

# Microgrids for Critical Facility Resiliency in New York State

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# **Microgrids for Critical Facility Resiliency in New York State**

*Final Report*

Prepared for:

**New York State Legislature**

Albany, NY

Prepared by:

**New York State Energy Research and Development Authority (NYSERDA)**

Albany, NY

**and**

**New York State Department of Public Service (DPS)**

Albany, NY

**and**

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# Notice

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# Foreword

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This report, along with previous research on microgrids by the New York State Energy Research and Development Authority (NYSERDA)<sup>1</sup>, provides information on the challenges facing microgrid development in today's utility environment. Specifically, it examined five case studies and took a focused look at the use of microgrids to support mission critical functionality - generally at facilities which already had backup generation installed.

Highlights are:

- In the particular scenarios examined, the economic case for reconfiguring resources into a microgrid was made challenging by the facilities' existing as-built status, and the primary focus on mission critical functionality.
- Microgrid investments may provide important value streams for which there are presently no mechanisms to compensate microgrid or distributed generator owners for distribution-level ancillary services and transmission and distribution investment deferral or other socially important benefits –such as reduced environmental consequences. This may result in the underutilization of otherwise economically feasible options and reduces the potential revenue streams that could be used to fund investments in microgrids. These issues will be examined by the Public Service Commission as part of its “Reforming the Energy Vision” (REV) initiative.
- A useful cost benefit analysis tool was developed as part of the study, but a more expanded version of a benefit cost model should be developed that will satisfy the need to account for the full spectrum of costs and benefits associated with microgrids in a REV environment.
- Technology development is required to reduce the costs of engineering the microgrid, specifically the control systems and electrical infrastructure necessary to balance supply and demand that currently result in elevated system costs.
- There is a need to develop standard models/approaches to ensure effective microgrid integration with existing utility distribution networks, particularly for more complex microgrid configurations (e.g., multiple distributed energy resources (DER), multiple points of common coupling with the utility system and/or connection to urban secondary networks).

Next steps are:

While easing some of the hurdles to microgrid development raised by the study depend on regulatory reforms through REV, continued research into technology evolution, testing and adoption is necessary. Achieving long-term clean energy goals and other REV objectives will require a scaling up of efforts to improve end-to-end system efficiency and development of new customer-to generator-to utility transaction models. Increasing resiliency will require expanded options to island portions of the grid using DER and advanced controls.

There is progress to report already. NYSERDA, through its Smart Grid Research program, is currently funding research in partnership with utilities on the integration of DER for urban networked systems through a large demonstration project in New York City. Additionally, several other rural/suburban microgrid design efforts are

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<sup>1</sup> Microgrids: An Assessment of the Value, Opportunities and Barriers to Deployment in New York State; NYSERDA Report 10-35, September 2010, Center for Energy, Marine Transportation and Public Policy at Columbia University.

being supported including two projects, in Potsdam and Buffalo, which have also been awarded significant funding from U.S. Department of Energy to develop and demonstrate microgrid control systems, whose lack thereof was identified in the Study as impeding development of community based microgrids. The electric utilities in New York represent the full suite of distribution network configurations (rural radial, suburban loop, and urban network) and provide the perfect proving ground for new technologies. A new request for research proposals under NYSERDA's Smart Grid Research program will provide additional opportunities for developing technologies essential to building the new energy ecosystems that REV envisions for New York.

Finally, NYSERDA in partnership with the Governor's Office of Storm Recovery will launch the NY Prize Community Grid Competition to support developing community microgrids aimed at improving the local distribution system performance and resiliency. Picking up where this study left off, NY Prize will leverage the knowledge of incumbent utilities about their system conditions with the creativity of community members to encourage broad customer participation, protect vulnerable populations and provide tools for building an efficient, cleaner and more reliable local-scale energy system. Several local community microgrids grids are expected to be built through NY Prize where REV principles could be tested.

The outcomes from this Critical Facility Resiliency Assessment, taken in the proper context, coupled with ongoing NYSERDA and utility sponsored smart grid research supported through a strategically administered Clean Energy Fund (CEF), will fully reinforce a vibrant REV "ecosystem" across New York State.

# Acknowledgement

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# Summary

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In 2013, the New York State Legislature directed the New York State Energy Research and Development Authority (NYSERDA), the New York State Department of Public Service (DPS), and the New York State Division of Homeland Security and Emergency Services (DHSES) to develop recommendations regarding the establishment of microgrids in New York State (A3008D/S2508D-Part T). The primary objective of the study was to assess the practical feasibility of establishing microgrids to enhance the resiliency of facilities that provide critical public safety, health, and security support upon loss of the electric grid for an extended period (more than 72 hours) due to natural or manmade disasters.

For this study, a microgrid is defined as a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity which can connect and disconnect from the surrounding utility grid and operate in both grid-connected or island mode.

The legislation required that the interagency team (the Project Team) develop recommendations in response to eight different topics. These eight topics are listed below and showing the specific text language in the bill and the associated section number of this report where it is addressed:

- Whether hospitals, first responder headquarters, such as police and fire stations, emergency shelters, schools, water filtration plants, sewage treatment plants, municipalities, commercial entities, not-for-profit organizations with a mission to assist in disaster relief and recovery, and other locations in the state of New York may desire to collaborate on successful microgrids (Section 1).
- Consider the geographic areas in the state of New York where the establishment of such microgrids should be a priority, based upon severe storm damage during the two years prior to the effective date of this act (2011 and 2012) (Section 1).
- The type of microgrid projects that may be implemented, including, but not limited to, distributed generation (DG), combined heat and power (CHP); or utilizing renewable technologies such as fuel cells, wind, solar, energy storage, or other energy systems (Section 2).
- How the operation of microgrids would conform with the current requirements of utilities to provide safe and adequate service to ratepayers (Section 3).
- The regulatory structure under which microgrid systems would operate (Section 4).
- The technical and regulatory aspect of how a microgrid will be interconnected to the power grid (Section 5).
- The adequacy of a microgrid system to operate in emergency situations and that proper protections are in place to ensure operation in the event of an emergency situation (Section 6).
- Funding mechanisms that should be considered in order to pay for the establishment, operation, and maintenance of such microgrids (Section 7), including a cost benefit analysis for the development and implementation of microgrids (Sections 8).

Although this study reviewed many aspects of deploying microgrid systems, the Project Team focused specifically on their application to critical infrastructure sites. These sites are, by their nature, very unique. The presence of significant back-up generation at the sites studied for this report was also an important variable. The study did not focus on campus style microgrids (e.g., New York University – single owner) that have been successfully deployed for years, but rather on unique and challenging applications where multiple entities (e.g. fire station, police station, school, etc.) would be connected from an electrical distribution standpoint.

To gain greater insight and enhance the analysis supporting the recommendations, the Project Team evaluated the feasibility of deploying microgrids at five specific critical infrastructure sites in New York. These sites (also known as case studies) are:

- New York City – Metropolitan Hospital Area.
- Broome County – Public Safety Facility Area – Binghamton.
- Nassau County – Cedar Creek Pollution Control Plant Area.
- Suffolk County – County Buildings Area – Yaphank.
- Rockland County – County Administration and Public Safety Area – New City.

These sites represent a variety of microgrid configurations including urban, suburban, and rural applications. The Findings and Recommendations in this report are based upon the information/data obtained from these five existing sites and should not be extrapolated to all potential microgrid configurations across New York State.

It is expected that this study will complement two statewide initiatives currently underway as part of the Statewide comprehensive strategy "Reforming the Energy Vision" (REV), namely the New York Prize Initiative and the New York State Public Service Commission's proceeding under REV to reform New York State's energy industry and regulatory practices. In particular, the Benefit-Cost Analysis (BCA) tool developed under this project may provide a foundation for assessing the benefits of more broadly defined community grids that serve all classes of consumers – both public and private.

This report was written under the existing paradigm of energy infrastructure, which REV is working to modernize. The values and constructs of energy infrastructure will evolve as regulations and the industry as a whole respond to advancements in technology and business models, improving the economic feasibility of distributed energy resources, including microgrids. This report does not comprehensively address all microgrid applications. Rather, the focus was to determine the feasibility of microgrids to support critical infrastructure in the event of an extended power outage. This summary outlines the findings and recommendations, which are further explained in the main body of the report.

## **S.1 Major Findings**

- Based on the sites analyzed and modeling used, this study found that the deployment of microgrids in support of critical infrastructure is usually not feasible based on a benefit-cost analysis. This is primarily due to the robust backup generation available at most of the critical facilities and the high costs of the electrical, communication and controls infrastructure of the microgrid.
- Microgrid designs are highly unique. It is difficult to compare or extrapolate benefits and costs from one site to another.
- The approximate cost for microgrid design and installation at the rural site in Broome County was \$3 million while the estimate for the more complex urban location in New York City was \$11 million.
- The cost-effectiveness of a microgrid improves if the system can economically operate on a more frequent basis, rather than solely as back-up generation in the event of emergencies.
- There is a lack of information available to potential microgrid developers on site characteristics that favor microgrid development. These sites would ideally yield significant advantages to their enterprise, the utility system, and the local and regional community. The combined private utility and social benefit of microgrids appear to be greatest at host sites where there are numerous benefit streams.
- Economic constraints (e.g., limited budgets) for municipal facilities are likely to impede implementation of microgrids without funding support from the state, federal government, or other entities.

## **S.2 Major Recommendations**

- New York State should pursue microgrid development at critical infrastructure sites only if supported by a favorable benefit-cost analysis in which all of the benefits and costs have been validated and accurately quantified.
- New York State, in conjunction with federal and private sector partners, should encourage further development on microgrid technology and appropriate applications.
- The State should disseminate objective information, tools, and other resources to encourage development of promising and cost effective microgrid projects that may improve the resiliency of critical infrastructure.
- Facilities should perform a benefit-cost analysis structured to function much like the model developed and applied under this study to determine if a microgrid that includes neighboring buildings and an alternate generation configuration or technology is a better option.

## **S.3 Additional Findings and Recommendations**

### **S.3.1 Section 1: Assessment of interest in collaborating on microgrids at critical facilities in regions of the State impacted by severe storms in 2011 and 2012**

Due to their value to public safety, health, and security, facilities that provide essential public services are considered high priority candidates for potential microgrid development. To evaluate the feasibility of deploying microgrids at critical facilities, a letter was sent by the Project Team to the Mayor of New York City and 10 County Executives and Emergency Managers to gauge their interest in evaluating the feasibility of establishing microgrids in support of critical infrastructure at locations within their jurisdiction. Initial outreach to the Counties was deemed

to be the most effective strategy since local emergency operations are predominantly managed at this level. The 10 Counties selected for outreach experienced the most pervasive and prolonged power outages due to storms in 2011 and 2012.

Five sites in the State were ultimately selected based on their nomination by the County Executive and the proximity and diversity of critical facilities within a concentrated geographic area. The sites included facilities in New York City, Broome, Nassau, Rockland, and Suffolk Counties. These sites collectively provide a basic framework for identifying other potentially high-value candidate sites in the future.

### **S.3.1.1 Findings**

**Finding 1.1:** While support was expressed at the County level for studying the potential for a microgrid to support critical infrastructure, there was not a significant desire on the part of the individual facilities to implement a microgrid architecture. Facility managers expressed concern that “sharing” their backup generation capability with other facilities via an interconnected microgrid network might adversely affect their facility’s operations by introducing instability into the system.

**Finding 1.2:** The vast majority of critical facilities evaluated in the study have invested in robust backup generation systems, limiting the number of economically feasible investment options.

**Finding 1.3:** The ability to operate backup generation at critical facilities for prolonged periods of time is dependent upon the availability of fuel. Facilities typically store only enough liquid fuel on-site to operate their backup generators for a maximum of two to four days and rely on contracts with private vendors to replenish their supply.

**Finding 1.4:** The study examined critical facilities across the storm-affected areas and found them to be largely geographically dispersed with only a handful of critical facilities clustered in close proximity (within a half-mile radius) to each other. A tight clustering of facilities served by a microgrid will have a positive impact on the benefit-cost analysis.

### **S.3.2 Section 2: Type of Microgrid Projects that May Be Implemented**

Microgrids can utilize a broad array of power generation, distribution, and management technologies. A variety of different generation technologies, controls, and distribution infrastructure can comprise the operating parts of a microgrid. The portfolio of technologies selected for a specific microgrid can have a significant impact on costs and can include, but is not limited to, renewable generation, combined heat and power systems, smart grid technologies, traditional backup generators and energy storage. The process of designing a microgrid begins with a robust phase of data collection to determine the existing energy needs and assets at a proposed site.

### **S.3.2.1 Findings**

#### Data Collection

**Finding 2.1:** Data needed for a microgrid design may not be readily available. To make effective use of shared data, utility assistance is typically necessary and may require the execution of a Non-Disclosure Agreement (NDA).

**Finding 2.2:** The microgrid designs for the critical facilities considered in this study were constrained by the lack of sufficiently granular consumption data. In many cases, granular usage (or “load”) data is not available because of a lack of interval metering. For this study, critical infrastructure facilities and their supporting utilities were often only able to provide monthly load data, as opposed to more discrete (every 15 minutes) data. The critical load in each facility needed to be served by the microgrid is also not always clearly distinguishable. This may have resulted in suboptimal microgrid designs as more detailed usage information can maximize system efficiency and reduce costs.

#### Microgrid Design

**Finding 2.3:** Within any given microgrid, the distributed generation, loads and electrical components must be adequately controlled in order to maintain stability and optimally balance supply and demand. Project costs associated with controlling multiple microgrid devices are high, reflecting that commercial microgrid and generation controllers are still evolving.

**Finding 2.4:** System integration and design/development of switching infrastructure are key cost drivers in the migration from facility deployed backup generation to a formal microgrid architecture. At some evaluated sites, it was cheaper to install new, independent microgrid wiring than to install switching equipment that would be needed to use the existing utility wiring.

**Finding 2.5:** Microgrids relying exclusively on renewable energy resources cannot provide electric power during grid outages with the level of reliability required for emergency loads.

### **S.3.2.2 Recommendation**

**Recommendation 2.1:** The State should support research leading to the further development of commercially available microgrid controllers.

### **S.3.3 Section 3: How the operation of microgrids would conform with the current requirements of utilities to provide safe and adequate service to ratepayers**

Microgrid systems can operate on network, loop, and radial distribution systems in urban, suburban, and rural environments. In order to provide safe and adequate service, microgrids will need to coordinate with local distribution utilities, which will impose requirements on microgrid operation. These requirements will vary based on the complexity of the systems and their ability to operate both independently (islanded) and with the macrogrid (parallel).

#### **S.3.3.1 Recommendation**

**Recommendation 3.1:** The State in collaboration with utilities should continue supporting research into the development of standard models/approaches to ensure effective microgrid integration with existing utility distribution networks, particularly for more complex microgrid configurations (e.g., multiple distributed generation (DG) sources, multiple points of common coupling with the utility system and/or connection to urban secondary networks).

### **S.3.4 Section 4: Regulatory Structure Under Which Microgrids Would Operate**

Microgrids currently exist in New York State. The majority are campus-style microgrids with a single interconnection with the utility. More complex microgrids with multiple interconnections and multiple users located at different locations provide additional challenges and are not adequately addressed under the existing rules and regulatory framework.

#### **S.3.4.1 Findings**

**Finding 4.1:** The legal and regulatory environment in New York State for facilitating the deployment of microgrids is currently being reviewed by the Public Service Commission (PSC), within the Reforming the Energy Vision (REV) proceeding (C. 14-M-0101). Under the REV proceeding, there will be a comprehensive review of rules pertaining to microgrids, including an identification of best practices; investigation into the valuation of costs and benefits of microgrids; establishment or modification of interconnection rules; and review of existing statutory ambiguities such as the extent to which a microgrid could be considered a qualifying facility.

**Finding 4.2:** Microgrids that include natural gas-fired generation may require additional gas service from the local utility. The availability and cost of expanding or extending natural gas service for microgrids impacts the economic feasibility of a potential microgrid.

**Finding 4.3:** Municipal regulation may impede the deployment of microgrids. Revision of county, town, city, and village municipal regulations and planning processes may be necessary for those municipalities considering microgrid development.

### **S.3.5 Section 5: Technical and Regulatory Aspect of Microgrid Interconnections**

For microgrids that serve critical infrastructure, interconnecting with the macrogrid may be desired even if the microgrid can serve 100% of the users' loads. Interconnection would allow the macrogrid to serve as backup for the microgrid's internal generation. Interconnecting with the macrogrid may also allow for the development of more optimized microgrid designs that may create value or reduce costs by utilizing grid-supplied energy when it is more economical, or by providing additional benefits to the macrogrid, such as ancillary services and capacity constraint relief.

#### **S.3.5.1 Findings**

**Finding 5.1:** In order to conform to existing utility interconnection requirements, microgrids may require more specialized protection equipment (e.g., transfer trip switches) than typical generation interconnections.

**Finding 5.2:** No standard utility interconnection requirements presently exist that would universally address all potential sizes and micro-to-macrogrid configurations.

**Finding 5.3:** The microgrid design for facilities willing to tolerate a short duration outage when switching to islanded mode is less complicated and costly than designs for facilities that require seamless, non-interrupted ("bumpless") power.

**Finding 5.4:** As part of an interconnection agreement with the local utility, the microgrid developer may be responsible for the costs associated with any upgrades to the electric infrastructure that are required to support the microgrid installation. Rules related to microgrid developer cost contributions are being reviewed by the Public Service Commission in the Reforming the Energy Vision (REV) proceeding.

#### **S.3.5.2 Recommendation**

**Recommendation 5.1:** The State should continue to support development of microgrid interconnection technologies (e.g., power electronics) and designs.

### **S.3.6 Section 6: Microgrid Operations During Emergency Situations**

The primary value microgrids add to critical infrastructure is in their ability to provide continuous power to essential public services during and throughout emergencies that cause interruptions in service from the local utility. This ability, however, depends upon the microgrid being designed to appropriately serve the critical loads.

#### **S.3.6.1 Findings**

**Finding 6.1:** Microgrids may be susceptible to many of the same problems that cause interruptions in service from the local utility. For example, microgrid circuits with overhead exposure may be susceptible to storm damage. In areas affected by flooding, damage to non-submersible underground equipment may occur. Just like the local utility, a microgrid can experience faults/failure; there is no guarantee that it will function as intended, especially if aspects pertaining to its resiliency were not adequately designed and maintained.

**Finding 6.2:** Providing enough power to meet all critical loads while electrically islanded may entail designing and installing redundant generation to protect against the failure of one or more generators. This will allow the microgrid to provide adequate generation to serve critical loads even if a generator fails or is out of service.

**Finding 6.3:** Inadequately designed or implemented microgrids can introduce additional safety hazards during storm events, particularly from live, downed conductors and potential reverse electric power flows.

#### **S.3.6.2 Recommendation**

**Recommendation 6.1:** Facilities should develop regular testing procedures to ensure that all equipment associated with the microgrid is adequately maintained and operates as intended.

### **S.3.7 Section 7: Microgrid Funding Mechanisms**

Effective funding mechanisms are critical for facilitating the deployment of microgrids. Due to the lack of broad experience in building and operating microgrids, financiers may not adequately understand the risks and rewards of these investments, thereby increasing the cost of capital for such projects. Innovative funding mechanisms and ownership models may be able to allocate the benefits and costs of a microgrid more effectively than would otherwise be possible.

#### **S.3.7.1 Findings**

**Finding 7.1:** Microgrid developers may pay a risk premium for finance capital as there is limited microgrid performance data to inform potential investors.

**Finding 7.2:** A microgrid developer’s ability to secure long-term revenue streams is critical in assuring their investment.

**Finding 7.3:** Some microgrid revenue streams cannot be captured by non-utility microgrid owners. For example, there are presently no mechanisms to compensate microgrid or distributed generator owners for distribution-level ancillary services and transmission and distribution investment deferral. This may result in the underutilization of otherwise economically feasible options and reduces the potential revenue streams that could be used to fund investments in microgrids. These issues are being examined by the Public Service Commission under the REV proceeding.

**Finding 7.4:** A typical feasibility study for a potential microgrid project commonly exceeds \$50,000 and takes approximately six months to complete.

### **S.3.7.2 Recommendation**

**Recommendation 7.1:** The State should evaluate public-private partnerships to enhance microgrid economics through economies of scale and collaborative procurement.

## **S.3.8 Section 8: Benefit-Cost Analysis**

The full spectrum of benefits a microgrid provides may not be able to be monetized by the developers/investors. In fact, the sum of the social and private benefits may exceed the total costs. However, if the owner/investor cannot monetize such benefits, they may forego making the investment.

The economic viability of microgrids varies significantly from case to case, depending upon the design of the system and the characteristics of the facilities served. A benefit-cost assessment (BCA) model was developed for assessing the economic viability of microgrids at critical facilities based on the specific attributes of each site and taking into account the benefits and costs of providing essential services during a prolonged emergency. The model also estimates a range of other potential benefits, including energy cost savings; savings in the development of energy generation, transmission, or distribution capacity; power quality benefits; and environmental benefits.

**Finding 8.1:** Microgrids designed with distributed generation that runs only when the local utility is interrupted are difficult to justify economically. This is particularly true if there are existing backup systems that are appropriately designed and maintained. While the integration of standby generators into a microgrid can enhance the reliability of backup service, this benefit alone may not outweigh the incremental cost of designing and installing the control, communication, and electrical infrastructure that a microgrid requires.

