets is $5.371 million. The operating costs of the power generating assets will be borne by the asset owners.

3.5.4 Business Model Profitability

The Resiliency reserve mechanism will ensure the microgrid SPV has sufficient cash flow available to pay monthly debt service on T&D investment.

3.5.5 Financing Structure

The City of Binghamton is considering a bond offering to finance the incremental investment in infrastructure. Credit enhancement may be needed to secure a higher credit rating.

3.6 Legal Viability

3.6.1 Proposed Project Ownership

The microgrid SPV will hold title to the T&D infrastructure assets, which will potentially be financed with municipal bonds. The distributed generation and other demand side resources located behind the customer meter will be owned by customers directly. This ownership arrangement could be characterized as an "unbundled utility microgrid."

In particular, NYSEG would own a majority stake in the SPV created to own and operate the microgrid system. The SPV would be used to "ring fence" the microgrid's T&D assets to insulate ratepayers not served by the microgrid from potential operating risks.

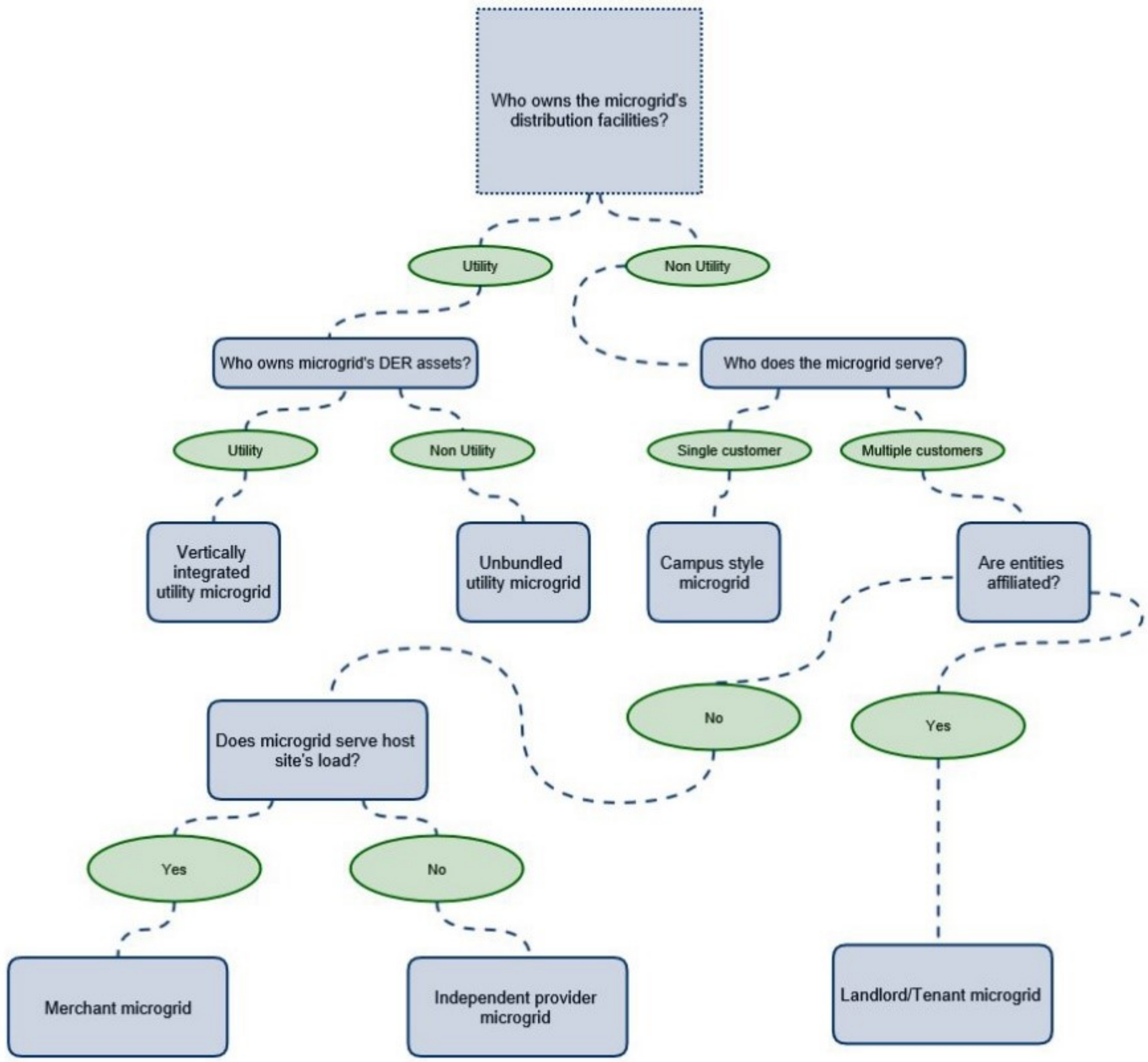

Figure 3-1 Microgrid Ownership Model Flowchart

3.6.2 Project Owner Identification

The microgrid would be organized as a special purpose vehicle (the Microgrid SPV) for designing, building, owning, operating and transferring (DBOOT) the microgrid assets for microgrid customers.

3.6.3 Site Ownership

The project stakeholders own the site(s) where microgrid equipment/systems are to be installed and will be able to access the sites as needed.

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.[7]

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:

- Restrictions on utility ownership of generating assets;
- Lack of rate structures for allocating costs of shared T&D assets among microgrid customers;
- Difficulty valuing ancillary and related services provided by microgrid customers to the microgrid owner, operator or utility;
- Investor concerns about the reliability of microgrids due to limited operational history;
- Lack of clarity on applicability of consumer protection laws to microgrid owners;
- Potential constraints on use of sub metering and telemetry systems used by the microgrid;
- Barriers to microgrid owners acting as DR aggregators for wholesale markets; and

Natural gas pipeline constraints and lack of mechanisms for procuring firm natural gas contracts.

[7] 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.

4 SUMARRY 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 for the first Scenario indicate that even if there are no major power outages over the 20-year period analyzed, the project's benefits would exceed its cost by a factor of 1.6 (see Table 4-2 and Figure 4-1 below). As a result, IEc decided not to consider the second scenario, since any length of major outage will simply increase the project's considerably positive benefit-cost ratio.

Table 4-1: BCA Results (Assuming 7 Percent Discount Rate)

ECONOMIC MEASURE	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2
Net Benefits - Present Value	$12,300,000	Not Evaluated
Benefit-Cost Ratio	1.6	Not Evaluated
Internal Rate of Return	28.4%	Not Evaluated