**Finding 8.2:** The economics of a microgrid are enhanced if the system can provide services to the macrogrid, such as energy capacity, ancillary services, and demand response. This is a priority of the REV initiative. The value of these services is higher in New York City and on Long Island than elsewhere in New York; thus, microgrids in these areas are best positioned to take advantage of these potential benefits.

**S.3.8.1 Recommendation**

**Recommendation 8.1:** The State should continue to develop case studies on the costs and benefits of developing microgrids, with the goal of formulating screening criteria describing the circumstances under which microgrids are likely to prove economically viable.

# Overview and Goals of the Report

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This report grows out of New York’s continuing commitment to its citizens and the resiliency of the electric grid supporting critical public safety, health, and security infrastructure. The New York State Legislature commissioned this report for the purpose of “develop[ing] recommendations regarding the establishment of microgrids in the state of New York.”<sup>2</sup> The Legislature tasked the New York State Energy Research and Development Authority (NYSERDA), New York State Department of Public Service (DPS), and New York State Division of Homeland Security and Emergency Services (DHSES) to work collaboratively to assess how microgrids can be used in New York State to sustain mission critical operations during and after severe weather events. The Legislature requested for several specific areas of inquiry to be answered in a “final report of recommendations [served] to the governor, the temporary president of the senate and the speaker of the assembly.” This report seeks to respond to those specific requirements.

Each section of the report addresses one of the eight specific areas that the Legislation requested to be studied.

These include:

- Whether hospitals, first responder headquarters such as police and fire stations, emergency shelters, schools, water filtration plants, sewage treatment plants, municipalities, commercial entities, not-for-profit organizations with a mission to assist in disaster relief and recovery, and other locations in New York State may desire to collaborate on successful microgrids (Section 1).
- Consider the geographic areas in the state of New York where the establishment of such microgrids should be a priority, based upon severe storm damage during the two years prior to the effective date of the legislation (2011 and 2012) (Section 1).
- The regulatory structure under which microgrid systems would operate (Section 4).
- How the operation of microgrids would conform with the current requirements of utilities to provide safe and adequate service to ratepayers (Section 3).
- The type of microgrid projects that may be implemented, including, but not limited to, distributed generation (DG), combined heat and power (CHP); or utilizing renewable technologies such as fuel cells, wind, solar, energy storage, or other energy systems (Section 2).
- The technical and regulatory aspect of how a microgrid will be interconnected to the power grid (Section 5).
- The adequacy of a microgrid system to operate in emergency situations and that proper protections are in place to ensure operation in the event of an emergency situation (Section 6).
- Funding mechanisms that should be considered to pay for the establishment, operation, and maintenance of such microgrids (Section 7), including a cost benefit analysis for the development and implementation of microgrids (Section 8).

To better inform this report’s findings and recommendations, the Project Team also selected five individual sites and conducted a feasibility study at each site. The feasibility study included a potential microgrid design and an associated benefit-cost assessment at each site. The results of these studies are discussed at greater length in a series of appendices to the report. The rationale and process for selecting these sites is discussed in the next section.

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<sup>2</sup> Budget Bill 2013 NY A.B. 3008 / S2508D, Part T. Reprinted in Appendix A.

# Background

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## The Impact of Extreme Weather on the Electrical Grid

Extreme weather and other natural disasters can threaten lives, disable communities, disrupt economic activities, and lead to the devastation of power generation, transmission, and distribution infrastructure. According to the U.S. Department of Energy, outages caused by severe weather such as thunderstorms, hurricanes, and blizzards account for 58 percent of outages observed since 2002 and 87 percent of outages affecting 50,000 or more customers.<sup>3</sup>

Over the last two years, the State of New York has experienced several unprecedented weather events, including Hurricane Irene, Tropical Storm Lee, the October 2011 snowstorm, and Superstorm Sandy in 2012, which caused significant damage across the State, and cost the economy well over a billion dollars (see Figure O-1). According to many experts, the frequency and intensity of extreme weather events is expected to increase even as utilities struggle with physical, fiscal, and resource constraints, increased scrutiny, and rising expectations for performance.

The impact of extreme weather on the electric distribution system is being studied at both the local and national level. At the national level, the White House has released multiple reports speaking to this challenge. In June 2011, President Obama released “A Policy Framework for the 21st Century Grid,” which set out a four-pillared strategy for modernizing the electric grid.<sup>4</sup> The initiative directed billions of dollars toward investments in 21st century smart grid technologies focused at increasing the grid’s efficiency, reliability, and resiliency, as well as making it less vulnerable to weather-related outages and reducing the time it takes to restore power after an outage occurs. In August 2013, the Executive Office of the President issued a report, “Economic Benefits of Increasing Electric Grid Resilience to Weather Outages.”<sup>5</sup> That report estimated the annual cost of power outages caused by severe weather between 2003 and 2012 and described various strategies for modernizing the grid and increasing grid resilience. One such strategy is to increase system flexibility and robustness by employing microgrids.

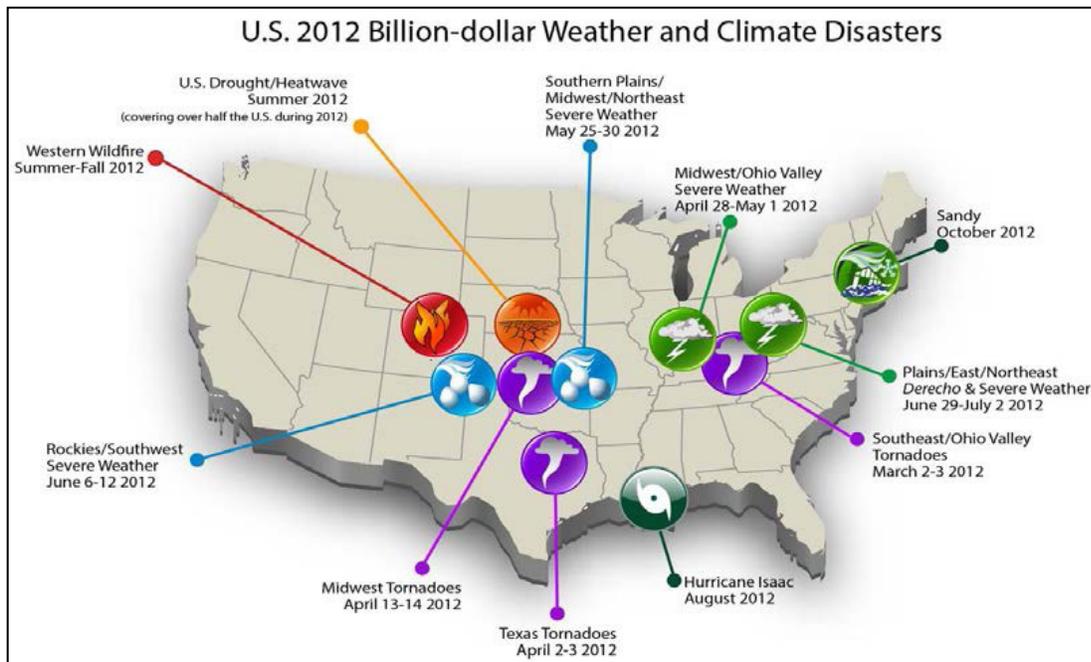
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<sup>3</sup> “Economics Benefits of Increasing Electric Grid Resilience to Weather Outages,” Executive Office of the President, August 2013, at 8, [http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report\\_FINAL.pdf](http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf).

<sup>4</sup> “A Policy Framework for the 21<sup>st</sup> Century Grid: Enabling Our Secure Energy Future,” Executive Office of the President, June 2011, <http://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc-smart-grid-june2011.pdf>.

<sup>5</sup> See Footnote 2.

**Figure O-1. Billion Dollar Weather and Climate Disasters in 2012** <sup>6</sup>



Numerous states are studying the effect of extreme weather. Impacted by a number of weather events, the State of Connecticut has developed policies that position microgrids as a key element in providing a resilient energy supply. Connecticut’s microgrid strategy aims to keep the power on at facilities like hospitals, sewage treatment plants, and prisons during weather events.<sup>7</sup>

New Jersey also has initiated a plan for making its grid more resilient. For New Jersey, the current focus is on its transit system, the third largest in the nation, carrying 900,000 people a day, and a major evacuation route for Manhattan. The microgrid will have more than 50 megawatts of power, consisting of smart grid technologies and distributed energy resources such as backup generators, small wind and solar, and energy storage.<sup>8</sup>

<sup>6</sup> “NCDC Releases Billion-Dollar Weather and Climate Disasters Information,” <http://www.ncdc.noaa.gov/news/ncdc-releases-2012-billion-dollar-weather-and-climate-disasters-information>.

<sup>7</sup> “Microgrid Grant and Loan Program,” State of Connecticut Department of Energy and Environmental Protection, <http://www.ct.gov/deep/cwp/view.asp?a=4120&Q=508780>.

<sup>8</sup> US. DOE. 2013. “Energy Department Partners with State of New Jersey to Study Ways to Improve the Reliability and New Jersey’s transit System in the Aftermath of Superstorm Sandy,” <http://energy.gov/articles/energy-department-partners-state-new-jersey-study-ways-improve-reliability-new-jersey-s>.

New York is keeping pace with its neighbors in identifying the impact of extreme weather on its electric distribution systems. New York has identified improving the State’s readiness, emergency preparedness, and response capabilities as a critical need. A key aspect of this effort is improving the resiliency of the energy infrastructure. Numerous studies following Superstorm Sandy provided recommendations concerning resiliency including the Moreland Commission<sup>9</sup> and a separate report prepared by the City of New York.<sup>10</sup>

As extreme weather events increase, communities in the Northeast have become increasingly receptive to developing clean, cost-effective, efficient, and resilient systems that can provide power by “islanding,” or operate independently of the larger utility electric grid in the event of an outage and keep critical services online.

## **What is a microgrid?**

Originally, electric power in the United States, including generation and distribution systems, operated on a small, local scale. Over time, regional utilities and infrastructure were developed to deliver cost-effective, safe, and reliable water, heat, power, fuel, and communications over significantly broader distances. These large, networked systems of electric power generation, transmission, distribution, and delivery offer the benefits of fuel diversity, proximity of generating assets to large fuel and water resources, efficiencies of scale, reliability through diversity of assets, quality of life benefits from locating large emissions sources away from population centers, and least-cost-dispatch.

These systems are, however, vulnerable to outages that can impact large regions and thousands of businesses and citizens particularly due to destructive extreme weather. Microgrids could help minimize the impact of these outages by localizing power generation, distribution, and consumption so that a fallen tree or downed wire will not interrupt critical services for miles around. Microgrids are essentially self-sustaining, small electric grids with their own generation resources and internal loads that may or may not be connected to the larger electric utility “macrogrid” (Figure O-2).

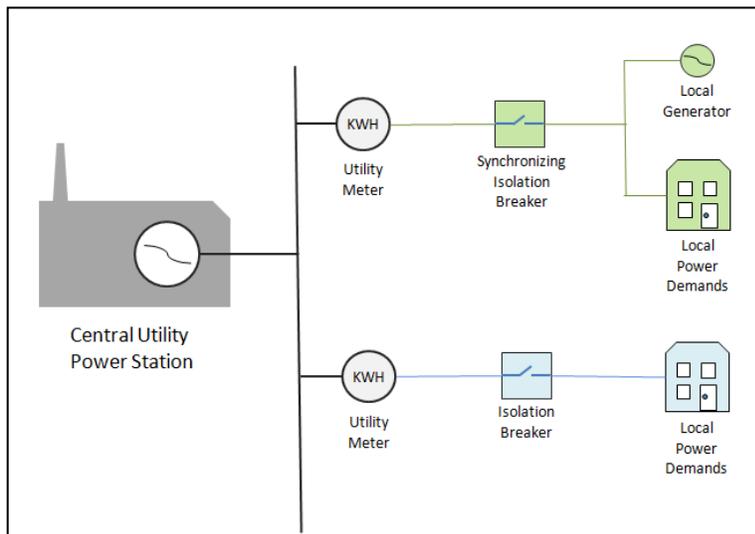
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<sup>9</sup> “Final Report,” Moreland Commission on Utility Storm Preparation and Response, June 2013, <http://utilitystormmanagement.moreland.ny.gov/sites/default/files/MACfinalreportjune22.pdf>.

<sup>10</sup> “A Stronger, More Resilient New York,” PlaNYC, The City of New York, June 2013, <http://www.nyc.gov/html/sirr/html/report/report.shtml>.

**Figure O-2. A microgrid is located between a utility meter and customer loads**

It includes at least one generator that can operate in parallel (synchronized) with the utility, or in isolation.



Of note, there is not one standard, utility industry-accepted definition of a microgrid largely due to the many models and applications available. For the purposes of this study, a microgrid is defined as a group of interconnected loads and distributed energy resources that form a single controllable entity capable of operating continuously in both grid-connected and islanded mode.”

What follows is a description of some of the general features and types of resources that can be employed in a microgrid.

## **Distributed Energy Resources for Microgrids**

Microgrids rely on a combination of demand-side resources (i.e., resources that impact how energy is consumed) and supply-side resources (i.e., resources that impact how energy is produced).

### **Demand-Side Resources**

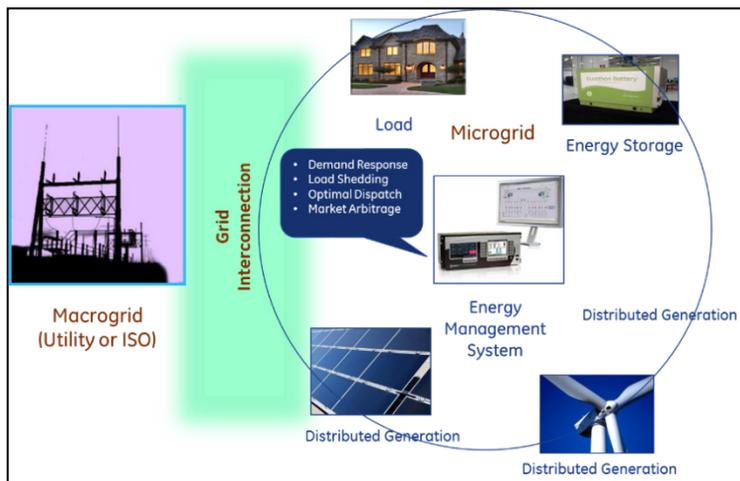
Demand-side resources are those that affect how and when energy is consumed within the microgrid. Most commonly, these will include intelligent energy management systems and energy efficiency investments. Intelligent energy management technologies are systems that monitor and control electricity consumption in real time. These technologies allow the operator of the microgrid to reduce demand for either practical reasons (such as the microgrid islanding and needing to curtail consumption to match local generation) or in response to economic incentives (such as the microgrid’s participation in a demand response program).

Energy efficiency (EE) investments are another form of demand-side resource that may present the most compelling economic opportunity for a microgrid. There are significant, untapped opportunities for enhancing energy-efficiency in buildings, including critical infrastructure facilities. Investing in energy-saving equipment and processes often yields the highest rate of return among all energy related expenditures. Efficiency investments that meet the end-users profitability threshold should be undertaken prior to sizing the power generation and delivery infrastructure requirements. Failure to take account of higher return EE capital investments can lead to oversizing the requirements of the power generation and infrastructure equipment. Where cost-effective EE investments are not undertaken first, more will be spent on generation and delivery equipment than is necessary. In addition, these assets will not be fully utilized, and they will be supplying loads that are operated in a sub-optimal fashion.

## Supply-Side Resources

Supply-side resources affect energy production within a microgrid. The most common are distributed generators (DG). DG encompasses a wide range of generation technologies, including gas turbines, solar electric (photovoltaic or PV), wind turbines, fuel cells, biomass, and small hydroelectric generators. Some DG units that use conventional fuel-burning engines are designed to operate as combined heat and power (CHP) systems that are capable of providing heat for buildings or industrial processes using the “waste” energy from electricity generation. Some of the key attributes for microgrid developers to consider when choosing between types of DG to install in a microgrid include the intermittency of the generator’s output (e.g., solar panels produce power only “intermittently,” when the sun is shining), whether it is renewable or non-renewable, its location, its size, its relationship with the conventional electric grid, and its operating regime (Figure O-3).

**Figure O-3. Components of a Microgrid**



# What are the typical benefits and costs of microgrids?

## Benefits

Microgrid benefits are generally categorized in terms of reliability, cost, and environmental, and directly accrue to the microgrid users, the utility, or society in general. These benefits are summarized in Table O-1 and discussed in much greater detail in Section 7.

**Table O-1. Microgrid Benefit Accrual**

<b>Benefits</b>	<b>Users</b>	<b>Utility</b>	<b>Society</b>
<i>Energy benefits</i>			
Energy cost savings	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
Ancillary services	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
Capacity cost savings		<input checked="" type="checkbox"/>	
<i>Reliability benefits</i>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
<i>Environmental benefits</i>			<input checked="" type="checkbox"/>
<i>Safety and security benefits</i>			<input checked="" type="checkbox"/>

## Costs

Microgrid costs are generally categorized in terms of project planning and administration, capital investment, operations and maintenance, and environmental. Under current financial incentive programs, regulations, and utility practices, the majority of these costs will be directly borne by or easily passed onto the microgrid owner. Some costs, however, may still be incurred by the utility to which the microgrid interconnects or by society. These costs are summarized in Table O-2 and discussed in much greater detail in Section 7.

**Table O-2. Microgrid Cost Accrual**

<b>Costs</b>	<b>Owner</b>	<b>Utility</b>	<b>Society</b>
<i>Project planning and administration costs</i>			
Project design	<input checked="" type="checkbox"/>		
Building and development permits	<input checked="" type="checkbox"/>		
Efforts to secure financing	<input checked="" type="checkbox"/>		
Marketing the project	<input checked="" type="checkbox"/>		
Negotiating and administering contracts	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
<i>Capital investment costs</i>			
Energy generation equipment	<input checked="" type="checkbox"/>		
Energy storage equipment	<input checked="" type="checkbox"/>		
Energy distribution infrastructure	<input checked="" type="checkbox"/>		
Upgrades to macrogrid		<input checked="" type="checkbox"/>	
<i>Operation and maintenance costs</i>			
O&M for generation and storage equipment	<input checked="" type="checkbox"/>		
O&M for distribution infrastructure	<input checked="" type="checkbox"/>		
O&M for dedicated utility infrastructure		<input checked="" type="checkbox"/>	
<i>Environmental costs</i>			
Capital costs of emissions control equipment	<input checked="" type="checkbox"/>		
O&M of emissions control equipment	<input checked="" type="checkbox"/>		
Emission allowances	<input checked="" type="checkbox"/>		
Human health and ecological damage			<input checked="" type="checkbox"/>

# 1 Assessment of interest in collaborating on microgrids at critical facilities and geographic areas of the State where microgrid development should be a priority based on recent storm damage

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## **Findings**

**Finding 1.1:** While support was expressed at the County level for studying the potential for a microgrid to support critical infrastructure, there was not a significant desire on the part of the individual facilities to implement a microgrid architecture. Facility managers expressed concern that “sharing” their backup generation capability with other facilities via an interconnected microgrid network might adversely affect their facility’s operations by introducing instability into the system.

**Finding 1.2:** The vast majority of critical facilities evaluated in the study have invested in robust backup generation systems, limiting the number of economically feasible investment options.

**Finding 1.3:** The ability to operate backup generation at critical facilities for prolonged periods of time depends on the availability of fuel. Facilities typically store only enough liquid fuel on-site to operate their backup generators for a maximum of two to four days and rely on contracts with private vendors to replenish their supply.

**Finding 1.4:** The study examined critical facilities across the storm-affected areas and found them to be largely geographically dispersed with only a handful of critical facilities clustered in close proximity (within a half-mile radius) to each other. A tight clustering of facilities served by a microgrid will have a positive impact on the benefit-cost analysis.

The Legislation required that the Project Team determine:

- Whether hospitals, first responder headquarters such as police and fire stations, emergency shelters, schools, water filtration plants, sewage treatment plants, municipalities, commercial entities, not-for-profit organizations with a mission to assist in disaster relief and recovery, and other locations in New York State may desire to collaborate on successful microgrids.
- Consider the geographic areas in New York State where the establishment of such microgrids should be a priority, based upon severe storm damage during the two years prior to the effective date of this act (2011 and 2012).

To accomplish these tasks, the Project Team performed the following steps:

- Identified the geographic regions impacted by severe storm damage.
- Determined criteria for site selection.
- Engaged and educated County Executives, Emergency Managers and state agencies about the study and requested site nominations from County Chief Executives.
- Received site nominations and reviewed them against study criteria.
- Decided on sites to participate.
- Notified Counties regarding site selection and coordinated site visits.

Additional detail regarding each of these steps is provided in the following sections.