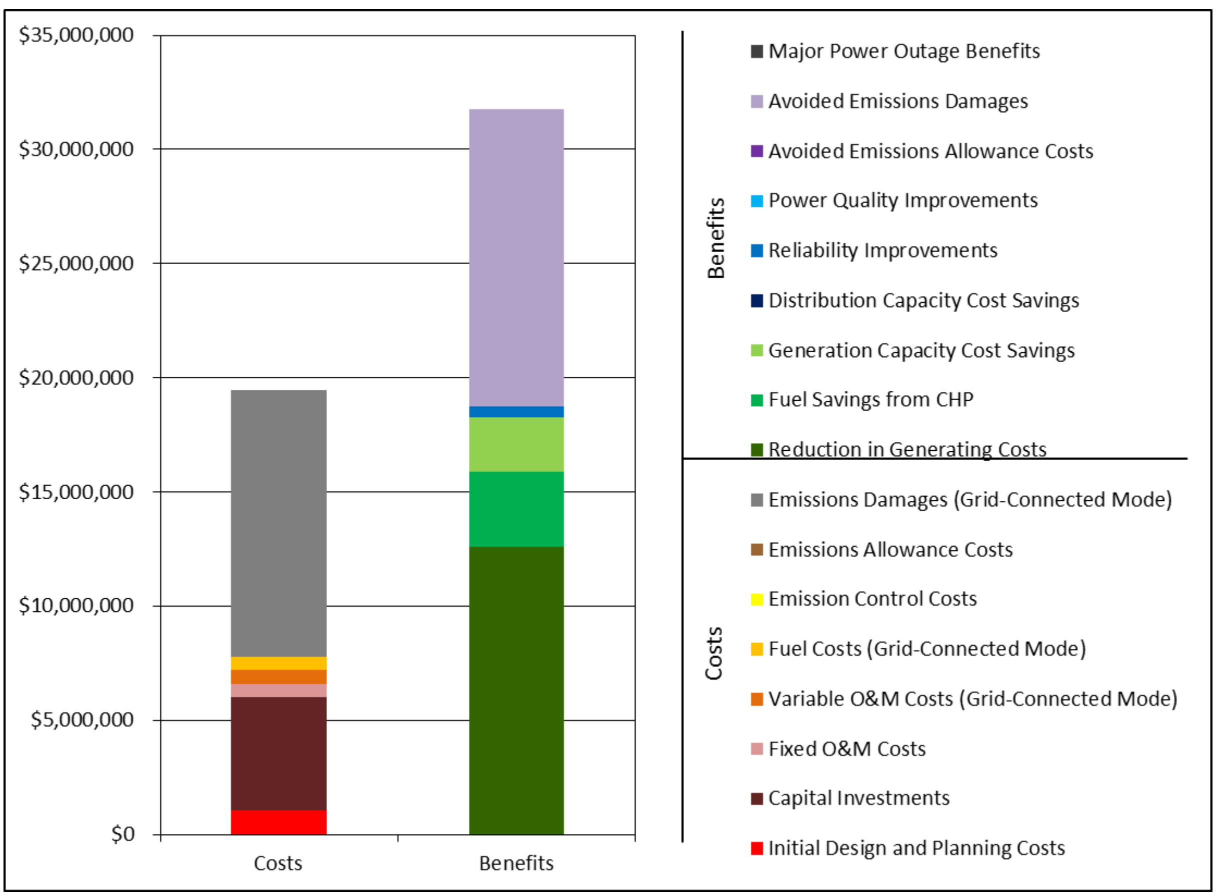

Figure 4-1: Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

As seen above, the major cost component is the emission damages of the microgrid generation resources during grid connected operations (due to the fuel consumption by the CCHP running during normal days). Next is the capital investment in the microgrid. The DER fuel costs during grid connected operations are actually a small portion of the total cost.

The major benefit component is the reduction in grid generation costs (attributable to the Rock Bottom Dam generation that displaces other conventional generation in the grid), and avoided emissions damages (also attributable to the clean energy of Rock Bottom Dam). The other significant benefits are based on fuel savings from CCHP (i.e., recovered thermal energy from CCHP replacing the use of boilers for heating or central chillers for cooling), and the generation capacity savings, due to the peak load support provided by the microgrid resources.

Table 4-2 below summarizes the detailed results of the Scenario 1 benefit cost analysis.

Table 4-2: 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	$1,050,000	$92,900
Capital Investments	$4,970,000	$439,000
Fixed O&M	$567,000	$50,000
Variable O&M (Grid-Connected Mode)	$626,000	$55,200
Fuel (Grid-Connected Mode)	$559,000	$49,300
Emission Control	$7,930	$700
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$11,700,000	$761,000
Total Costs	**$19,500,000**	
Benefits		
Reduction in Generating Costs	$12,600,000	$1,110,000
Fuel Savings from CHP	$3,310,000	$292,000
Generation Capacity Cost Savings	$2,370,000	$209,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$465,000	$41,100
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$6,910	$609
Avoided Emissions Damages	$13,000,000	$851,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$31,800,000**	
Net Benefits	**$12,300,000**	
Benefit/Cost Ratio	**1.6**	
Internal Rate of Return	**28.4%**	

APPENDIX A – BENEFIT-COST ANALYSIS SUMMARY REPORT

Site 64 – City of Binghamton

PROJECT OVERVIEW

As part of NYSERDA's NY Prize community microgrid competition, the City of Binghamton has proposed a microgrid that will combine a mix of generation technologies. To assist with completion of the project's NY Prize Stage 1 feasibility study, IEc conducted a screening-level analysis of the project's potential costs and benefits. This report describes the results of that analysis.

Binghamton is a medium-sized city of approximately 47,000 residents, located in south-central New York State, at the confluence of the Susquehanna and Chenango Rivers. Severe flooding in recent years has encouraged planners to pursue more reliable electrical supply systems and eliminate flood-related outages. The proposed microgrid would serve several customers:

- The Binghamton City Hall, Police Bureau, and Fire Headquarters complex;
- A YMCA and YWCA located at separate sites;
- Superior Ambulance, an EMS provider;
- A commercial office complex (Keystone Associates); and
- Senior and low-income housing operated by the Binghamton Housing Authority (BHA).

The project's design is centered around the Rockbottom Dam, a low-head hydropower facility located on the Susquehanna River, near downtown Binghamton. An energy developer is currently adding hydropower capability to the dam; when that project is complete, the dam will have a nameplate capacity of 1.95 MW and would generate a large share of the proposed microgrid's power. The microgrid design also features combined heat and power (CHP) capabilities, including two units located at the YWCA and a larger single unit located at the YMCA, all fed by natural gas. The design also incorporates solar generation capability as well as two existing natural gas-fueled generators that currently provide backup power to the City Hall and BHA facilities.

METHODOLOGY AND ASSUMPTIONS

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

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

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

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[11] It also calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the ratio of project benefits to project costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2014 dollars.

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

The BCA considers costs and benefits for two scenarios:

Scenario 1: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).

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.[12]

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[11] 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 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.]

[12] 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

RESULTS

Table 1 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that even if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's benefits would exceed its costs by roughly 60 percent.

Since the Scenario 1 results suggest a benefit-cost ratio greater than one, this report does not provide a detailed analysis of the impact of major power outages under Scenario 2. Consideration of Scenario 2 would further increase the project's already positive benefit-cost ratio.

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

ECONOMIC MEASURE	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2
Net Benefits - Present Value	$12,300,000	Not Evaluated
Benefit-Cost Ratio	1.6	Not Evaluated
Internal Rate of Return	28.4%	Not Evaluated

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)