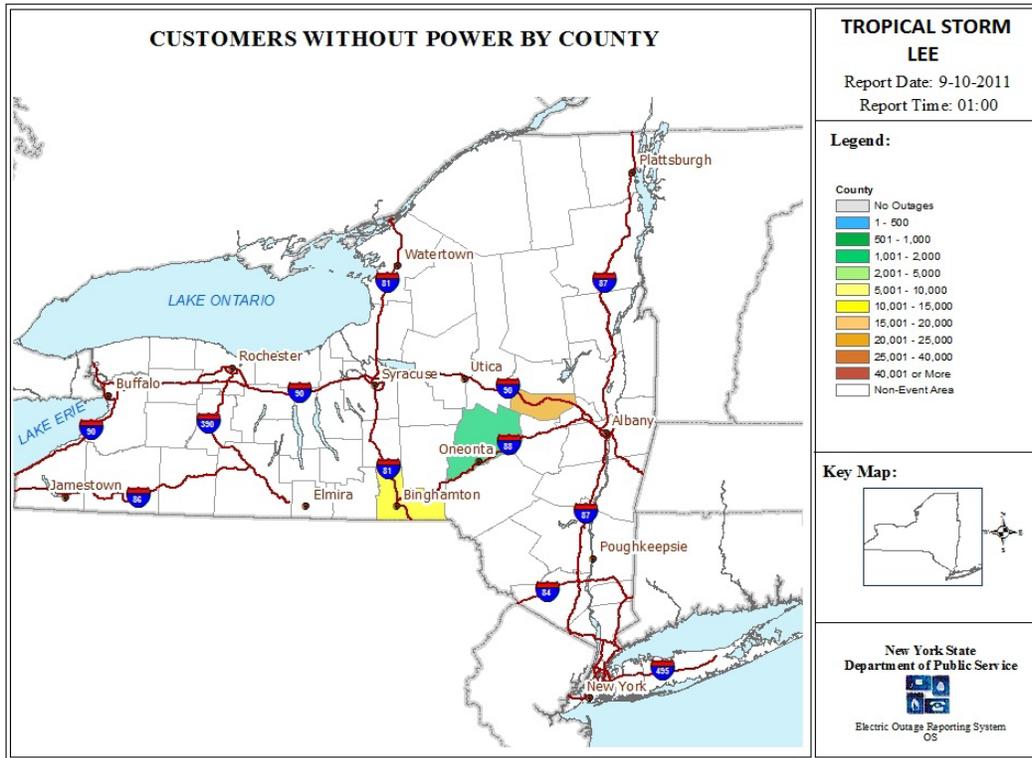
Although not required specifically by the Legislation, the Project Team performed engineering and benefit-cost analyses at each site to accurately inform the report’s findings and recommendations. The design and analysis for each site is described in detail in separate appendices to this report.

## **1.1 Selecting Geographic Regions**

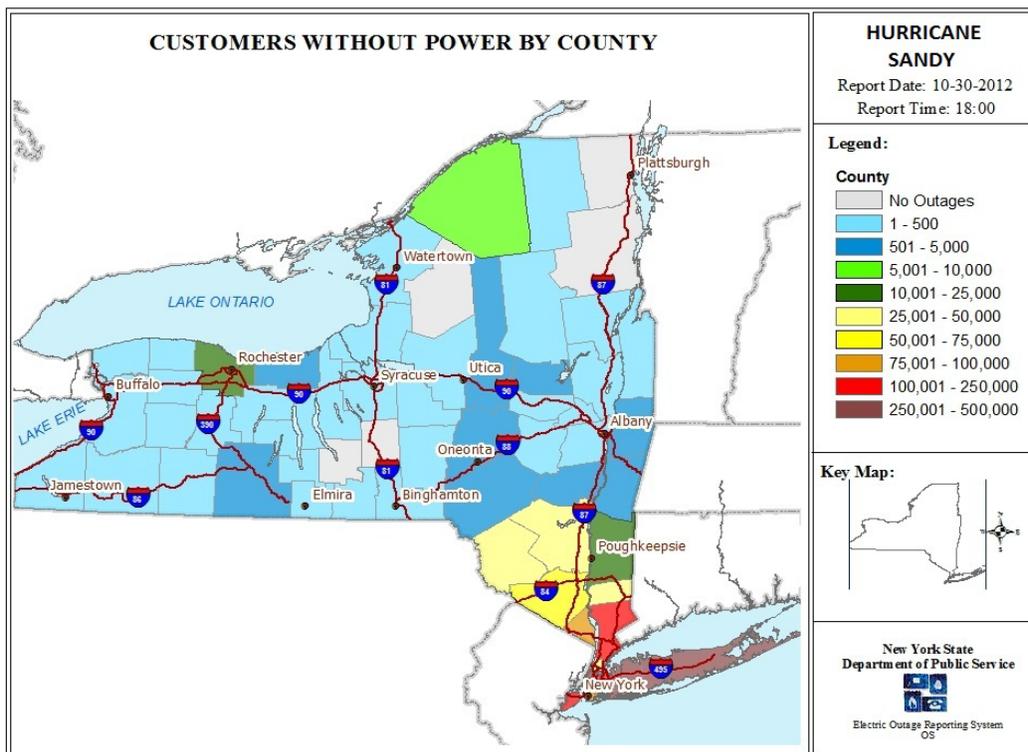
The Legislation stated that microgrid recommendations should be “based upon severe storm damage during the two years prior to the effective date of this act.” To meet this requirement, DPS provided power outage data over a 24- month period that covered calendar years 2011 – 2012 (Figures 1-1 through 1-4). This period included outages caused by Superstorm Sandy, Hurricane Irene, Tropical Storm Lee, and the October 2011 snowstorm affecting the Hudson Valley and New York City. Analysis of this data indicated that 10 Counties and New York City had outages affecting over 5,000 customers lasting at least six days (144 hours). Please see Appendix K for this data. Based on these criteria the Project Team solicited site nominations from New York City and 10 Counties: Broome, Dutchess, Nassau, Orange, Putnam, Rockland, Suffolk, Sullivan, Ulster, and Westchester.

The Project Team elected to seek microgrid site nominations at the County level (rather than approach individual towns and cities) because County Executives were in the best position to prioritize possibly multiple microgrid site nominations within a County. In addition, DHSES works closely with New York State County Executives and Emergency Managers on a wide range of homeland security and emergency preparedness issues.

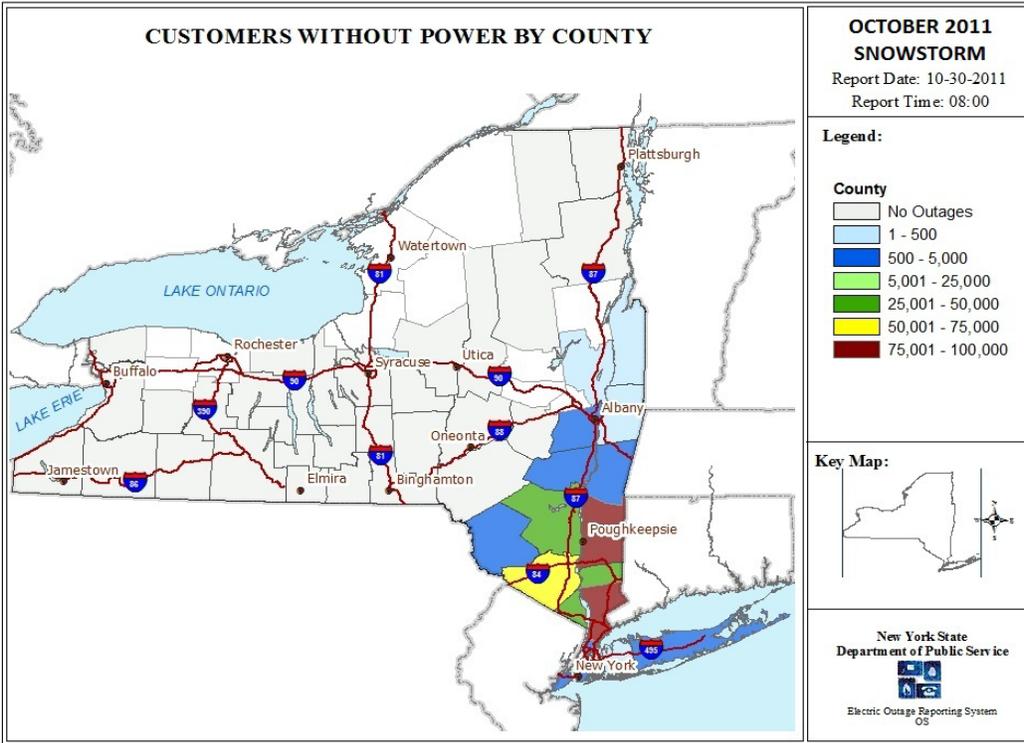
**Figure 1-1. Customers without power by County from Tropical Storm Lee**



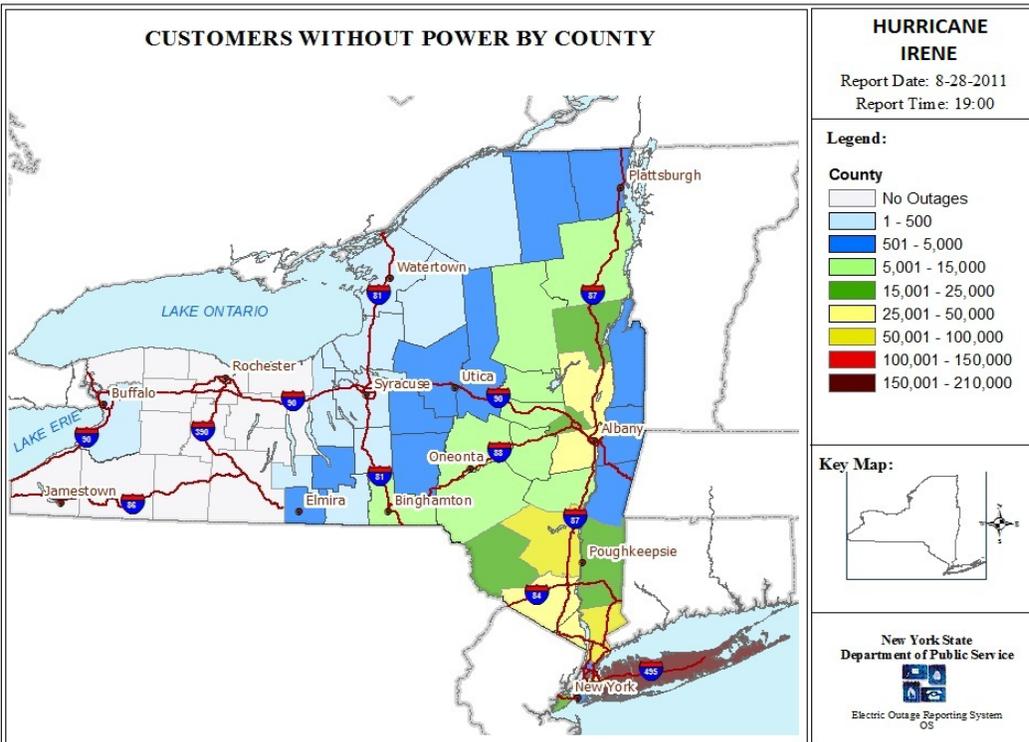
**Figure 1-2. Customers without power by County from Superstorm Sandy**



**Figure 1-3. Customers without power by County from October 2011 Snowstorm**



**Figure 1-4. Customers without power by County from Hurricane Irene**



## **1.2 Selecting Specific Sites**

A screening process was used to select specific sites to participate in a feasibility study from among the previously identified geographic regions.

### **1.2.1 Determine Criteria for Site Selection**

Establishing the criteria for selecting the specific sites to be evaluated was a critical part of the process. The most significant criteria were the number of critical infrastructure (CI) facilities in the nomination and the density of the CI at the site. A larger number of CI in close proximity to one another was considered optimal. For example, if nominee A and B each proposed three types of critical infrastructure within the microgrid, but the proximity of the three sites in B were grouped much more closely than the proximity in A, there would be a tendency to favor B, the proposal with the greater density of critical infrastructure within the microgrid. Next, the Project Team determined that diversity of sites was an important part of the study across three areas, i.e., at least one site each in a rural, suburban and urban environment. Finally, the Project Team wanted diversity in the type of electric grid systems studied, i.e., that network, looped and radial systems were represented in the study.

The “diversity” selection criteria reflected one of the overarching objectives of the study, which was to ensure a wide variety of applications in the study. This met the previously mentioned objective that the study findings might be generally applicable to other similar settings throughout New York State. With its distribution of population across dense urban centers, as well as suburban and rural communities, it was crucial that each of these types of municipal configurations be represented.

### **1.2.2 Engage and Educate County Executives, Emergency Managers, and State agencies about the study and request site nominations from County Chief Executives**

Having identified the most significantly affected counties and the site selection criteria, the next step was to conduct outreach and education on the study with select County Executives and Emergency Managers and solicit site nominations from them. Concurrently, DHSES notified State agencies that often interact with critical infrastructure facilities and organizations at the regional and County level, such as the Office of Fire Prevention and Control (who conduct outreach to fire departments throughout the State), the Department of Health, and the State Police, to inform them of the study and solicit their input.

To initiate the outreach and communication process and request nominations, DHSES Commissioner Jerome Hauer sent a letter to 10 County Executives (with copies sent to the County Emergency Managers) and the Mayor of New York City.<sup>11</sup> The letter informed the County Executive about the study and requested that they contact DHSES if they were interested in exploring the concept of a microgrid.

To facilitate a deeper understanding of this microgrid project nomination initiative, DHSES commenced an education process in mid-summer of 2013 as a follow-up to the outreach letter. Conference calls were conducted on several occasions with interested County representatives and Emergency Managers. The calls were a means of addressing important questions and concerns raised by potential County hosts. DHSES used this mechanism to further elaborate on the goals and objectives of the study. Counties sought and received clarification on the parameters of the study, the benefits of participation, the overall expected time and resource commitment, and their receipt of the study results. The Project Team conducted these calls and a workshop over the period of August and September 2013. As a consequence of this education and outreach effort, 10 microgrid project nominations were received from five Counties and the City of New York.

### **1.2.3 Conduct Analysis and Decide on Sites**

The next stage in the process was the analysis of the site nominations against the selection criteria to determine the best possible sites to participate in the study. This analysis resulted in the Project Team's recommendation to senior leadership at DHSES, DPS and NYSERDA that five sites be selected to participate in the study.

### **1.2.4 Notify Counties and Coordinate Site Visits**

In October 2013, DHSES Commissioner Hauer notified County Executives and Emergency Managers of the sites selected to participate in the study.<sup>12</sup> Following the notification of site selections, the Project Team then arranged a series of initial meetings, one for each approved microgrid study site. The meetings brought together all of the key participants in the project, including the County Executive/Emergency Manager, facility managers for individual facilities in the cluster, the utility currently providing electrical service to the facilities, and the consultant hired to design possible microgrid configurations for each site.

Prior to the initial meetings, project site representatives were provided a questionnaire soliciting information ranging from identifying the types of facilities represented at the site to electrical infrastructure blueprints, types of lighting, trends in electrical usage, and how building energy use is managed.<sup>13</sup>

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<sup>11</sup> An example letter is included as Appendix H.1.

<sup>12</sup> An example letter is included as Appendix H.2.

<sup>13</sup> A copy of this questionnaire is attached as Appendix H.3. The questionnaire provided essential data to inform the microgrid design process and requirements.

## 1.2.5 Selected Microgrid Sites

The specific sites selected and evaluated in each County were:

- **New York City:** Critical infrastructure cluster including the Metropolitan Hospital, NYC Housing Authority (Washington and Lincoln Houses), and a telecommunications switching station.
- **Broome County:** Critical infrastructure cluster including the Broome County Public Safety Facility, the State University of New York (SUNY) Broome campus and the Elizabeth Church Nursing Home facilities.
- **Nassau County:** Critical infrastructure cluster including the Cedar Creek Water Pollution Plant; the Wantagh Fire Department District Administration Building, Dispatch Center, and Emergency Operations Center; and the Seaford Harbor Elementary School.
- **Suffolk County:** Critical infrastructure cluster including several municipal facilities in Yaphank including the Fire Rescue facility, the County Police facility, the Suffolk County Sheriff facility, the County Public Works facility, the Board of Elections, the County Health facility, the American Red Cross facility, and the County Probation facility.
- **Rockland County:** Critical infrastructure cluster in New City including the County Jail, the Allison-Parris County Office Building, the County Court House, the County Highway garage, the Clarkstown Town Hall, the Clarkstown Police Department, the New City Fire Department, and a telecommunications switching station.

## 2 The type of microgrid projects that may be implemented

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### **Findings**

#### ***Data Collection***

**Finding 2.1:** Data needed for a microgrid design may not be readily available. To make effective use of shared data, utility assistance is typically necessary and may require the execution of a Non-Disclosure Agreement (NDA).

**Finding 2.2:** The microgrid designs for the critical facilities considered in this study were constrained by the lack of sufficiently granular consumption data. In many cases, granular usage (or load) data is not available because of a lack of interval metering. For this study, critical infrastructure facilities and their supporting utilities were often only able to provide monthly load data, as opposed to more discrete (every 15 minutes) data. The critical load in each facility needed to be served by the microgrid is also not always clearly distinguishable. This may have resulted in suboptimal microgrid designs as more detailed usage information can maximize system efficiency and reduce costs.

#### ***Microgrid Design***

**Finding 2.3:** Within any given microgrid, the distributed generation, loads and electrical components must be adequately controlled in order to maintain stability and optimally balance supply and demand. Project costs associated with controlling multiple microgrid devices are high, reflecting that commercial microgrid and generation controllers are still evolving.

**Finding 2.4:** System integration and design/development switching infrastructure are key cost drivers in the migration from facility deployed backup generation to a formal microgrid architecture. At some evaluated sites, it was cheaper to install new, independent microgrid wiring than to install switching equipment that would be needed to use the existing utility wiring.

**Finding 2.5:** Microgrids relying exclusively on renewable energy resources cannot provide electric power during grid outages with the level of reliability required for emergency loads.

### **Recommendation**

**Recommendation 2.1:** The State should support research leading to the further development of commercially available microgrid controllers.

The Legislation required that the Project Team determine:

- The type of microgrid projects that may be implemented, including, but not limited to, distributed generation (DG), combined heat and power (CHP); or utilizing renewable technologies such as fuel cells, wind, solar, energy storage, or other energy systems.

There is not an industry-accepted definition of a microgrid. This is largely due to the nascent development of the field and the fact that different stakeholders view microgrids from different perspectives. For example, engineers working for a developer may tend to think of microgrids as being distinguished from each other by the kinds of generation they use. Engineers working for a utility may tend to think of microgrids as being distinguished by the type of distribution system they interconnect with. Lawyers and financiers may tend to think that the operative difference between different microgrids comes down to their ownership structure or financing arrangements. To this end, different sections of this study classify the types of microgrids according to the following parameters:

- Generation types (i.e., DG technologies).
- Loads/Customers types.
- Types of Interconnection arrangement with the macrogrid.
- Types of Ownership structures.<sup>14</sup>

The rest of this section will survey some of the major distinctions along these parameters and direct the reader to sections in the report for more discussion of each of these parameters in the report.

## 2.1 Generation Type

A microgrid must contain some form of distributed generation (DG) in order to operate in island-mode.<sup>15</sup> DG encompasses a wide range of generation technologies including, but not limited to, gas turbines, solar electric systems, wind turbines, fuel cells, biomass, and small hydroelectric generators. Some DG units that use conventional fuel-burning engines are designed to operate as combined heat and power (CHP) systems that are capable of providing heating and cooling for buildings or industrial processes using the “waste” energy from electricity generation.

The key attributes of DG include the intermittency of the generator’s output, its fuel, its location, its size, and its relationship with the conventional electric grid. These attributes can influence a microgrid’s regulatory treatment, operational characteristics, and value streams. Table 2-1 lists different types of DG with typical module sizes and differentiates between renewable and nonrenewable generation sources.

### 2.1.1 Emergency, Base Load, and Intermittent Generation

An important distinction to make among microgrid DG is whether it is emergency, base load, or intermittent generation.

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<sup>14</sup> While these parameters are the primary focus of this study, they are not necessarily exhaustive.

<sup>15</sup> Theoretically, a microgrid could operate in island-mode with only energy storage resources, but this configuration is impractical with current technology.

**Emergency generators** are utilized solely to avoid the negative consequences of power outages. Accordingly, emergency generators rarely run. Diesel generators are the most common emergency power generation source. They can ramp up to full power and respond to varying demands within a few seconds. They can start and run completely unattended. Diesel fuel is more polluting than natural gas and is typically more expensive, so they are less cost-effective where high capacity factor is desired. They are reliable and can easily be designed with black-start capability. Natural gas-fired units are also becoming increasingly more prevalent because of the lesser complexity in operating these units and the recent drop in natural gas fuel costs.

**Base load generators**, on the other hand, run frequently or continuously—typically only shutting down for maintenance. They tend to be more expensive but more durable than emergency generators. Base load generators also tend to have more strict emissions requirements, more complex permitting processes, and higher maintenance requirements. However, they can also provide additional benefits than emergency generators. Because they operate frequently—even in the absence of a power outage—they can reduce a site’s energy purchases from the macrogrid. They may also be able to provide other services to the macrogrid. The revenues and savings created by base load generation are typically anticipated to provide a return on investment that justifies the additional cost. Table 2-1 lists different engine types that may be utilized as base load generation.