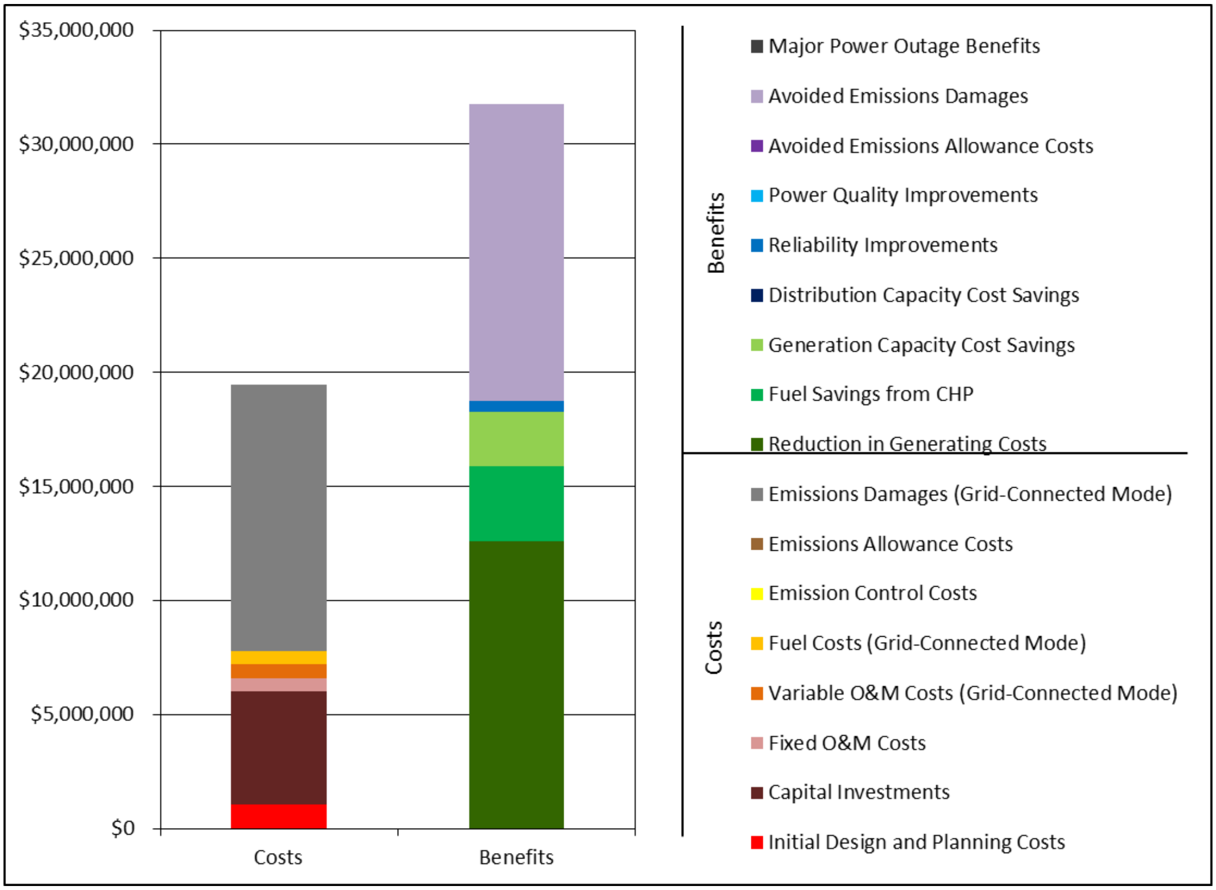

Table 2. Detailed BCA Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$1,050,000	$92,900
Capital Investments	$4,970,000	$439,000
Fixed O&M	$567,000	$50,000
Variable O&M (Grid-Connected Mode)	$626,000	$55,200
Fuel (Grid-Connected Mode)	$559,000	$49,300
Emission Control	$7,930	$700
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$11,700,000	$761,000
Total Costs	**$19,500,000**	
Benefits		

Reduction in Generating Costs	$12,600,000	$1,110,000
Fuel Savings from CHP	$3,310,000	$292,000
Generation Capacity Cost Savings	$2,370,000	$209,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$465,000	$41,100
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$6,910	$609
Avoided Emissions Damages	$13,000,000	$851,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$31,800,000**	
Net Benefits	**$12,300,000**	
Benefit/Cost Ratio	**1.6**	
Internal Rate of Return	**28.4%**	

Fixed Costs

The BCA relies on information provided by the project team to estimate the fixed costs of developing the microgrid. The project team's best estimate of initial design and planning costs is approximately $1.1 million. The present value of the project's capital costs is estimated at approximately $5.0 million. The major contributors to capital costs are the CHP units (one 0.2 MW unit and two 0.05 MW units); the absorption chillers used to covert hot water to cold water for summertime cooling applications; and the microgrid control 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 $756,000. The analysis assumes a 20-year lifespan for this equipment.

In addition, the present value of the microgrid's fixed operations and maintenance (O&M) costs (i.e., O&M costs that do not vary with the amount of energy produced) is estimated at approximately $567,000, or $50,000 annually.

Variable Costs

One significant variable cost associated with the proposed project is the cost of natural gas to operate the system's fuel-based generating systems (CHP units and conventional generators). 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.[13] The

[13] 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.

present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $559,000.[14]

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 $626,000.

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 $761,000 annually. The majority of these damages are attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $11.7 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 $12.6 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 $3.3 million. These reductions in demand for electricity 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 $13.0 million.[15]