**Table 2-1. Types of DG Technologies**

	<b>DG Technology</b>	<b>Typical Module Size</b>
<b>Nonrenewable</b>	Combined cycle gas turbine	35–400 MW
	Internal combustion engines	5 kW–10 MW
	Combustion turbine	1–250 MW
	Micro-Turbines	35 kW–1 MW
	Fuel cells	1 kW–5 MW
	Stirling engine	2-10kW
	Reciprocating engine	5 kW–50 MW
<b>Renewable</b>	Small hydro	25 kW –10 MW
	Wind turbine	200 W–5 MW
	Solar electric	20 W–100 kW
	Solar thermal	1–80 MW
	Biomass	100 kW–20 MW
	Geothermal	5 kW–100 MW
	Ocean energy	100 kW–1 MW

**Intermittent generators** are any generator that may not run continuously due to some external factor. These generators include many renewable sources such as wind and solar. Intermittent generation cannot be relied upon to supply adequate generation capacity when the microgrid is in island-mode, unless the microgrid also incorporates substantial energy storage or other continuous sources.

The distinction between these types of generators is significant because microgrids that incorporate only emergency generation will only benefit from the reduction in localized power outages, while microgrids that incorporate base load and intermittent generation may be able to monetize other value streams that can aid in cost recovery of microgrid expenses. An entity may invest in the components of a microgrid with emergency generation if they find the cost of owning and maintaining it is lower than the cost of service interruptions. However, when base load generation such as CHP is included, complete microgrid assets can often be justified through energy savings, alone. For a more detailed discussion on the value streams of microgrid generation, see Section 7.

**Table 2-2. Base Load Generator Engine Types**

Engine	Description
Gas Turbines	Gas turbines produce a lot of power in a compact footprint. They are reliable and can easily be designed with black-start capability. They are commonly used in microgrid CHP applications. They can be fired by natural gas, diesel fuel, or both. They range in size from less than 1 MW to more than 100 MW. They can be designed with black start capability. The low inertia and extreme responsiveness of aero derivative engines makes them excellent participants in the frequency and voltage regulation markets.
Reciprocating Engines	Reciprocating engines can be fueled by natural gas, diesel, and biofuels. Each of these variants will have some impact on the performance of the engine. Natural gas burns cleaner, and is often less expensive than distillate fuels. Maintenance costs tend to be lower than with liquid-fuel engines. But as a compressible fuel natural gas results in an engine that is slower to respond to load changes. Diesel engines will therefore tend to be more responsive under quickly changing load conditions. Natural gas engines can be used to produce low-cost base-load or supplementary power. It can have a very high efficiency and low life-cycle cost and low carbon footprint in CHP applications. Fuel is usually delivered by underground pipeline. Reciprocating gas engines are not ideally suited to be the <i>only</i> engine supporting a microgrid. With thoughtful use of digital controls, they can however be coupled with other power generation very cost-effectively. Some manufacturers offer dual-fuel gas/diesel reciprocating engines. Reciprocating engines can also be made to run on biodiesel or biofuels.
Microturbines	Microturbines are small packaged gas turbine power generation units. They can provide on-site electrical power for standby applications, peak shaving, or base loading. Microturbines may generate power while synchronized with an electrical utility or isolated from it. The microturbine system is sold as a package consisting of a turbine engine, solid-state power electronics, a fuel system, and an indoor/outdoor-rated enclosure. Individual microturbines typically produce 5 kW to 100 kW each. They can be combined for larger applications.
Steam Turbines	Boilers coupled with steam turbines are the workhorses of the utility power industry. They can be built to produce up to a thousand or more megawatts each. They can be designed to deliver 250 kW or less depending on the application. They can be designed to burn essentially any combustible fuel. In high capacity factor combined-cycle or CHP applications, they can be extremely efficient and deliver a low life-cycle cost. Steam turbines usually require large capital investments, significant real estate, and dedicated operations personnel. They have long start-up and shutdown periods. They are not appropriate for standby or emergency power generation.

## 2.1.2 Size, Fuel-Type, and CHP

The size, fuel-type, and application of CHP systems can also differentiate microgrids because it can impact the regulatory regime under which one may operate. New York Public Service Law (NY PSL) specifies many requirements of “electric corporations,” which are defined as any entity owning, operating, or managing an electric plant, respectively. Whether or not a particular generator or generators are deemed an electric plant depends on the size, fuel-type, and whether or not cogeneration is utilized. For a more detailed discussion on the regulatory impact of microgrid DG, see Section 4.

## 2.2 Loads/Customers

Microgrids may also be defined by the types of loads/customers they serve. These loads may all belong to the same entity, or they may belong to different and unaffiliated entities.

Microgrids that serve a single entity are sometimes referred to as “campus-style” microgrids because they commonly serve the MUSH (military, universities, schools, and hospitals) market, and because such large institutions are typically sited on single pieces of property, such as a university campus or hospital complex. Currently, these types of microgrids are the most common in the United States. In New York, both Cornell University and New York University own and operate microgrids on their respective campuses.

### Example of Microgrids That Serve Single Entities

**Cornell Microgrid.** Cornell University owns, operates, and maintains an extensive microgrid that serves the school’s various buildings located on its Ithaca, NY, campus. Cornell does not provide service to unaffiliated customers and the microgrid does not cross a public right of way to deliver energy to any of the campus buildings. Many of the campus buildings shelter advanced research with a need for highly reliable electricity services. Loss of energy to labs for even relatively short periods could result in loss of research with significant financial consequences. The microgrid contains a diverse array of DERs, but the main generation assets are two 14.7 MW dual-fuel combustion engines with heat recovery for combined heat and power.

**NYU-Washington Square Microgrid.** New York University owns and operates a microgrid at its Washington Square campus in New York City. The microgrid is powered by a 13.4-MW, natural-gas fired cogeneration plant. The microgrid’s distribution facilities cross public streets to deliver both electric and thermal energy to interconnected buildings, but it does not provide service to any unaffiliated customers. With the exception of the underground vault where the cogeneration plant is located, which NYU leases from the New York City Department of Transportation, NYU owns all of the property, on both sides of the street, to which energy from the microgrid is delivered. The microgrid provides electricity to 22 buildings and thermal energy to 37 buildings.

Microgrids that serve multiple unaffiliated entities are less common in the United States. This rarity can be attributed to many factors, including increased regulatory barriers for microgrids serving multiple customers, as well as the increased difficulty of capital expenditure decisions when multiple parties are involved, because cost recovery will likely need to be secured through a power purchase agreement (PPA) or similar mechanism. For example, microgrids serving multiple customers may be subject to many of the regulations that utility companies are subject to unless exempted as a “qualifying facility,” and this designation has only been extended to one microgrid in New York serving multiple customers.<sup>16</sup> Microgrids that serve critical infrastructure will likely serve multiple different entities as critical facilities are often not clustered directly together. For more information on the regulatory issues surrounding microgrids serving multiple customers, see Section 4. For more information on cost-recovery mechanisms for microgrids serving multiple customers, see Section 7.

### **Example of Microgrid Serving Multiple Entities: Burrstone LLC**

In Utica NY, Burrstone LLC owns, operates, and maintains a microgrid that serves several previously unrelated end-users. The microgrid employs three 1.1-MWe natural gas reciprocating engines and one 334-kWe natural gas reciprocating engine. Two of the larger engines are dedicated to serving the load of Faxton-St. Luke’s Hospital Campus, the remaining large engine is dedicated to serving Utica College, and the smaller engine is dedicated to serving St. Luke’s Nursing Home. A public road separates the college from the hospital and home. Energy distribution facilities link the separate properties. Due to the unique nature of the project, certain regulatory approvals were required by the Public Service Commission, which are detailed in Section 4.2 of this report. The project is estimated to generate approximately 29,000 MWh of electricity and 32,000 MWh of thermal energy in the form of steam, hot water, and chilled water to participating customers annually.

## **2.3 Interconnection Arrangement with the Macrogrid**

Microgrids may interconnect with the macrogrid in a variety of different arrangements depending upon the existing utility infrastructure surrounding the microgrid. In rural and suburban areas, the surrounding existing utility infrastructure is likely to consist of either radial or looped distribution systems. Radial distribution systems connect multiple users to a single source of power, while looped distribution systems connect end loads to feeds from two directions. In urban settings, microgrids are likely to interconnect with spot or grid networks. Both of these types of networks are distinguished from radial and looped distribution systems by the fact that each customer will be connected to multiple (more than two) sources of power, each of which can supply their load. The type of utility infrastructure to which the microgrid interconnects will influence the type of metering and monitoring, over current protection, voltage control and power control, and other requirements needed to safely and reliably interconnect with the macrogrid. For a further description of distribution systems or more information on interconnection arrangements, see Section 5 of this report.

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<sup>16</sup> Case 07-E-0802 - Burrstone Energy Center LLC – Petition For a Declaratory Ruling That the Owner and Operator of a Proposed Cogeneration Facility Will Not Be Subject to Commission Jurisdiction (August 28, 2007).

## 2.4 Ownership Structures

Microgrids can be grouped by their ownership structure. Who owns the microgrid can impact both the regulatory model under which the microgrid will operate as well as the potential cost recovery mechanisms that may be employed. The main partition among ownership structures is between utility owned, nonutility owned, and hybrid microgrids. Under current law, each of these ownership structures will operate under significantly different regulatory models. Section 4 of this report covers this aspect in some detail. Additionally, a microgrid's ownership structure will also have a significant impact on the cost recovery mechanisms employed. For a more detailed discussion of microgrid ownership structures, see Section 7 of this report.

Microgrids may be organized under different ownership structures to provide various types of services to participating customers. Incumbent utilities may want to provide microgrids as a way to differentiate their services, particularly to customers that require very high levels of reliability or power quality, such as hospitals or data centers. For example, in the Town of Denning, NY, Central Hudson Gas & Electric (Central Hudson) developed a microgrid system to serve an electric load center located more than 14 miles from the distribution substation after an evaluation of the electric service reliability of the area found service to be unacceptable.<sup>17</sup> Nonutility entities may also want to form microgrids to provide cost savings to participants or higher levels of renewable energy than the utility can provide. Nonutility microgrids could be intended solely for self-service (owners are also the customers) or merchant activities (an independent company in competition with the utility). Microgrids might only serve commercial or industrial customers, or could serve a new residential subdivision or group of apartment buildings. The ownership and service orientation of a microgrid will likely be important to regulators, raising important policy questions such as how much oversight is required over a microgrid or whether customer protection requirements should apply.

### Example of Utility-Owned Microgrid: Central Hudson Gas and Electric's Town of Denning Project

In the Town of Denning, NY, Central Hudson Gas & Electric (Central Hudson) developed a microgrid system to serve an electric load center located more than 14 miles from the distribution substation after an evaluation of the electric service reliability of the area found service to be unacceptable.<sup>18</sup> The microgrid's internal DER consists of a 1,000-kVA diesel engine—owned and operated by Central Hudson—which is capable of serving the total peak load of the feeder. The microgrid is able to island from the macrogrid at an automated point of isolation established through a series of automatic transfer switches within switchgear compartments, which allows Central Hudson to continue to serve the community when the feeder line to the distribution substation is down due to weather or servicing.

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<sup>17</sup> Central Hudson Gas & Electric EPTD 1208 Program Proposal

<sup>18</sup> *Ibid.*

### 3 How the operation of microgrids would conform with the current requirements of utilities to provide safe and adequate service to ratepayers

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#### **Recommendations**

**Recommendation 3.1:** The State in collaboration with utilities should continue supporting research into the development of standard models/approaches to ensure effective microgrid integration with existing utility distribution networks, particularly for more complex microgrid configurations (e.g., multiple distributed generation (DG) sources, multiple points of common coupling with the utility system and/or connection to urban secondary networks).

The Legislation required that the Project Team determine:

- How the operation of microgrids would conform with the current requirements of utilities to provide safe and adequate service to ratepayers.

Given the various “types” of microgrids discussed in Sections 2 and 5 of this report, it should not be surprising that there are several ways that the New York State Public Service Commission would require microgrid sites to provide safe and adequate service to ratepayers, as utilities are required to do under New York State Public Service Law.

Potential requirements include:

- The Public Service Commission may consider the microgrid a stand-alone utility and thus subject to all of the provisions of Article 4.
- The microgrid may be a wholly owned component of a utility and thus the requirements on the microgrid are assumed by the utility.
- The Public Service Commission may consent to reduced regulations due to the microgrid’s unique structure and purpose.

Providing direction and guidance in this area is a major focus of the current REV proceedings.

Section 3.1 summarizes the Article 4 regulations that the microgrid may face if it is treated as a utility itself (including a note on how existing utilities may operate microgrids). Section 3.2 addresses requirements and challenges the microgrid may face even if it is not treated as a utility, but rather must purchase regulated services from a utility. In both cases, Public Service Law applies to define or place limits on the scope of the burden the microgrid may face.

### 3.1 Regulatory Powers of the PSC and Exemption

Under Article 4 of New York State Public Service Law (PSL), the Public Service Commission (PSC) is granted expansive powers to regulate electric and steam corporations. Electric corporations are defined as any corporation (or similar entity) “owning, operating or managing any electric plant” subject to specific exemptions. Section 4 of this report, “Regulatory Structure Under Which Microgrids Would Operate,” will provide a further survey of these exemptions, as it is often assumed that the most viable path forward for private microgrid developers is to claim an exemption from this regulatory burden.<sup>19</sup> Furthermore, if a project is not exempt, it may nevertheless receive a reduced regulatory requirement, a process that depends on applying a “realistic appraisal” test, which essentially gives the PSC some latitude to determine what degree of regulation is proper.<sup>20</sup>

Assuming, however, that a microgrid is regulated by the Public Service Commission as a utility and must comply with all applicable regulations that a utility would, Article 4 provides a catalogue of the regulatory powers that the PSC would apply. These powers are:

- General supervision: The PSC has the power of general supervision over all electric corporations, which includes the powers to investigate the manufacture, distribution, and transmission of electricity; to order improvements and provision of service; and to perform five-year audits to investigate the efficiency and customer response (i.e., quality of service) to the corporation’s operations.<sup>21</sup>
- Rates: The PSC determines the rates that electric corporations are permitted to charge. Charges made by electric corporations are required to be just and reasonable,<sup>22</sup> and the PSC has the authority to require electric corporations to disgorge revenues in excess of the corporation’s authorized annual rate of return.<sup>23</sup>
- Quality of service: Electric corporations are required to furnish safe and adequate service.<sup>24</sup> The PSC has the power to determine the safety and adequacy of service.
- Billing: The PSC has control over all aspects of the billing process, including the format and informational requirements of bills.
- Administration and public reports: The PSC has power over the financial and recordkeeping requirements of electric corporations. The PSC may prescribe methods of accounting and record keeping and inspect all records; require an annual report of stock, bonds, and property; and order reports of charged rates to be filed and made publicly available.<sup>25</sup>

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<sup>19</sup> See Section 4.2.1 for specific discussion on exemption from Public Service Commission jurisdiction over electric corporations.

<sup>20</sup> See Section 4.2.1.3 for a specific discussion on applying the realistic appraisal test to determine whether or not a reduced regulatory burden can be applied to a facility not otherwise exempt from regulation as an electric or steam corporation.

<sup>21</sup> PSL § 66.

<sup>22</sup> PSL § 65.

<sup>23</sup> PSL § 66.

<sup>24</sup> PSL § 65.

<sup>25</sup> PSL §§ 66, 68(a).

- Corporate finance and structure: An electric corporation must apply for the PSC’s approval before issuing stock, bonds, and other forms of indebtedness and must provide information about the amount of stock, proceeds and the purposes for which proceeds will be used. The PSC must also approve mergers, consolidations, and reorganizations by electric corporations.<sup>26</sup>
- Incorporation, franchises, and certificates: An electric corporation may not construct a plant without PSC’s permission and approval. A corporation may not exercise a right or privilege under a granted franchise without the PSC’s permission and approval. Before a franchise is issued, an electric corporation must file a certified copy of its charter with a verified statement of the president and secretary of the corporation showing that it has received the required consent of the proper municipal authorities. The PSC has the power to grant its permission and approval after a hearing and determination that construction or such exercise of the right, privilege or franchise is necessary or convenient for the public service.<sup>27</sup>
- Residential service: New York State’s policy on the provision of electric service to residential customers provides that “the continued provision of all or any part of such gas, electric and steam service to all residential customers without unreasonable qualifications or lengthy delays is necessary for the preservation of the health and general welfare and is in the public interest.”<sup>28</sup> Additional information on protections for residential customers under the Home Energy Fair Practices Act is contained in Appendix I.

### **3.1.1 Providers of Last Resort and the Obligation to Serve**

In addition to the regulatory powers outlined, a microgrid may be subject to an obligation to serve a group of customers if it is determined to be a provider of last resort. The PSL requires every electric corporation to “provide residential service upon the oral or written request of an applicant, provided that the commission may require that requests for service be in writing under circumstances as it deems necessary and proper as set forth by regulation, and provided further that the applicant” can pay.<sup>29</sup> This requirement and its potential application to microgrids is explained more thoroughly in Section 4.2.2.

### **3.1.2 PSC’s Regulatory Authority Over Steam Corporations**

Microgrids that use cogeneration technology distribute thermal energy and, therefore, may be subject to regulations for steam corporations. Cogeneration requires the use of “steam plants,” which are covered under the PSL, and defined as “all real estate, fixtures and personal property operated, owned, used or to be used for or in connection with or to facilitate the generation, transmission, distribution, sale or furnishing of steam for heat or power.”<sup>30</sup> The powers of the Commission over steam corporations generally mirror those of electric and gas corporations and are outlined in PSL § 80.

For more detail on the regulation of steam corporations, please see Section 4.2.1.2.

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<sup>26</sup> PSL § 69.

<sup>27</sup> PSL § 68.

<sup>28</sup> PSL § 30.

<sup>29</sup> PSL § 31(1).

<sup>30</sup> PSL § 2(21).

### **3.1.3 How Restructuring in 1996 Affects Utility Microgrids**

For many practical reasons, there may be advantages to allowing utility companies to own or operate microgrids: utilities have a great deal of institutional expertise about connecting with their system; utilities may be better able to see what congested parts of the grid could most benefit financially from installing distributed generation; utilities would not need to contend with franchise issues<sup>31</sup>; and more.<sup>32</sup> However, the electric industry restructuring order from 1996 required utilities to submit restructuring plans that included the total divestiture of generation assets, which are crucial in a microgrid. The PSC later stipulated certain circumstances whereby utility ownership of generation assets may be permissible. These circumstances are described in the Vertical Market Power Policy (VMPP) Statement of 1998, where the PSC stated that ownership of generation by a transmission and distribution company is allowed if there is a demonstration of “substantial ratepayer benefits, together with [market power] mitigation measures.”

This policy may be critical to the future of utility ownership of microgrids, and may be part of the ongoing discussions about the future of New York’s electric system in the REV proceeding discussed in Section 3.1.4. See Section 4.1.1 for more information on the VMPP and utility ownership of generation assets.

### **3.1.4 Future of the Industry: Reforming the Energy Vision Proceeding and Potential for New Regulatory Models**

Each of the foregoing Sections concerns the breadth of regulatory powers that the Public Service Commission may exercise over a microgrid if it is determined to be an electric corporation (and, again, not qualify for exemption or lightened regulatory regime as discussed in Sections 4.2.1 of this report). However, the Public Service Commission’s REV proceeding, currently underway, may introduce significant changes to the way in which microgrids are regulated. REV’s microgrid working group has identified five of the foremost legal issues affecting microgrids for the PSC to consider, including:

- When the obligation to serve might attach to a microgrid.
- Clarity on what microgrid facilities will be exempt from regulation as an electric corporation.
- Whether standby rates should be revised, particularly for microgrids servicing critical infrastructure.
- Whether net metering policies can be clarified to address how mixed assets will be treated.
- If a standardized interconnection process for microgrids might be feasible.

In addition, the REV proceeding more broadly identifies a goal of transforming utilities into “distributed service platform providers,” which may mean that new rules are put in place for utilities owning, operating, or providing markets and revenue streams for distributed energy assets of the sort that might make up a microgrid. As the utility evolves, it may have profound impacts on the market for microgrid development.

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<sup>31</sup> See Section 4.2.3 of this report for a more detailed discussion of franchise rules.

<sup>32</sup> See Section 7.1.4.1 for a more detailed discussion of the benefits of utility ownership of microgrids.

## **3.2 Utility Requirements and Services for an Interconnected Microgrid**

Section 3.1 surveyed the requirements for a microgrid that is itself regulated like a utility. This section will survey some of the requirements for a nonutility microgrid to be interconnected with a utility, including some outstanding issues surrounding costs and revenue streams for such a microgrid. Interconnection, standby rates, net metering, and other services offered by existing utilities may be crucial for a microgrid to access and are regulated by the PSC.

### **3.2.1 Interconnection**

To install any form of distributed resource (including generation and storage) that is interconnected with the utility grid, the customer and utility will need to reach an interconnection agreement. This agreement will typically stipulate conditions for the operation of the resource and may (depending on the size of the resource) involve the utility conducting a study of how the new resource will impact the existing local distribution system or require the utility to install new distribution equipment in the local area to ensure the continued safe and reliable operation of the local distribution network. The process each utility follows for approving a new interconnection must be in compliance with the New York State Department of Public Service's Standard Interconnection Requirements, which by reference incorporates nationally approved standards for interconnection published by the Institute of Electrical and Electronics Engineers (IEEE), Standard 1547. These standards address such technical requirements as overcurrent protection, voltage regulation, effective grounding, harmonics, and more. Section 5 of this report provides a detailed discussion of interconnection requirements and how they are likely to impact microgrids installed in a variety of settings.

IEEE's standards are continuously being updated, and processes are underway to generate more robust guidelines for how to interconnect intentionally electrically islanding systems, which include microgrids. On the procedural side, the microgrid working group within REV has suggested the PSC weigh in on standardized interconnection processes for microgrids. This may include standardized processes and time limits for reviewing islanding systems, different size limits applied to the NYS Standardized Interconnection Requirements (SIR), and clarified standards for how the SIR would apply to distributed service platform providers. Going forward, both of these processes will be important for understanding how microgrids can interconnect in New York State.

### **3.2.2 Standby Rates**

Microgrids with distributed generation may be subject to applicable standby rates. Standby rates are utility tariffs applied to users with onsite generation that use the macrogrid for supplemental power such as when load exceeds onsite generation capacity or when onsite generation is offline for planned or unplanned reasons. These rates are intended to recover the costs the transmission and distribution infrastructure required to provide supplemental service to the onsite generation customer without providing unwarranted barriers or incentives for onsite generation.<sup>33</sup> These rates may be revisited through the REV proceeding. For a detailed discussion of standby rates and their components, see Section 4.1.2.1.

### **3.2.3 Net Metering**

Microgrids with distributed generation may be able to take advantage of net metering service for eligible generation sources. Net metering allows onsite generators to offset grid electricity purchases (when onsite demand exceeds onsite generation) with power exported to the grid (when onsite generation exceeds onsite demand). Under this mechanism, qualifying generators can effectively receive retail rates for their excess generation. Net metering is available in New York to residential and nonresidential solar, wind, fuel cells, microhydroelectric, agricultural biogas, and residential micro-CHP. New York's net metering policies may be revisited through the REV proceeding, and the Microgrid Working Group has particularly flagged for resolution the issue of how eligible and non-eligible net metering resources at a given site will be accounted for. For a detailed discussion of net metering in New York, see Section 4.1.2.2. Section 4.1.2.3 also provides a discussion of buy-back tariffs, which require utilities to buy customer power at a lower rate, and which are subject to fewer restrictions.

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<sup>33</sup> Opinion No. 01-4

## 4 Regulatory Structure

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### Findings

**Finding 4.1:** The legal and regulatory environment in New York State for facilitating the deployment of microgrids is currently being reviewed by the Public Service Commission (PSC), within the Reforming the Energy Vision (REV) proceeding (C. 14-M-0101). Under the REV proceeding there will be a comprehensive review of rules pertaining to microgrids, including an identification of best practices; investigation into the valuation of costs and benefits of microgrids; establishment or modification of interconnection rules; and review of existing statutory ambiguities such as the extent to which a microgrid could be considered a qualifying facility.

**Finding 4.2:** Microgrids that include natural gas-fired generation may require additional gas service from the local utility. The availability and cost of expanding or extending natural gas service for microgrids impacts the feasibility of a potential microgrid.

**Finding 4.3:** Municipal regulation may impede the deployment of microgrids. Revision of county, town, city and village municipal regulations and planning processes may be necessary for those municipalities considering microgrid development.

The Legislation required that the Project Team determine:

- The regulatory structure under which microgrid systems would operate.

There is no single regulatory model for microgrids in New York State. Microgrids are not explicitly addressed in New York State Public Service Law (PSL), and the microgrids that currently exist in the State have been addressed by the PSC on a case-by-case basis. As a result, the regulatory models under which microgrids are currently likely to be managed are uncertain and dependent upon a variety of different variables including ownership structure, geographical boundaries, and technologies employed. This analysis describes the likely regulatory models for managing microgrids under current law and proposes recommendations for reducing regulatory uncertainty for microgrid development.

Under current law, the most significant regulatory questions emanate from ownership of the microgrid's electric distribution infrastructure. For this reason, this analysis separately considers regulatory models for microgrids where the distribution infrastructure is owned by an electricity distribution company (referred to as a utility microgrid) and by a non-utility entity (referred to as a nonutility microgrid).

As mentioned in Section 3 of this report, all legal analysis embodied in this report is subject to revision depending on the outcome of the REV currently underway at the PSC. That effort, which touches on and is alluded to in many sections of this Report, has specifically appointed a Microgrids Working Group to consider the regulatory models under which microgrids may function in the future. It has also embraced an overarching purpose of transforming utility companies into “distributed services platform providers,” a role that may encourage utilities to foster greater deployment of the same distributed resources that are at the heart of most microgrids. Analysis in this section should be considered with that context in mind.

## 4.1 Utility Microgrids

The regulatory model under which a utility microgrid would operate is likely to be similar to the current regulatory requirements that govern utility service. This includes the regulations that apply in the course of normal ratemaking such as ensuring rate-based investments are cost-justified as well as the safety, reliability, administrative and other requirements imposed by PSL and the PSC.<sup>34</sup> Although the normal utility regulatory model is stringent and far-reaching, the marginal cost of complying with these requirements for a utility microgrid (as opposed to a nonutility microgrid faced with the same regulatory requirements) are likely to be minimal since currently regulated utilities will presumably already have the institutional capacity to comply. Utility microgrids will also likely avoid complications resulting from microgrid infrastructure crossing public rights-of-way because the utility will already hold the relevant franchise in their service territory.<sup>35</sup>

Ownership of a utility microgrid’s internal distributed energy resources (DER) can influence the regulatory treatment of the microgrid. Because New York is an energy-deregulated state, utilities are generally discouraged from owning electric generation assets. A utility microgrid that incorporates utility-owned DERs will need to meet certain requirements to gain approval from the PSC. If a utility microgrid incorporates nonutility-owned DERs, the interaction between the DERs and the utility grid will likely be governed by current laws, regulations, and rates that govern such activities. The following sections detail the differing regulatory models a utility microgrid might encounter depending on the ownership of the microgrid’s internal DERs.

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<sup>34</sup> See Section 3 for a full accounting of the regulatory powers exercised over a utility.

<sup>35</sup> See Section 4.2.3 for more information on microgrid franchise issues.

### 4.1.1 Utility-Owned DERs

Utility microgrids that contain utility-owned DERs will be impacted by New York’s deregulated electricity market, which generally discourages utility ownership of generation assets. Through a 1996 opinion, the PSC has required utilities to submit restructuring plans that included the total divestiture of generation assets. However, the PSC later stipulated certain circumstances whereby utility ownership of generation assets may be permissible. These circumstances are described in the Vertical Market Power Policy (VMPP) Statement of 1998, where the PSC stated that ownership of generation by a T&D company is allowed if there is a demonstration of “substantial ratepayer benefits, together with [market power] mitigation measures.”<sup>36</sup>

While the VMPP has not been invoked to address utility-owned DER operating in a microgrid, the PSC has reflected the spirit of the VMPP in discussing utility ownership of DG on two occasions. On the first occasion, the PSC directed distribution companies to implement a three-year pilot program to investigate whether DG could cost-effectively defer distribution upgrades. The recommendation report for the directive clearly stated that utility affiliates were allowed to participate in the pilot provided that the “utility does not extend preference to its affiliates in violation of code of conduct requirements.”<sup>37</sup> On the second occasion, the PSC stated:

there may be merit in allowing utilities to participate further in [the Renewable Portfolio Standard], at a later date, if it were to be found the private investment is not available or sufficient in areas where utility ownership may be better targeted, more cost-effective and beneficial.<sup>38</sup>

Consistent with the VMPP, the PSC held that utility ownership would require a showing that “such a structure is in the best interest of the ratepayer and that utilities are not able to monopolize any market segment.”<sup>39</sup>

The August 2014 REV Proposal from DPS staff recommends that utilities fulfill the role of the Distributed Services Platform Provider in the future, which may entail utility ownership of DERs. The accompanying market power concerns are addressed by staff in recommending “the following approach to utility engagement in DER:”

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<sup>36</sup> NYS PSC Case 96-E-0099 (1998).

<sup>37</sup> NYS PSC Case 00-E-0005 (2001).

<sup>38</sup> NYS PSC Case 03-E-0133 (2010).

<sup>39</sup> Ibid.

“For direct activities of regulated utilities:

- The following limited forms of direct utility participation in DER are permitted:
  - sponsorship and management of energy efficiency programs; and
  - generation or storage located on utility distribution property.
- other proposals for engagement in DER must be specified in utility Distributed System Implementation Plans and must meet the following conditions:
  - the proposal must address a substantial system need;
  - the proposal must demonstrate why the benefits of utility engagement outweigh the market power concerns, with reference to the factors discussed above; and
  - where the proposal involves ownership, it must include a competitive solicitation for construction and operation, absent compelling circumstances.”<sup>40</sup>

## 4.1.2 Nonutility-owned DERs

If a nonutility entity (or entities) owns the microgrid’s internal DERs, the regulatory model under which the microgrid operates must address how the utility and DER owners will interact with each other. Current laws, regulations, and rate-design in New York stipulate how nonutility owned DERs interact with the utility through mechanisms such as interconnect rules, standby rates, net-metering laws, and buy-back tariffs. Additionally, there are other mechanisms that are not currently practiced in New York but may be considered in the future, such as a “microgrid wheeling charge.”<sup>41</sup>

### 4.1.2.1 Standby Rates

Nonutility DER owners within a utility microgrid may be subject to applicable standby rates. Standby rates are customer tariffs applied to users with onsite generation that use the macrogrid for supplemental power such as when load exceeds onsite generation capacity or when onsite generation is offline for planned or unplanned reasons. These standby rates are intended to recover the costs of the transmission and distribution infrastructure required to provide supplemental service to the onsite generation customer without providing unwarranted barriers or incentives for onsite generation.<sup>42</sup> In New York, standby rates consist of three distinct charges—customer charges, contract demand charges, and daily as used demand charges—as described in Table 4-1.

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<sup>40</sup> ASE 14-M-0101, Developing the REV Market in New York: DPS Staff Straw Proposal on Track One Issues (Aug. 22, 2014).

<sup>41</sup> See Section 7.7.1.3 of this report for more information about microgrid wheeling charges.

<sup>42</sup> Ibid.

**Table 4-1. Standby Rate Composition**

<b>Charge</b>	<b>Description</b>
Customer charge	The customer charge recovers certain fixed costs, such as metering and administrative expenses, which do not vary with energy use. It is a fixed monthly charge on the customer's bill.
Contract demand charge	The contract demand charge is intended to recover the costs associated with distribution infrastructure dedicated to the customer (e.g., nearby infrastructure that only serves the single customer). These costs are correlated with the maximum peak demand of the customer since distribution infrastructure must be sized to accommodate maximum load. Accordingly, the contract demand charge is based on the customer's maximum metered demand during some previous 12 month period of time. The charge is levied regardless of whether the customer's actual maximum peak demand approaches the level at which the charge is set.
Daily as-used demand charge	The daily as-used demand charge is designed to recover the costs of distribution infrastructure needed to meet the entire system's demand peaks. Therefore, the charge is assessed based upon the customer's daily maximum metered demand during peak-hour periods on the macro-system. Although some standard service classes are subject to demand charges for use at night, the daily as-used demand charges do not reflect night-time use.

The efficacy of the current standby rate structure, insofar as it is able to monetize the value that microgrids or other DERs provide to the grid, is still a topic of debate and is being explored through the ongoing REV proceeding.

#### **4.1.2.2 Net Metering**

Nonutility DER owners within a utility microgrid may be able to take advantage of net metering service for eligible generation sources. Net metering allows onsite generators to offset grid electricity purchases (when onsite demand exceeds onsite generation) with power exported to the grid (when onsite generation exceeds onsite demand). Under this mechanism, qualifying generators can effectively receive retail rates for their excess generation.

Net metering is available in New York to residential and nonresidential solar, wind, fuel cells, micro-hydroelectric, agricultural biogas, and residential micro- CHP. The size of the eligible generator is capped depending on the kind of generation (e.g., solar, wind, etc.) and customer type (e.g., residential, nonresidential, farm). The cap for residential solar, wind, and micro-hydroelectric is 25 kW. The cap for nonresidential solar, wind and micro-hydroelectric is 2 MW. The cap for farm-based wind is 500 kW, and the cap for farm-based biogas is 1 MW. The cap for residential fuel cells and micro-CHP is 10 kW, while the cap for nonresidential fuel cells is 1.5 MW.

Customers apply to their utilities for net metering service on a first-come, first-served basis, and utilities are required to provide this service up to a certain cumulative amount across their entire service territory. If a utility has already interconnected the maximum number of net metering customers required by the PSC, it may deny new entrants. The PSC recently raised this cap to require utilities to accept 3% of its 2005 peak demand from customers selling power from solar, small hydropower, CHP, farm biogas, and fuel cells. Utilities must also accept net-metered power equal to 0.3% of their 2005 peak demand from wind generators.

In June 2011, New York enacted legislation allowing eligible farm-based and nonresidential customer-generators to engage in remote net metering of solar, wind, and farm-based biogas systems. Micro-hydroelectric facilities were added as eligible for this arrangement in August 2012. The law permits eligible customer-generators to designate net metering credits from equipment located on property which they own or lease to any other meter that is located on property owned or leased by the customer, and is within the same utility territory and load zone as the net metered facility. Credits will accrue to the highest use meter first, and as with standard net metering, excess credits may be carried forward from month to month.

Net metering is a topic under consideration through the REV proceeding. The PSC has posed how the future pricing of DER values would affect existing net metering policies as a question, and stated that “[a] DSPP [Distributed System Platform Provider] market for DER could, in time, replace the function provided by net metering, as market prices reflect the additional system and environmental values represented by technologies that are currently eligible for net metering.”<sup>43</sup>

#### **4.1.2.3 Buy Back Service Tariffs**

If a nonutility DER owner does not qualify for net metering or exports more energy to the grid than is consumed, the DER owner may be eligible to sell power back to the utility under a buy back service tariff. Under a buy back service tariff, a qualifying facility can sell power directly to the utility, provided it is properly connected at high voltage and properly configured to respond to system conditions. A "qualifying facility" encompasses the definitions adopted under PSL, as discussed in Section 4.2.1.1. Significantly, the qualifying facility is allowed to export power at a size of up to 80 MW, while net metering, as discussed, is limited to much smaller facilities. The utility may purchase this power at the Locational Based Marginal Price (LBMP) set by the New York Independent System Operator (NYISO). This price reflects the wholesale price of energy offered to generators that sell power through NYISO's bulk power markets at the transmission level.

#### **4.1.2.4 Con Edison's Offset Tariff**

Non-utility owned CHP facilities in Con Edison service territory may be eligible for service under the utility's offset tariff. In 2011, Con Edison filed a novel standby tariff with the PSC that allows a customer to receive standby service for multiple proximate buildings when interconnecting a qualifying CHP facility at high-tension voltage on Con Edison's side of the revenue meter. The tariff allows customers to size CHP facilities to serve multiple buildings with less electrical infrastructure investment than would be needed for a similar configuration behind Con Edison's meter because existing utility distribution infrastructure is used to connect the customer's buildings with the CHP facility. This tariff effectively makes it more affordable for microgrid owners to install large CHP units that serve multiple buildings because they will not have to pay for duplicative utility infrastructure.

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<sup>43</sup> Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision, Order Instituting Proceeding, (Apr. 25, 2014) at 64.

The tariff is applicable to CHP facilities with a total nameplate rating between 2 MW and 20 MW and to buildings under a common Con Edison account (i.e., a single owner). The participating buildings do not need to be physically connected (e.g. by underground hot water pipes) but must be on a single premises, defined as buildings or lands “proximate to each other if there is common use.” For determining standby rates, each building’s contract demand charge is set at the building’s maximum potential demand. The daily as-used charge is determined by the net of the daily maximum metered 15-minute demand minus the proportional simultaneous 15-minute supply from the customer’s generator.

Con Edison’s offset tariff provides a framework for connecting DERs to multiple buildings, but it does not explicitly address the ability to island the customer’s DER and buildings in a microgrid configuration.

Con Edison’s offset tariff could provide a viable framework for a utility microgrid with nonutility-owned DERs. At present, however, notable hurdles to utilizing this tariff to promote microgrids include the lack of established procedures for incorporating the ability to island, and the single customer limitation. It has also not been applied yet to territories aside from Con Edison’s.

In the proceedings establishing the offset tariff, Con Edison argued to the PSC that if multiple customers were part of a campus-style arrangement, the utility would become embroiled in billing disputes between and among the related campus-style customers, and that the risk of additional costs related to such disputes and complexities might be recovered from outside customers. Comments opposing this position have argued that Con Edison can insulate itself and its rate base from these risks in other ways that better promote DG. “For example, the Company could require that multiple customers applying under the campus-style tariff be required to hold the Company harmless from any customer vs. customer billing issues.”<sup>44</sup> Additionally, there exists in New York State at least one similar interconnection arrangement where more than one customer utilizes the output from a single DG.<sup>45</sup>

#### **4.1.2.5 Microgrid Wheeling Charge**

An alternative mechanism that may be contemplated for utility microgrids with nonutility DERs is a microgrid wheeling charge. A microgrid wheeling charge would allow a nonutility DER owner to contract directly with another user on the microgrid for the provision of energy services. The utility would assess a wheeling charge for facilitating the distribution of these energy services between buyer and seller. Wheeling charges are generally assessed by multiplying the quantity of energy wheeled by some price. In theory, these charges could be structured to cover the revenue requirement of providing distribution services within the microgrid including the cost of developing and maintaining the necessary distribution facilities to provide microgrid capabilities.

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<sup>44</sup> Case No. 13-E-0030, Testimony of Robert R. Stephens at Footnote 44.

<sup>45</sup> See, e.g., NYS PSC Case 07-E-0802, Burrstone Energy Center LLC, Declaratory Ruling on Exemption from Regulation (issued August 28, 2007).

## 4.2 Nonutility Microgrids

For nonutility microgrids, the regulatory model under which the microgrid will operate will be heavily dependent on whether the project will be considered a public utility under PSL. Currently, a clear definition of a microgrid and the extent to which a microgrid should be regulated is absent in PSL. For this reason, proposed nonutility microgrid developers/investors face uncertain regulatory requirements. If a nonutility microgrid is regulated as a public utility, the microgrid owner will be subject to PSL, which could likely make the project unviable, because the cost of complying with these regulations may be impractical for small entities. Accordingly, whether a microgrid project will be regulated as a public utility is an important consideration for nonutility microgrid development.

Additionally, nonutility microgrids face an assortment of other regulatory questions. The microgrid may be deemed a “provider of last resort” by the PSC, which carries its own requirements. Nonutility microgrids that cross public rights-of-way must also be granted permission by the presiding municipal authority in the form of a franchise or some lesser consent. Without a franchise or lesser consent, a potential microgrid will not be allowed to develop. Finally, nonutility microgrids’ interaction with the macrogrid will also be governed by the same or similar mechanisms that govern interaction between the macrogrid and non-utility DERs such as standby rates and net metering. However, because many of these mechanisms were developed without microgrids in mind, their application to microgrids may not be appropriate.

### 4.2.1 Will the microgrid be regulated as a utility?

Under PSL, the PSC has the authority to regulate electric and steam corporations, which are defined as any entity owning, operating, or managing an electric or steam plant, respectively. For nonutility microgrid developers, the fundamental regulatory question is whether a proposed microgrid would be considered an electric or steam plant under PSL.<sup>46</sup>

#### 4.2.1.1 Will the microgrid be considered an electric plant?

As currently codified, PSL provides two exemptions from electric plant consideration:

- “Where electricity is generated by the producer solely from one or more co-generation, small hydro or alternate energy production facilities or distributed solely from one or more of such facilities to users located at or near a project site.” (referred to here as the “qualifying facility (QF) exemption”).<sup>47</sup>
- “Where electricity is generated or distributed by the producer solely on or through private property ... for its own use or the use of its tenants and not for sale to others” (referred to here as the “landlord-tenant exemption”).<sup>48</sup>

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<sup>46</sup> Potential regulation as a steam plant will only apply to microgrids that distribute thermal energy in addition to electrical energy.

<sup>47</sup> PSL §§ 2(2-d).

The QF exemption will be most applicable to microgrids that serve multiple unaffiliated users, while the landlord-tenant exemption will be most applicable to microgrids that serve only the microgrid owner or its tenants.

**QF Exemption.** For microgrids that serve multiple unaffiliated users, the microgrid project’s generation and distribution facilities will need to be considered a qualifying facility to be exempt from utility regulation.<sup>49</sup> To achieve this under current law, a microgrid’s internal generating facilities will need to be considered a co-generation, small hydro, or alternate energy production facility, and the microgrid’s distribution facilities will need to be considered related facilities as defined in Table 4-2.

**Table 4-2. Qualifying Facility (QF) Categories**

Category	Definition
Co-generation facility	“Any facility with an electric generating capacity of up to eighty megawatts.... together with any related facilities located at the same project site, which is fueled by coal, gas, wood, alcohol, solid waste refuse-derived fuel, water or oil, .... and which simultaneously or sequentially produces either electricity or shaft horsepower and useful thermal energy that is used solely for industrial and/or commercial purposes.” <sup>50</sup>
Small hydro facility	“Any hydroelectric facility, together with any related facilities located at the same project site, with an electric generating capacity of up to eighty megawatts.” <sup>51</sup>
Alternate energy production facilities	“Any solar, wind turbine, fuel cell, tidal, wave energy, waste management resource recovery, refuse-derived fuel or wood burning facility, together with any related facilities located at the same project site, with an electric generating capacity of up to eighty megawatts, which produces electricity, gas or useful thermal energy.” <sup>52</sup>
Related facilities	“Any land, work, system, building, improvement, instrumentality or thing necessary or convenient to the construction, completion or operation of any co-generation, alternate energy production or small hydro facility and also include such transmission or distribution facilities as may be necessary to conduct electricity, gas or useful thermal energy to users located at or near a project site.” <sup>53</sup>

Although the requirements for being considered a co-generation, small hydro, or alternate energy production facility are fairly uncontroversial, the 80-MW ceiling on generation capacity, however, may be of importance for microgrids that aggregate multiple generators into a single system. For alternate energy production facilities, the 80-MW limit applies to the aggregate generating capacity of sources within the facility. This requirement may invite dispute where multiple alternate energy sources are located closely together, while being owned by separate parties, such as

<sup>48</sup> *Ibid*

<sup>49</sup> The PSL explicitly contemplates that service may be provided to multiple users: the statutory language states “transmission or distribution facilities as may be necessary to conduct electricity, gas or useful thermal energy to users located at or near a project site.” In *Burrstone*, the PSC found that “furnishing electric service to multiple users” is specifically contemplated in PSL §2(2-d) “by providing that electricity may be distributed to ‘users,’ in the plural.”