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.[16] Based on the application of appropriate availability factors for each DER, the project team estimates the impact of the microgrid on generating capacity requirements to be approximately 2.79 MW

[14] The CHP unit planned for the WWTP would be fueled by a mix of natural gas (75 percent) and digester gas from the treatment system (25 percent). The gas the digester produces is both a product of the project and an input to the production of heat and power, therefore, the analysis of fuel costs assigns the digester gas a net cost of zero. The costs associated with producing the gas are fully reflected in the cost of installing, operating, and maintaining the digester.

[15] 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.

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

per year.[17] Based on these figures, the BCA estimates the present value of the project's generating capacity benefits to be approximately $2.4 million over a 20-year operating period.

The project team has indicated that the proposed microgrid would be designed to provide real power support, 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 such 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 $41,100 per year, with a present value of $465,000 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:[18]

System Average Interruption Frequency Index (SAIFI) – 1.03 events per year.

Customer Average Interruption Duration Index (CAIDI) – 118.2 minutes.[19]

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.[20] 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.

[17] The project team originally credited the full nameplate capacity of the solar resources in estimating the project's impact on system-wide generating capacity requirements. The analysis assumes that these resources would be available 30 percent of the time; this assumption is consistent with the project team's estimate of solar availability over the course of the year.

[18] www.icecalculator.com.

[19] SAIFI and CAIDI values were provided by the project team for New York State Electric & Gas.

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

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 1.6; i.e., the estimate of project benefits exceeds costs by about 60 percent. Accordingly, the analysis does not consider the potential for the microgrid to mitigate the impact of major power outages in Scenario 2. Consideration of such benefits would further increase the net benefits of the project's development.