<sup>50</sup> NY CLS Pub Ser § 2-a.

<sup>51</sup> NY CLS Pub Ser § 2-c.

<sup>52</sup> NY CLS Pub Ser § 2-b. The 80 MW limit for alternate energy production facilities applies to the aggregate generating capacity of sources within the facility.

<sup>53</sup> NY CLS Pub Ser § 2-d.

in a microgrid. In Petition for Advocates of Prattsburgh, the PSC noted that generating capacities of physically separate projects proposed by separate owners “have not previously been aggregated in determining whether a facility is a State qualifying facility under PSL §2(2-a), (2-b), or (2-c).”<sup>54</sup> The PSC noted, however, that if the proposed projects were interconnected (e.g., in a microgrid), they would likely not obtain qualifying facility exemption if generation capacity exceeded 80 MW.

As opposed to the type and size of generation, the most pertinent factor influencing a project’s exemption status is likely to be whether the microgrid’s distribution facilities are considered “located at or near a project site” to thereby qualify as “related facilities.”<sup>55</sup> PSL does not explicitly define what is considered “at or near a project site.” This lack of clarity typically means that prospective developers have to petition the PSC to determine whether or not their pipes or wires qualify as being “at or near” its generators.

The PSC has decided a number of cases that interpret this standard, but the cases do not provide firm guidelines that can be followed to ensure a microgrid project will be exempt. Instead, the cases provide data points offering different perspectives on what “at or near” might mean in different contexts (see Table 4-3).

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<sup>54</sup> NYS PSC Case 07-E-0674 - Petition of Advocates for Prattsburgh, Cohocton Wind Watch and Concerned Citizens of Italy for a Declaratory Ruling on Windfarm Prattsburgh.

<sup>55</sup> NY PSL § 2 (2-d).

**Table 4-3. “At or near” case examples**

	<b>Case Name</b>	<b>Description</b>
<b>Deemed “at or near”</b>	<i>Nissoquoque Cogen Partners – Petition for a Declaratory Ruling</i>	A 1.5-mile steam line connecting a 40-MW cogeneration facility to SUNY Stony Brook’s campus (crossing a public thoroughfare) was deemed a related facility at or near the qualifying generation source.
	<i>Nassau District Energy Corporation</i>	A 1.7-mile electric distribution line was deemed a related facility at or near the qualifying generation source. The distribution line passed almost entirely on the builder’s property—a fact the PSC noted as persuasive in its “at or near” determination.
	<i>Steel Winds Project, LLC</i>	The distribution facilities needed to connect a 20MW wind installation to a substation (~4,500 ft. from the wind installation) to users ranging up to 1-mile from the substation were deemed at or near the project site.
	<i>Advocates for Prattsburgh</i>	Electric distribution lines up to 4.2 miles in length were deemed at or near a 2,500 acre wind farm.
	<i>Burrstone LLC</i>	The electric distribution lines connecting several cogeneration units on one piece of property to buildings located on separate pieces of property (crossing property lines and a public highway) were deemed at or near as part “project site”
<b>Deemed not “at or near”</b>	<i>Griffiss Utility Service Corporation</i>	The PSC reserved judgment on whether a 3,500 acre campus qualified for the exemption, stating that a finding of fact would need to be made as to whether the related facilities were “at or near” the project site over such a large acreage. A follow-up judgment was never sought by the petitioners.
	<i>Seneca Power</i>	An 11.2-mile gas line delivering gas to a cogeneration plant was deemed not at or near the project site
	<i>Project Orange Associates LLC</i>	A 9.5-mile gas line delivering gas to a cogeneration plant was deemed not at or near the project site. In the case, the PSC distinguished between distribution facilities that deliver energy to end users and distribution facilities that deliver energy to generating facilities—arguing that the latter may need to be judged under a harsher standard.

A limited review of prior cases interpreting the “at or near” requirement could suggest that a project will be deemed a qualifying facility if its distribution network is under two miles. However, this range might expand (or contract) depending on several types of variables: whether the project site is in a densely or sparsely developed location; what type of technologies it uses (e.g., wind farm will naturally require a broader distribution network due to the acreage it takes up); and whether those facilities stay on private property or cross public rights of way. In Nassau County, the PSC also considered the argument that what qualifies as “at or near” in a densely populated area may be subject to a more restrictive interpretation than what qualifies in a more rural area. For example, a two-mile distribution network in a densely populated city may not benefit from this precedent.

**Landlord-Tenant Exemption.** Microgrids that provide service only for their own use or the use of their tenants will be able to seek regulatory relief under the landlord-tenant exemption. This seemingly narrow exemption may potentially be applied to achieve broader exemptions than would otherwise be available under the “at or near” test of the QF exemption. In a separate *Griffiss* decision from 1998, the PSC ruled on whether the Griffiss Industrial Park would qualify under the landlord/tenant exemption. The park was “a 500-acre complex containing 120 buildings, 29.5 miles of road, and a steam generating and distribution system that [met] the heating needs of almost all of the buildings.”<sup>56</sup> The Griffiss Local Development Corporation (GLDC) contracted to lease and manage the Park, and operate the steam system. Several previously unrelated users would lease buildings in the industrial park. The dispositive fact in the decision was not, however, the size or the users of the park, in spite of it being far larger than any of the aforementioned qualifying facilities, and making use of neither renewable energy nor cogeneration. The dispositive fact in the decision was that the U.S. Department of Defense, which had sold most of the land in the park to the GLDC, had held onto a few parcels of land that the steam distribution system would continue providing service for. The PSC held that continuing to provide this service to land it did not own, and needing to cross property lines to do so, disqualified GLDC for the exemption. The decision otherwise strongly suggests that GLDC would qualify, making clear that who holds title to the land being serviced and the need to utilize the property of others can be dispositive factors in the analysis under this theory.

**Reducing Regulatory Uncertainty.** As discussed in Finding 4.1, the current REV proceedings will consider the regulatory exemptions available to microgrids, although the depth to which these issues will be discussed is yet undetermined. The Microgrids Working Group within the REV proceeding is considering the following areas<sup>57</sup>: when the obligation to serve might attach to a microgrid; clarity on what microgrid facilities will be exempt from regulation as an electric corporation (which, broadly speaking, is the concern addressed by this section); whether standby rates should be reduced or eliminated, particularly for microgrids servicing critical infrastructure; whether net metering policies can be clarified to address how mixed assets will be treated; and if a standardized interconnection process for microgrids might be feasible.

Greater regulatory certainty may be achieved through defining a “qualifying microgrid” that would offer a clear path to appropriate regulatory exemption. This report does not take a position on the optimal definition of a qualifying microgrid. The PSC may wish to consider what features of a microgrid – the appropriate size of generators, types of generation, types of customers, dependence on the utility – it desires to promote and craft a statutory definition of a “qualifying microgrid” that would offer a clear path to appropriate regulatory exemption. To clear up the regulatory uncertainty addressed in the Burrstone case, the Legislature could consider expressly allowing a single generation source to serve multiple electric and thermal loads among previously unaffiliated utility customers.

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<sup>56</sup> Case 98-S-1174, *Griffiss Local Development Corporation*, 1998 WL 850011 (N.Y.P.S.C.). This case precedes the aforementioned Griffiss case, in which the developer later tried to qualify for exemption for utilizing cogeneration.

<sup>57</sup> Draft Final Report dated 06/13/2014, Reforming the Energy Vision, Working Group 2: Platform Technology, Subcommittee on Microgrids and Community Grids.

Previous case law seems to set the threshold of what qualifies as “at or near” somewhere between 2 and 10 miles distance. In prior cases, the PSC has also considered factors other than mere distance in its “at or near” analysis, such as crossing public rights-of-way, crossing property boundaries, and development density of the surrounding area. By providing more clarity on the facilities that qualify for the “at or near” exemption, the PSC could reduce regulatory uncertainty for non-utility microgrids.

In doing so, the PSC may wish to incorporate a microgrid definition into the determination of “at or near.” In developing a flexible rubric for the “at or near” test, the PSC could incorporate as much of the DOE’s microgrids definition into the PSL as possible.

There is no clear statutory authority for the PSC to limit the number of previously unrelated users that may be served by a microgrid, at least by regulating the number itself. The statutory term “users” does not seem to anticipate a ceiling. Functionally, the limit on the number of users that may be served by the microgrid seems to be set by the “at or near” standard.

#### **4.2.1.2 Will the microgrid be regulated as a steam plant?**

Microgrids that use cogeneration technology distribute thermal energy and, therefore, may be subject to regulations for steam corporations. Cogeneration requires the use of “steam plants,” which are covered under the PSL, and defined as “all real estate, fixtures and personal property operated, owned, used or to be used for or in connection with or to facilitate the generation, transmission, distribution, sale or furnishing of steam for heat or power.”<sup>58</sup> As with the regulation of electric corporations, the default rule is that virtually every steam plant will be considered part of a regulated steam corporation, which is defined as “every corporation, company, association, joint stock association, partnership and person, their lessees, trustees or receivers appointed by any court whatsoever, owning, operating or managing any steam plant.” A steam corporation can be regulated for the “manufacture, holding, distribution, transmission, sale or furnishing of steam for heat or power, to steam plants and to the persons or corporations owning, leasing or operating the same.” The powers of the PSC over steam corporations generally mirror those of electric and gas corporations and are outlined in PSL § 80.

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<sup>58</sup> PSL § 2(21).

However, the smaller scale of certain microgrid models will likely allow those microgrids to fall into one or more exceptions to the “steam corporation” designation, thus excluding them from the PSC’s jurisdiction.

These exceptions are:

- (1) “where steam is made or produced and distributed by the maker, on or through private property solely for the maker’s own use or the use of the maker’s tenant and not for sale to others”
- (2) “where steam is made or produced by the maker solely from one or more of such facilities to users located at or near a project site”
- (3) “where steam is made or produced and distributed solely for the use of its members by a non-profit cooperative corporation organized under the cooperative corporations law.”

In determining whether a cogeneration plant will qualify for regulatory exemption as a steam corporation, a comparable analysis to electric regulatory exemption should be undertaken. See Section 2.2.1 for a detailed analysis of the QF and the Landlord-Tenant Exemptions.

Even if an exemption cannot be obtained, the PSC has shown a willingness to reduce regulatory oversight of steam operations when steam service is incidental to the property owner’s primary business. In an Order addressing the Griffiss Local Development Corporation (GLDC) of Rome, NY, the PSC approved a lightened regulatory regime for the project.<sup>59</sup> GLDC had previously been determined to be a steam corporation under PSL §2(22)(a). As such, GLDC was required to obtain a Certificate of Public Convenience and Necessity (Certificate) in order to serve its customers.

However, GLDC also qualified for incidental regulation of its steam operations under PSL § 80(11). That statute provides that a steam utility may be exempted from filing and recordkeeping requirements, where the steam service provided is incidental in character. GLDC adequately demonstrated that the steam revenues it collected were subsidiary to its primary purpose of promoting economic development by operating the park and attracting new business to the Rome area. The fact that the GLDC was in competition to lure businesses to its park by offering the lowest steam service rates justified to the PSC that these consumers did not require additional PSC protection. Therefore, GLDC was exempted from keeping accounts, records, and books; from the filing of annual reports; and, from the filing of rate schedules and tariffs.

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<sup>59</sup> PSC Case 98-S-1174, Griffiss Local Development Corporation - Petition for a Declaratory Ruling that it is not a Steam Corporation Subject to the Jurisdiction or Oversight of the Commission (Sep. 9, 1999).

In the Eastman Park proceeding, RED-Rochester LLC (RED) was authorized to provide a suite of utility services, including electric, gas, steam, and various types of water, to customers located within an islanded site that nevertheless extends over several square miles.<sup>60</sup> RED currently serves 13 customers within the park, including Kodak Corporation (Kodak) the former provider of utility services at the park. While RED could not qualify for the incidental regulation available under PSL §66(13) and analogous statutory provisions, it was afforded lightened regulation by the PSC. Under lightened regulation, which was specifically justified through a realistic appraisal approach, RED was exempted from various PSL statutory provisions and was advised that its filings under other provisions would be reviewed with reduced scrutiny. The lightened regulation afforded by the PSC was sufficient to permit RED to move forward with its plans to operate the utility services provided at the Eastman Park. Moreover, certification under PSL §68 was sufficient to define the boundaries of the Park and the locations that RED could serve.

#### **4.2.1.3 If a non-utility microgrid does not receive regulatory exemption**

If a microgrid is not exempted from regulation as an electric or steam corporation, it will have to comply with a variety of powers exercised by the PSC. These powers, as well as additional protections applying specifically to residential customers, are described in Section 3. However, because the statutory definition of electric and steam corporations is broad, the PSC will not apply the same regulatory regime to all entities that qualify under these definitions. Instead, the PSC has adopted a flexible, “realistic appraisal” approach to determine how to regulate different forms of electric corporations.

The PSC’s realistic appraisal consists of a three-prong analysis: 1) whether a particular section of the PSL is inapplicable on its face (i.e., evident without need for proof or reasoning); 2) if a provision is facially applicable, whether it is possible for an entity to comply with its requirements; and 3) whether imposing the requirements on an entity is necessary to protect the public interest, or whether doing so would adversely affect the public interest.

A realistic appraisal yields different results depending upon the provider’s characteristics. The “realistic appraisal” test could be used to determine the regulatory treatment of a microgrid that fails to qualify for regulatory exemption. The PSC recently applied the “realistic appraisal” test to the Eastman Park facility, which resembles a microgrid in the sense in which it is defined in this report. It has also approved a lightened regulatory regime for the Griffiss Local Development Corporation (GLDC) project, which resembles a microgrid, but did so without citing the “realistic appraisal” standard. It is difficult, therefore, to prognosticate how this standard would be applied to microgrids generally.

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<sup>60</sup> Case 13-M-0028, RED-Rochester LLC and Eastman Kodak Company, Order Confirming Prior Order and Granting Certificates of Public Convenience and Necessity (issued June 13, 2013).

## 4.2.2 Will the nonutility microgrid be deemed a provider of last resort?

In addition to the regulatory powers outlined in previous sections, a microgrid may be subject to an obligation to serve a group of customers. The obligation to serve a customer is only imposed on a “provider of last resort,” a designation traditionally reserved for utilities. The obligation has yet to be imposed on a microgrid. It could hypothetically occur, however, if a microgrid were deployed in an area that had not previously received service from a distribution utility, such as a greenfield development.

In New York State, electric corporations have a statutory obligation to serve customers. The PSL requires every electric corporation to “provide residential service upon the oral or written request of an applicant, provided that the commission may require that requests for service be in writing under circumstances as it deems necessary and proper as set forth by regulation, and provided further that the applicant” can pay.<sup>61</sup> As the default service provider, a local distribution utility has a legal obligation to provide electric service to any customer who requests it and is willing to pay the rates established for such service. If a building is not supplied with electricity, an electric corporation is “obligated to provide service to such a building, provided however, that the commission may require applicants for service to buildings located in excess of one hundred feet from gas or electric transmission lines to pay or agree in writing to pay material and installation costs relating to the applicant's proportion of the pipe, conduit, duct, or wire, or other facilities to be installed.”<sup>62</sup>

The PSC is unlikely to impose an “obligation to serve” on microgrids in the near future. In a 2004 “Statement of Policy on Further Steps Toward Competition in Retail Energy Markets,” the PSC rejected a proposal that would have imposed the obligation to serve on all energy service companies (ESCOs, which, for these purposes, may be analogized to microgrids) within the geographic area and with respect to the customer classes they elect to serve. The PSC held that “such an obligation could unduly constrain ESCOs and thereby impede development of the market.”<sup>63</sup> And, as detailed in Section 4.2.1, if a microgrid is eligible for regulatory exemption as a qualifying facility, it will not be considered an electric corporation, and the obligation to serve cannot attach.

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<sup>61</sup> PSL § 31(1).

<sup>62</sup> PSL § 31(4).

<sup>63</sup> Case 00-M-0504- Proceeding on Motion of the Commission Regarding Provider of Last Resort Responsibilities, the Role of Utilities in Competitive Energy Markets and Fostering Development of Retail Competitive Opportunities (August 25, 2004).

### **4.2.3 Will the nonutility microgrid be allowed to distribute energy across public rights-of-way?**

All microgrids that cross a public right of way (e.g., for moving transmission or distribution facilities over public streets) must be granted permission by the presiding municipal authority in the form of a franchise or some lesser consent, depending on the scope of the usage. The grant of a franchise is typically a more demanding process, and a lesser consent is often preferable. The cities, towns, and villages of New York have specific statutory authority to grant franchises. As provided by N.Y. Gen. City Law § 20(10), every city is empowered to grant franchises or rights to use the streets, waters, waterfront, public ways, and public places of the city. “Use” encompasses occupying public rights-of-way and operation of the provider’s built infrastructure to provide the public service. Individual franchises—contracts between a company and the municipal authority—require specific legislative authority and are granted for a limited term of years after a public bidding process.

In New York State, franchises are typically nonexclusive, at least in principle, and the territory in which facility installation is permitted under a given franchise is the territory where the public service is provided. In fact, except where a grant is by its terms exclusive, the grantor reserves the power to grant a subsequent, competitive franchise and the subsequent grant does not violate the first franchisee’s contractual or constitutional rights. Monopoly is not an essential feature of a franchise, and in view of the competition-increasing changes in regulation, it is not a feature that is required in New York.

More typically, municipalities provide for minor encroachments into public spaces by administering special permissions that may offer an alternative to the large-scale franchise. These permissions might be referred to as permits, right of way permits, revocable licenses, revocable consents, and similar instruments. Where the municipality does not use a standardized permitting process for conferring this type of property right, an authorized party, such as a mayor, counsel, or commissioner of public works must grant permission on an individual basis.

In the case of New York City, the City administers a formal, organized system through which applicants may obtain a revocable consent enabling them to install and use infrastructure within public space as a quasi-owner of that property. The New York City Department of Transportation (DOT) website provides that obtaining a revocable consent requires petitioning the Division of Franchises, Concessions and Consents and submitting a petition for the DOT’s review. The DOT then distributes the petition to appropriate City agencies, which, depending on the nature of the revocable consent structure proposed, may include the Department of Buildings, Department of City Planning, and various other agencies responsible for administering rules for safety, zoning, and preservation of landmarks. The DOT next holds a public hearing regarding the merits of the petition, which is followed by a 10-day comment period. Where no issues arise, the DOT executes a revocable consent agreement with the applicant subject to approval by the Mayor. Other cities in New York State have systems that offer similar permits for use of public space.

If a microgrid project attempts to provide service within an existing franchise area, any other current franchisee, as an interested party, may intervene or be invited to comment on proceedings between municipal authorities and the incoming microgrid developer over the grant of new property use permissions.

#### **4.2.4 Nonutility microgrid interaction with the macrogrid**

Nonutility microgrids may interconnect with the macrogrid and receive, at a minimum, back-up electric service from the local utility. They may also use the macrogrid to export extra power when microgrid generation exceeds microgrid demand. For these reasons, services such as standby rates, net metering, and buy back tariffs, as described in Sections 4.1.2.1, 4.1.2.2, and 4.1.2.3, may apply to nonutility microgrids. Depending on the microgrid configuration, these services may be supplied directly to the individual microgrid users or to the microgrid at a single point of common coupling. If the microgrid is behind a point of common coupling, there may be complexities to the application of standby rates and net metering.

For a nonutility microgrid receiving services from the macrogrid from a point of common coupling, assessing standby rates for microgrid users individually may not accurately account for the true costs each user imposes on the grid. In this configuration, each microgrid user collectively shares the utility infrastructure that interconnects with the microgrid with every other microgrid user and therefore, does not require any individually dedicated utility infrastructure. Consequently, individually assessed contract demand charges may overestimate the true cost to the macrogrid because the maximum peak demand experienced by the utility will likely be less than the sum of each individual user's maximum peak demand. By assessing the charge individually, the collective contract demand charge effectively assumes that each user's peak occurs simultaneously.

A nonutility microgrid that incorporates several different types of DERs (e.g. CHP and solar) may contain generation facilities behind the point of common coupling that qualify for net metering along with generation facilities that do not qualify for net metering. This scenario introduces additional complexity in ensuring that only qualifying generation receives net metering benefits. In previous cases, the PSC has found on a case-by-case basis that it is possible to ensure only qualifying generation receives the benefit through additional metering at various points within the customer's system configuration. Without a standardized method, a nonutility with a mixture of qualifying and nonqualifying generation would likely need PSC approval to receive net metering benefits.

## 4.3 Additional Regulatory Considerations

Microgrids, whether utility or nonutility, may also face other regulatory matters depending on their configuration and external factors.

## 4.4 If the microgrid incorporates natural gas-fired generators

Microgrids that incorporate new natural gas-fired generators or CHP systems may require the delivery of substantially more natural gas to the site than was previously provided by the local gas utility. If the additional natural gas demand exceeds the current infrastructure's capacity, the relevant natural gas mains, service piping, and related facilities will need to be upgraded for the project to succeed. Whether the utility bears the cost of all or some of these upgrades, however, depends on relevant regulation and utility practices. The economics of natural gas-fired DG can be diminished if customers are required to bear an unfair share of the cost of gas service upgrades.

### 4.4.1.1 Legal Standard

The requirements of utilities and gas upgrade applicants regarding gas service upgrades are governed by 16 New York Codes, Rules and Regulations §230. Prior to any upgrades, the applicant must sign an agreement to assure the utility that he/she will be a reasonably permanent customer, pay the utility for any installation and materials costs beyond the costs the utility is required to bear, and pay a rate for future gas delivery charged to similarly situated customers.<sup>64</sup> Section §230.2 outlines the "100 foot rule," which requires gas utilities to install up to 100 feet of main and service line extensions and related facilities at no cost to the applicants.<sup>65</sup> Utilities can bear the cost of extensions and additional facilities beyond 100 feet if the utility deems the expansion to be cost justified.<sup>66</sup> This situation, however, is relatively rare, and utilities will often require the applicant to pay for any installation and material costs beyond 100 feet.

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<sup>64</sup> 16 NYCRR § 230.2(b).

<sup>65</sup> 16 NYCRR § 230.2 (c), (d), and (e).

<sup>66</sup> 16 NYCRR § 230.2 (f). Methods for determining cost-justified upgrades are set forth in each utility's tariff. For example, Con Edison analyzes whether the projected net revenue derived from the potential customer will cover the cost to install the service line beyond the 100 ft. maximum. If so, Con Edison will provide line upgrades beyond 100 feet at no cost to the customer.

When gas service is expanded into new franchise territory, the Gas Expansion Policy Statement promulgated in Case 89-G-078 requires normal rate treatment for projects that will earn a rate of return at least equal to the PSC's allowed levels over the first five years of the project. If the costs cannot be recovered within five years, customers or municipalities can contribute additional funds to reduce revenue deficiencies associated with the project. If revenue deficiencies persist after contributions, the utility can assess surcharges on new customer sales to achieve allowable rates of return.<sup>67</sup> The utility infrastructure that expands into the new franchise area is subject to the same rules contained in 16 NYCRR §230, including the 100-foot rule.<sup>68</sup>

A PSC proceeding, issued on November 30, 2012, reflects the PSC's intention to amend the current expansion regulations to promote natural gas expansion within the State.<sup>69</sup> According to the PSC, natural gas market prices are favorable to expansion, and increasing natural gas usage over more carbon intensive fuels will offset harmful greenhouse gas emissions. DPS Staff has submitted a proposal on the 100-foot rule that also requests comment on when circumstances may warrant providing an additional length of main at no cost to the customer, e.g., when a customer commits to service for an agreed upon term, where construction costs can be minimized, or wherever else it might be "consistent with the best interests of the ratepayers."<sup>70</sup> Some commenters noted that the PSC could increase the period over which the utility must evaluate their return on investment from five to 10 years, and allow for an exit fee for any customer that breaks the contract before the 10-year time period. This change would decrease the amount existing customers would have to contribute to the project through increased rates because the rate payments from the new customers would cover a greater amount of the cost over a 10-year time period.<sup>71</sup>

In establishing this proceeding, the PSC was motivated by Governor Cuomo's Energy Highway Initiative, which seeks to create an advanced state grid while promoting business growth.<sup>72</sup>

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<sup>67</sup> Case 89-G-078, Policy for Rate Treatment of Gas Service Expansion into New Franchise Areas, Statement of Policy Regarding Rate Treatment to be Afforded to the Expansion of Gas Service into New Franchise Areas (issued December 11, 1989), 15-17.

<sup>68</sup> Id., 17-18.

<sup>69</sup> Case 12-G-0297, Proceeding on Motion of the Commission to Examine Policies Regarding the Expansion of Natural Gas Service, "Order Instituting Proceeding and Establishing Further Procedures," issued November 30, 2012.

<sup>70</sup> DPS Staff Proposal dated 06/05/2013, Case 12-G-0297, Proceeding on Motion of the Commission to Examine Policies Regarding the Expansion of Natural Gas Service.

<sup>71</sup> Case 12-G-0297, City of New York comment, at 16.

<sup>72</sup> Governor Andrew M. Cuomo, New York Energy Highway, Blueprint, available at [http://www.nyenergyhighway.com/content/pdf/Blueprint\\_FINAL.pdf](http://www.nyenergyhighway.com/content/pdf/Blueprint_FINAL.pdf).

**Gas Pressure and Access.** Distributed generation that is designed to receive gas at high inlet pressures may be more economical in cases where it can receive gas service directly from the utility company's high pressure transmission lines, rather than the comparatively lower pressure distribution lines that service most customers.<sup>73</sup> This strategy might save a customer-generator the cost of buying and maintaining gas compressors that raise the gas pressure to appropriate inlet levels. Such an arrangement may be feasible in circumstances where the generation is physically located near an existing high-pressure gas transmission line. In such a case, the customer must typically apply to the utility company for a dedicated service line at high pressure connecting to the transmission line, which would be built and paid for under the same set of rules that govern gas service upgrades as previously described. The utility company has some discretion to deny an application for access to the high-pressure system, even though it would otherwise permit access to the low-pressure system. The scope of the utility's discretion may be best explored through the following case study.

Metropolitan Hospital desired to build a new 25-foot, 270-psig dedicated service connection to a nearby 30-inch, high-pressure gas transmission main operated by Con Edison. It would support the operation of a 7.2-MW cogeneration facility sited at the hospital, which requires a 235 psig minimum inlet pressure. Con Edison stated that adequate service was available through the existing distribution main, which transports gas at 60 psig, that connection to the main system would introduce safety and reliability risks, and that the congested subsurface below 71st Street in Manhattan made construction of the new line not feasible because of physical and geographic constraints. Without a high-pressure connection, the hospital would have to install a more expensive compressor to bring 60 psig gas up to at least 235 psig, at a one-time cost of \$800,000 and an annual incremental cost of \$400,000.

The hospital protested Con Edison's decision not to allow the high-pressure interconnection on multiple grounds.<sup>74</sup> Two notable grounds of their petition offer legal tests that future customers may refer to:

- **Obligation to provide adequate service:** Transportation Corporations Law (TCL) §12 requires a gas corporation to supply gas to an owner of a building within 100 feet of any main or line, appropriate to the service requested, as implemented in PSC rules 16 NYCRR 230.2(e), requiring a gas corporation to construct the necessary mains and service connections to supply service to a nonresidential customer, within 100 feet of main and appurtenant facilities at the corporation's expense. Con Edison argued that TCL §12 only requires provision of service appropriate to the service requested," and that gas service is not an obligation if the ground presents "serious obstacles to laying pipe. The Commission accepted Consolidated Edison's interpretation of the regulation, holding that adequate service does not require a specific pressure, and that safety risks must be accounted for.

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<sup>73</sup> Different types of natural-gas powered DG may or may not require higher pressure gas service e.g., small scale reciprocating engines do not require high pressure gas lines to operate. A sub 500kWe unit may require 0.3(min)-0.8(max) PSIG input pressure. Small scale microturbines may require higher gas input pressure of about 75-80 psig.

<sup>74</sup> NY PSC Case 06-G-0723 - Petition of The New York and Presbyterian Hospital for high pressure service and penalty action against Consolidated Edison Company of New York, Inc., Order Denying Petition (Issued and Effective July 30, 2007).

- Prohibition of undue discrimination:** PSL § 65 prohibits undue discrimination by a gas corporation in providing gas or rendering service. Metropolitan Hospital stated that Con Edison served other customers from its transmission system and thereby violated this section in denying service specifically to them. Consolidated Edison argued that these facilities are either not similarly situated to the hospital (power plants and NYC-owned compressed natural gas facilities), or had their gas pressure lowered first by regulator stations that reduce the pressure to 60 psig. The PSC agreed that PSL §65 permits discrimination among different classes of customers where a rational basis for that discrimination exists, and that such basis existed here. In the future, however, other utility territories may have to be considered on a case-by-case basis, depending on whether they customarily allow or deny access to the high-pressure system. The inverse problem – that of acquiring access to low-pressure gas – may actually be more common, and can also be problematic for some developers, particularly where it is more expensive to connect to a higher pressure line than to a lower pressure line.<sup>75</sup> A utility may prefer to connect some large customer-generators to the high pressure system because the low pressure system cannot carry enough capacity to adequately supply a large generation project. The conflict these customers find themselves in will be governed by the same rules as govern the access to high-pressure gas..

**Gas Prices.** Gas customers can choose between multiple delivery rates set by the utility, or be served by a third-party, regulated gas marketer. A distributed generation rate is established in each territory, applying where “separately metered gas service is used solely for the purpose of the operation of a Distributed Generation Facility with a name plate rating less than 50 MW and having an Annual Load Factor equal to or greater than 50 percent.”<sup>76</sup> These rates vary by territory, however, generally many customers may find that for their applications, availing themselves to a Transportation Rate or the price offered by a marketer may be a more cost-effective solution. For example, commercial industrial customers with the gas demand associated with 5-10 MW of generation may find that gas marketers can provide the most affordable rate, depending on where they are located.<sup>77</sup> This tension between different rates offered by a utility and that offered by a third-party marketer is best analyzed on a case-by-case basis.

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<sup>75</sup> Interview with John Sano, New York Department of Public Service (Feb. 13, 2014).

<sup>76</sup> *See, e.g.*, Consolidated Edison’s Rider H tariff, available at [http://www.coned.com/documents/gas\\_tariff/pdf/0003\(06\)-General\\_Information.pdf#page=37](http://www.coned.com/documents/gas_tariff/pdf/0003(06)-General_Information.pdf#page=37).

<sup>77</sup> Interview with John Sano, New York Department of Public Service (Feb. 13, 2014).

## 5 Technical and Regulatory Aspect of Microgrid Interconnections

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### **Findings**

**Finding 5.1:** In order to conform to existing utility interconnection requirements, microgrids may require more specialized protection equipment (e.g., transfer trip switches) than typical generation interconnections.

**Finding 5.2:** No standard utility interconnection requirements presently exist that would universally address all potential sizes and micro-to-macrogrid configurations.

**Finding 5.3:** The microgrid design for facilities willing to tolerate a short duration outage when switching to islanded mode is less complicated and costly than designs for facilities that require seamless, non-interrupted (“bumpless”) power.

**Finding 5.4:** As part of an interconnection agreement with the local utility, the microgrid developer may be responsible for the costs associated with any upgrades to the electric infrastructure that are required to support the microgrid installation. Rules related to microgrid developer cost contributions are being reviewed by the Public Service Commission in the Reforming the Energy Vision (REV) proceeding.

### **Recommendation**

**Recommendation 5.1:** The State should continue to support development of microgrid interconnection technologies (e.g., power electronics) and designs.

The Legislation required that the Project Team determine:

- The technical and regulatory aspect of how a microgrid will be interconnected to the power grid.

In order to install any form of distributed energy resources (i.e., generation and storage) that is interconnected with the utility grid, the customer and utility will need to reach an interconnection agreement. This agreement will typically stipulate conditions for the operation of the resource, and may (depending on the size of the resource) involve the utility conducting a study of how the new resource will impact the existing local distribution system, or require the utility to install new distribution equipment in the local area to ensure the continued safe and reliable operation of the local distribution network (with much of the costs for this process accruing to the interconnecting customer-generator). The process each utility follows for approving a new interconnection must be in compliance with the New York State Department of Public Service’s Standard Interconnection Requirements (SIR), which covers new generation sources up to 2 MW in size. No standardized requirements exist for the interconnection process of generation larger than 2 MW, although the New York Independent System Operator (NYISO) and utilities have internal guidelines for this process that largely mirror the SIR for projects that are 2-20 MW.

The SIR is a largely procedural document, stipulating steps in the interconnection process with time limits for the utility to respond at each, and the allocation of costs. The bulk of the SIR's technical requirements are acquired by reference from the Institute of Electrical and Electronics Engineers (IEEE) 1547 series of standards. The IEEE develops technical standards and establishes best practices for the electronics, computing and electric power industry, including those related to the interconnection of distributed resources to the electric power grid. The SIR is "intended to be consistent with those contained in the most current version of the IEEE 1547 standards." IEEE 1547–2003 is the foundational standard for the IEEE 1547 series, which establish technical requirements for the interconnection of distributed resources to electrical power systems.<sup>78</sup> A full revision of IEEE 1547 Standards has now begun with the aim to release by 2018. The main revisions are likely to include microgrids – in particular, how the protection and anti-islanding schemes and settings in the prior Standards will need to be modified to accommodate them.

The IEEE 1547 series currently includes a total of six published standards, as follows:

- IEEE 1547–2003, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
- IEEE 1547.1–2005, IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
- IEEE 1547.2–2008, IEEE Application Guide for IEEE 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
- IEEE 1547.3–2007, IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems
- IEEE 1547.4–2011, Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems
- IEEE 1547.6–2011, Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Network.

IEEE 1547.4 and 1547.6 are specifically designed to address issues associated with the interconnection of microgrids to the electric grid. IEEE 1547.4 addresses issues associated with islanding, a condition in which a portion of the utility system that contains both load and distributed generation is isolated from the remainder of the utility system. The IEEE 1547 series uses the term "Distributed Resource Island System" interchangeably with "microgrids." DR island systems are electric power systems that: (1) include distributed resources and load and (2) have the ability to separate from and reconnect to the macro-grid while providing power to the islanded grid. IEEE 1547.6 addresses interconnection issues associated with distribution secondary network systems, including best practices for communication and control systems.

Like distribution generation, microgrids are required to meet several technical standards prior to interconnecting with the electric grid, including those associated with (1) overcurrent protection; (2) synchronization; (3) voltage control and power control; (4) metering and monitoring and (5) IEEE 1547 compliance.

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<sup>78</sup> The Energy Policy Act of 2005 identified IEEE as the primary organization for developing standards and best practices for interconnecting distributed resources with the electricity grid.

Different sets of technical requirements will affect a microgrid in grid-connected mode and in islanded mode. In grid-connected mode, all of the distributed resources in a microgrid will have to meet the requirements that apply to grid-connected distributed generation. Such requirements normally cover several topics, including impacts on the following:

- Utility voltage and voltage regulating equipment.
- Overcurrent protection.
- Effective grounding.
- Islanding prevention.
- Harmonics.
- Voltage flicker.
- Load rejection overvoltage.<sup>79</sup>

A different set of technical requirements will impact the microgrid when it transitions into islanded mode. With traditional distributed generation, islanding is something to be avoided, but with a microgrid, islanding is a key benefit for resiliency and reliability. Many of these integration issues will also apply when the microgrid is operating in standalone (islanded) mode, but the circuitry, control modes, and power flows may be quite different than when grid connected. Microgrids must meet utility standards when interconnected with the utility grid and when reconnecting with the grid. When operating in standalone mode, the microgrid may or may not need to follow utility standards, depending on who owns various parts of the microgrid infrastructure. Regardless of ownership and ruling guidelines, the technical issues are the same; all parties want safe, controllable electricity distribution within the microgrid that supplies suitable voltage and frequency to loads.

In standalone mode, several additional issues arise:

- Voltage control.
- Frequency control.
- Matching generation with load.
- Synchronization.
- Black start capability.

Section 5.1 details a series of general issues that affect microgrid interconnection in any environment, such as overcurrent protection, synchronization, voltage and power control, metering and monitoring, supplying critical infrastructure, and black starting. Sections 5.2 and 5.3 consider several different design typologies for microgrid distribution networks (e.g., a campus style microgrid vs. a microgrid operating in a grid network), each of which are most likely to be found in different environments (rural, suburban, and urban) with characteristics that also impact the microgrid.

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<sup>79</sup> For coverage of these impacts of conventional distributed generation, see Barker and De Mello (2000), CEA 128 D 767 (1994), EPRI 1024354 (2012), IEEE 1547-2003, IEEE 1547.2-2008, IEEE Working Group (2004), NY PSC (2014), Short (2014), and Walling et al. (2008). IEEE 1547.4-2011 (IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems) also covers operation of islanded systems such as microgrids.

## 5.1 Reforming the Energy Vision Proceeding and the Future of Microgrid Interconnection in New York

Within the Public Service Commission’s “Reforming the Energy Vision” (REV) proceeding, a Microgrids Working Group has been tasked with identifying several issues, including those related to microgrid interconnections. The working group has identified a variety of potential recommendations for the PSC to consider.<sup>80</sup> Pervasive issues affecting microgrid development identified by the working group include:

- Microgrids with multiple utility tie points generally do not conform to existing utility requirements. This issue will generally include microgrids installed into urban secondary network systems.
- Due to lack of standardized interconnection requirements for interconnection of microgrid projects over 2 MW, timely processes for interconnection design, approval, and construction needs to be reviewed and addressed.
- Existing utility interconnection requirements do not incorporate newer technologies, such as smart inverters, ride-through, voltage regulation schemes, and energy storage.
- Planning the operation and integration of microgrids interconnecting to the macrogrid may require sophisticated models that have not been fully tested and/or used in the industry at this time.
- There is a lack of mature microgrid controller technology.
- There may be ambiguity on who has the obligation to maintain or repair microgrid infrastructure interconnecting with the utility system.
- Communications infrastructure will be required between the microgrid DER and the macrogrid.

Highlights among the potential solutions identified by the working group include:

- Most interconnection issues could be resolved by the creation of a unified set of interconnection standards applicable both to utilities and microgrid developers.
- Expansion of the Standardized Interconnection Requirements from the existing 2 MW threshold or the adoption of FERC Order 792 for smaller (2 - 20 MW) generator interconnections needs to be reviewed and addresses to simplifying and assuring speedy completion of the interconnection application and review process.
- The topic of allocating the cost of interconnection needs to be reviewed and addressed in order to determine the economics of such interconnection / microgrid projects on the utility grid.
- The IEEE is expected to revise its 1547 standards, which will incorporate microgrid configurations, by 2018.

As the REV process moves forward, the PSC will consider these and other considerations put forward in its working groups that may influence how microgrids interconnect in the future.

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<sup>80</sup> PSC Subcommittee on Microgrids and Community Grids. June 2013, 2014, Reforming the Energy Vision, Working Group 2: Platform Technology (Draft Final Report)..

## 5.2 General Issues Affecting Microgrid Development

This section will explore a series of considerations that are likely to be important in any environment where microgrids are developed. It will introduce these issues from a general perspective. Sections 5.3 and 5.4 will then apply these considerations to a series of specific design typologies for microgrid distribution networks.

### 5.2.1 Overcurrent Protection and Relaying

Overcurrent or excess current is a situation where a larger than intended electric current passes through a conductor, leading to excessive generation of heat, and the risk of fire or damage to equipment. When connected to the grid, the utility will desire that the rest of the grid is protected from any overcurrent that is created by the microgrid. Various types of abnormal currents are more broadly referred to as faults. Typically, generation will have to be able to coordinate with existing overcurrent protection systems, and be able to separate from the utility system when a fault or other disturbance occurs. This separation can be accomplished by the use of relaying equipment, which senses when a fault occurs on one part of the system and communicates with a switch at another part of the system to “open” (i.e., prevent current from passing through) and thereby isolate the fault-bearing part of the system. Separation can isolate the microgrid from the broader grid, or even to isolate a part of the microgrid from the rest of the microgrid. Effective grounding of a line can also help control certain overcurrents and provide the fault current necessary to operate certain overcurrent protection devices.

In grid-connected mode, generators need to coordinate with overcurrent protection on the distribution system. The fault-current contributions from these generators should not cause other equipment to exceed short-circuit limits. The additional fault current supplied by generators should also minimize disruption of distribution relaying.

In addition to coordination, the microgrid needs to be able to separate from the utility in cases of faults or other disturbances either inside or outside of the microgrid zone. Table 5-1 shows required trip times for distributed generators based on IEEE 1547-2003. From the perspective of the utility system, having a microgrid separate within the times in Table 5-1 is sufficient.

**Table 5-1. Trip thresholds for distributed generators based on IEEE 1547-2003**

Voltage Setting			Trip Time, sec
	V	< 50%	0.16
50% ≤	V	< 88%	2.0
110% <	V	< 120%	1.0
120% ≤	V		0.16

Base voltages are the nominal voltages stated in ANSI C84.1:

- DR < 30 kW: Maximum Trip Time.
- DR > 30 kW: Default Trip Time or the utility operator may specify different voltage settings or trip times to accommodate utility requirements.

The normal scenario that would trigger the trip thresholds in Table 5-1 is a fault in the electrical system. This fault can be any of several places, including the subtransmission system, the distribution system outside the microgrid zone, or the distribution system inside the microgrid zone. For faults outside the microgrid, the microgrid should separate. Once the microgrid separates, the generation and loads are now separate from the disturbance. But because the generation and load may not match, the voltage and/or frequency may deviate high or low to compensate. These deviations from normal will last until the microgrid control balances generation and load. The microgrid must separate and match generation to load within one to two seconds for moderate disturbances and much faster for severe mismatches.

If the fault that caused the disturbance is inside the microgrid zone, then from the utility system point of view, fast separation is desirable. Depending on the fault location, either a utility or customer fault interrupter may operate. The fault interrupter may or may not be the same device that separates the microgrid. If the microgrid controller is measuring current at all interconnecting points with the utility, it should be able to determine if the fault is inside or outside the zone. If the controller identifies a fault inside the zone, it can separate the zone and trip all generation. If the controller cannot measure and determine if the fault is inside or outside the zone, the alternative is to separate and then continue looking for overcurrents at the generators. If a fault is subsequently identified, the generators can trip off to de-energize the microgrid.

Overcurrent protection is also a consideration when the microgrid is operating in standalone mode. If a fault occurs when electrically islanded, the fault must be cleared quickly to minimize damage at the fault location, reduce the chance of fires and explosions, and limit abnormal voltages to loads. The easiest form of overcurrent protection is overcurrent relaying at each generator. Generator-based protection can be implemented with off-the-shelf equipment. If the microgrid has multiple generators with different paths to loads, a controlled separation of a microgrid may be possible. A simple example is two buildings connected in a microgrid with a generator in one of the buildings. If a fault occurs in the cable between them, then the cable between buildings can be interrupted to maintain operation in the building with the generator. Operation of a microgrid in a radial configuration where loads are fed from a central generating area simplifies this type of overcurrent protection. If the system is arranged in a grid with generators at multiple locations, controlled separation is more difficult. In a true distributed grid, communications and a relatively sophisticated control are needed to separate faulted sections.

Another issue with overcurrent protection on a microgrid is having sufficient fault current to operate protective devices such as relays or fuses. Normally, the utility supplies a stiff source that has significant fault current available. Generators may be weaker sources, which may make some faults more difficult to detect. Inverted-based generators and storage systems can be particularly weak fault current sources. Weak fault sources may require different forms of overcurrent detection and protection.

An island with line-to-neutral connected loads should be effectively grounded. During line-to-ground faults, this grounding will help control overvoltages on the unfaulted phases and help provide sufficient line-to-ground fault current to operate overcurrent protective devices. Transformer connections and generator grounding should be reviewed to ensure effective grounding operation. If a line-to-ground fault occurs when islanding and the islanded microgrid is not effectively grounded, loads connected line-to-ground may see voltages higher than 1.8 per unit. If the generator interconnections cannot provide effective grounding, a supplemental grounding transformer can be supplied to effectively ground the system.

## 5.2.2 Safety

One of the most important benefits of microgrids is their ability to support critical infrastructure in a community during an outage. However, microgrids must be carefully planned so as not to introduce additional safety hazards during these major storm events. During major storm events, distribution circuits may have many downed wires. Utilities will have many local and outside crews working to restore service. Microgrids introduce additional safety hazards during storm events, particularly:

- Backfeeds—Microgrids may energize sections of distribution lines that utility workers may not expect to be energized.
- Downed conductors—Microgrids may energize downed conductors, which is a hazard to the public.

Normally, distribution circuits are operated as radial systems<sup>81</sup> where the source is known. That source normally opens when a fault occurs. Distributed generation and backup generation also increases these risks, but some microgrid arrangements may have more concern because their geographic coverage is larger than the typical area a backup generator might be able to energize.

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<sup>81</sup> Radial distribution systems connect multiple users to a single source of power. The distribution system runs from the power source and terminates at the end users, meaning any power failure on that line would cut off power supply to those customers, and must be fixed before power can be restored. No set of alternate lines connects end users with a separate power source or loops back to the original power source. This system is widely used in sparsely populated areas.

Keys to managing these risks with microgrids include:

- Unintentional islanding—Because microgrids are designed to intentionally island, microgrids may be more susceptible to islanding unintentionally relative to other distributed generation applications. Microgrids transition between islanded and grid-connected modes most efficiently when the local load matches the local generation. With a close match between load and generation, an island is likely to sustain, even if the microgrid controller is in grid-connected mode. An unintentional island can occur if a switch upstream of the normal microgrid intertie point opens. Depending on the location of utility switches and interrupters, transfer trip protection<sup>82</sup> may be needed.
- Boundaries— A microgrid should only energize circuitry within a defined boundary. Designs should ensure that areas outside the boundary are unable to be energized by the microgrid. This can occur either from an unintentional island that encompasses more than the normal boundary or from operation in standalone mode in a condition where one or more tie switches do not open.
- Communications and control—Utility system operators should know the operating state of the microgrid. If the utility can control the microgrid or override the microgrid control in emergencies, this extra level of control can reduce hazards during storm events. For example, a utility may get a call of wires down within a microgrid zone, so if the utility can de-energize the microgrid, risks will be reduced. Local control is also important. Local facility personnel or in-the-field utility personnel may need to de-energize or change operations locally, either for downed conductors or for other risks like buildings on fire.
- Grounding compatibility—If the microgrid is effectively grounded, it is easier to detect ground faults on the microgrid in standalone mode.

### 5.2.3 Synchronization

When reconnecting a microgrid to a utility system, an important consideration is synchronization of the microgrid to the utility system to avoid disturbances upon reconnection. Synchronization refers to matching the speed and frequency of power on the microgrid's distribution system to the speed and frequency of power on the utility's distribution system, so that these can seamlessly mesh once reconnected. Proper synchronization will help protect both utility-side and microgrid-side equipment. For synchronization, the voltage, frequency, and phase angle must be within certain bands to minimize connection transients.<sup>83</sup> From most sophisticated to least sophisticated, options to synchronize include:

- Active synchronization—If the microgrid voltage and frequency can be controlled sufficiently, then the microgrid controller can align the voltage and frequency to the utility power system and then reclose.
- Sync check—Reconnection can be blocked by a sync-check relay. The microgrid controller can initiate reclose, and the system should reconnect when the two systems are within synchronization tolerances. If the systems are badly out of sync, reconnection may not be possible.
- Open transition—Disturbances are avoided by de-energizing the microgrid and then reconnecting utility power system. Once reconnected, the distributed generation can be restarted if desired.

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<sup>82</sup> A transfer trip is a protection system that sends a trip command to remote circuit breakers when an electrical fault is detected, thereby helping isolate and clear the fault.

<sup>83</sup> “Connection transients” refer to a momentary electrical oscillation caused by the sudden change of a circuit, as may occur briefly when a microgrid reconnects to the utility system.

See Table 5-2 for synchronization limits from IEEE 1547-2003. Ability to synchronize is dependent on how well the microgrid can control voltage and frequency. Normally, if there are multiple switches than can be involved in a reconnection, the first switch closed will lock the microgrid into the wider system. One could have multiple microgrids or areas that must be reconnected where this would not apply. Such cases may require sophisticated control.

**Table 5-2. Synchronization thresholds for distributed generators based on IEEE 1547-2003**

	Aggregate generator size		
	0 – 500 kVA	500 – 1500 kVA	1500 – 10000 kVA
Voltage difference, percent	10	5	3
Frequency difference, Hz	0.3	0.2	0.1
Phase angle difference, degrees	20	15	10

#### 5.2.4 Voltage Control and Power Control

Each of the loads in a microgrid – every appliance, fixture, or motor that requires power to run – will need to take that power within a certain voltage. Voltage must be regulated to meet different needs at different parts of the system. Voltage must also be “stiff” enough to absorb all of the loads that may draw power off of the system without substantially dipping or producing irregularities. There are several methods for controlling voltage to maintain a stable power source suitable to serve the loads on the system.

Voltage support and regulation is important in a microgrid. Loads expect voltage within certain limits. Table 5-3 shows voltage ranges specified by ANSI C84.1-1995. This standard specifies acceptable operational ranges at two locations on electric power systems:

- Service voltage — The service voltage is the point where the electrical systems of the supplier and the user are interconnected, and is normally at the meter. Maintaining acceptable voltage at the service entrance is the utility’s responsibility.
- Utilization voltage — The voltage at the line terminals of utilization equipment. This voltage is the facility’s responsibility. Equipment manufacturers should design equipment which operates satisfactorily within the given limits.

The standard allows for some voltage drop within a facility, so service voltage requirements are tighter than utilization requirements. This standard also defines two ranges of voltage:

- Range A — Most service voltages are within these limits, and utilities should design electric systems to provide service voltages within these limits. As IEEE 1547 says, voltage excursions “should be infrequent.” For long-term microgrid operations, this range may be most appropriate.
- Range B— These requirements are more relaxed than Range A limits. According to the standard: “Although such conditions are a part of practical operations, they shall be limited in extent, frequency, and duration. When they occur, corrective measures shall be undertaken within a reasonable time to improve voltages to meet Range A requirements.” Utilization equipment should give acceptable performance when operating within the Range B utilization limits, “insofar as practical” according to the standard. For short-term microgrid operations for resiliency support during power system outages, this range may be most appropriate.

**Table 5-3. ANSI C84.1 voltage ranges for 120 V**

	Service Voltage		Utilization Voltage	
	Minimum	Maximum	Minimum	Maximum
Range A	114 (−5%)	126 (+5%)	110 (−8.3%)	125 (+4.2%)
Range B	110 (−8.3%)	127 (+5.8%)	106 (−11.7%)	127 (+5.8%)

In standalone operation, the controller(s) for a microgrid must regulate voltage. In grid-connected mode, the local generators should not try to regulate voltage. For single generators, voltage control is relatively straightforward. For multiple generators, control of voltage becomes more complicated.

If there is other voltage-controlling equipment in a microgrid, these devices must be coordinated with the generators. These devices include voltage regulators and voltage-controlled capacitor banks. One option is to disable voltage control on these devices when the microgrid is operating in standalone mode. Even in grid-connected mode, it is important to check that the microgrid does not affect voltage profiles and voltage control.

In addition to steady-state voltage control, other voltage characteristics are important. The microgrid must be stiff enough to provide torque to start motors within the microgrid. A utility source is normally stiffer than local generation within a microgrid. One option is to prevent large motors from starting or ensure that such motors have a soft enough start for the microgrid during standalone operation.

The local generation should also provide a stiff enough source to limit voltage unbalance, harmonics, and voltage flicker. Each of these characteristics is a function of the stiffness of the generation relative to the size of the load. During resiliency support, voltages with higher-than-normal excursions are likely to be tolerated, but problems will be limited if steady-state voltage, unbalance, harmonics, and voltage flicker can be restrained as much as possible. Sizing generators to have enough voltage support capability for the load is the most straightforward option for managing these. For microgrids, other options are also available:

- Load shedding—“Problem loads” that generate harmonics or flicker can be disconnected.
- Fast inverter support—Inverters with fast response can provide additional support quickly to counteract fluctuating loads or harmonic producers. Such support is most beneficial in situations when the system fluctuations can be met by reactive power support. If real power support is needed, energy storage options could provide it.

To support local loads, the real and reactive power must be controlled to maintain adequate voltage and frequency. The control must match generation with load and accommodate changes in load, including step changes. Under the classic model, real power mismatches first affect frequency of the microgrid system, and reactive-power mismatches affect voltage. IEEE 1547.4-2011 describes several voltage and frequency control approaches. For voltage control:

- Voltage droop—The voltage setpoint of a generator is reduced as reactive load increases.
- Reactive power sharing—A master controller adjusts the reactive power output of each generator to match the load.

For frequency control:

- Speed droop— The speed setpoint of a generator is reduced as real-power load increases.
- Real power sharing—A master controller adjusts the real power output of each generator to match the load.
- Isochronous control—One generator acts as a swing generator, and the other generators may droop against the swing generator and maintain constant power output.

In a microgrid, load shedding and/or load control is another option to help match generation and load for better voltage and frequency control.

## 5.3 Metering and Monitoring

Metering and monitoring are important considerations for microgrids. In many scenarios, monitoring is required for control and/or synchronization purposes. Remote control by the utility may also be desirable for safety and operability. Voltages may need to be measured at multiple locations to detect when to separate and when it is suitable to reconnect to the wider system. Useful measurement locations are at synchronization points, generators, and key loads. Voltage, frequency, real power, reactive power, current, switch status points, and relay status points are all key parameters.

Voltage measurement location is another important consideration. At a single distributed generator, voltages are normally measured on either the primary or secondary side of an interconnection transformer. For overvoltages, primary-side measurements are best, especially if the primary winding is ungrounded. Secondary measurements cannot detect the neutral shift on an ungrounded island with a ground fault. To detect and trip on overvoltages, every phase must have a relay, not just on an individual phase and not on an average of the three phases.

### **5.3.1 Supplying Critical Infrastructure**

In order to serve critical infrastructure, microgrid operators will have to make some practical decisions about what loads to designate as “critical,” how best to serve them, and what loads can be dropped in an emergency. Separation of critical and noncritical load can be challenging based on the electrical infrastructure of the facilities and the interconnection with the utility. Some options for supplying critical infrastructure are:

- Supply all load—One option is to supply all load in a physical area, both critical and noncritical. Often, it is not feasible or economic to separate critical and noncritical loads. Larger generators will be needed to supply both critical and noncritical loads.
- Separate electrical infrastructure— A microgrid could be made from electrical infrastructure operating in parallel with the existing infrastructure. Critical loads within a facility could also be separated from noncritical loads.
- Disconnect noncritical loads—When using existing electrical infrastructure, it may be possible to disconnect noncritical loads. Advanced Metering Infrastructure (AMI) with remote disconnection are one option that could be used to disconnect residential customers. For long-duration events, it may even be possible to provide residential customers with electricity for part of the day on a rotating basis as resiliency support if the local microgrid generation can handle the loading and has enough fuel.
- Combination strategies—A combination of these strategies is also possible. Another option in this mix is to use backup generation and/or local distributed generation as a way to supply critical loads that are not amenable to a microgrid configuration.
- Microgrid siting—Much infrastructure that is important for communities is available at multiple locations, like gas stations and supermarkets. Microgrids could be selected and located for portions of the community with the highest value in terms of facilities and services provided.

### **5.3.2 Black Starting**

Most microgrids will need black-start capability, or the ability to energize the microgrid from a de-energized state, without help from an external source. This will always be the case for a microgrid based on back-up generation where the loads go dead and then are energized after the back-up generation starts. Even in microgrids designed for seamless transitions, black starts may be needed in some cases. One example is for a fault on a microgrid. If the generators all trip to clear the fault, the microgrid will have to restart from the de-energized state if the fault is cleared.

Cold-load pickup and inrush are considerations for black starting. Upon energization, many components draw a high, short-lived inrush; the largest component magnetizes the magnetic material in transformers. Motors also draw inrush. Cold-load pickup is the extra load following an extended interruption due to loss of the normal diversity between customers. Following an interruption, the water in water heaters cools down and refrigerators warm up. When the power is restored, all appliances that need to catch up energize at once. In cold weather, following an extended interruption, heaters all come on at once (so it is especially bad with high concentrations of resistance heating). In hot weather, houses warm up, so all air conditioners start following an interruption. Cold-load pickup can be over three times the load prior to the interruption. As diversity is regained, the load slowly drops back to normal. This time constant varies depending on the types of loads and the duration of the interruption.

Cold-load pickup and inrush are both considerations for a black start. If the generators are not sized to handle this stepped load, then loads need to be brought online in steps that the generators can handle.

## **5.4 Suburban and Rural Microgrid Arrangements**

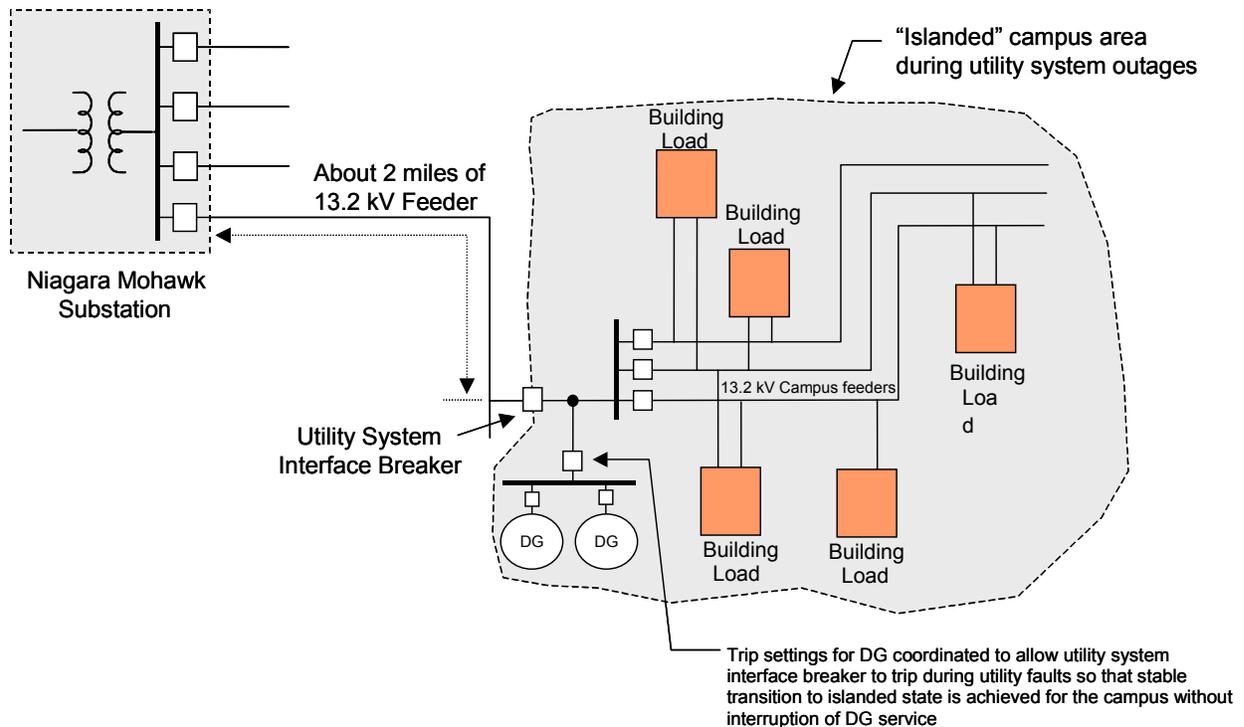
This section will consider several example microgrid arrangements for suburban (loop) and rural (radial) systems. For each example, it will consider various safety and interconnection issues. In most cases, suburban and rural distribution systems are operated in a radial fashion from the substation source. A common model employed in a radial system is a campus style system. Most campus models feature only one feeder supplying the microgrid.

### **5.4.1 Campus-Style Microgrid**

The campus arrangement is a relatively simple microgrid. In this configuration, the microgrid has one connection point to the utility system. All electrical infrastructure is used for both grid-connected and standalone operation. This design is suited for college campuses, government complexes, commercial or industrial parks, or any arrangement with one utility interconnection point that fans out and supplies load in a concentrated area. See Figure 5-1 for an example.

**Figure 5-1. Campus microgrid**

Source: Electric Power Research Institute. 2003. EPRI 1002286, *Partial Design of a Multi-Energy Park at Clarkson University: Simulating the Electrical Performance of the Multi-Energy Park.*



Some of the benefits of the campus microgrid are:

- Having one interconnection point eases many interconnection issues, including IEEE 1547 compliance, synchronization, overcurrent protection, monitoring, and control.
- Because most campus arrangements are relatively compact, this microgrid should have high reliability. Electrical lines feeding buildings in the campus will normally be relatively short, and in many cases, these will be underground rather than overhead. Shorter lines have less exposure to faults as do underground cables, especially during major storm events.

Consider the microgrid in Figure 5-1 as the base case. The peak demand is about 4.1 MW. This campus is fed by a radial utility supply, but most of the issues will also apply for the same campus fed by a looped utility system. The following interconnection issues can be associated with this design.

*Safety.* Because of the compact design and a mainly all-underground system, exposure to energized conductors is negligible as long as the overhead utility supply is not inadvertently included in the island. The main concern with this application is an inadvertent island that includes the 13.2-kV distribution feeder back to the substation. This issue could occur for a fault on this distribution feeder that causes the substation circuit breaker to open. Unintentional islands could occur in different ways:

- The substation breaker opens, and the fault self-clears quickly. In this case, the microgrid controller may think that the utility system is still intact, but because the load and generation closely match, the island can continue for some time before voltage or frequency relays trip.
- The microgrid may transition to standalone mode, but if the tie switch doesn't open properly, the microgrid will inadvertently include the two miles of distribution circuit.

Risks of unintentional islands reduce with a transfer trip that opens the microgrid intertie whenever the substation circuit breaker opens. The substation circuit breaker is not the only disconnection option on that utility circuit, though. The line may have manual switches that utility crews may operate, or crews may cut open a location. One risk management option is to add capability for utility operators to remotely view the status of the microgrid and shut down the microgrid if needed when they suspect unintentional islands. This could be for utility work on that circuit or for calls from the public of wires down near that circuit.

*Reliability.* As with most campus designs, this microgrid should have good reliability. Exposure is relatively small with mainly all underground lines. The generators in this microgrid can be used full time, part time, or only as emergency backup. The design does have a common point of failure: if faults occur in the zone from the utility intertie to the common campus bus, the whole campus will trip. In grid-connected mode, the facility is susceptible to voltage sags and other disturbances on the utility system. One option to reduce these events is to transition to standalone operation when storms approach.).

*IEEE 1547 Compliance.* When in macrogrid-connected mode, the microgrid must comply with IEEE 1547-2003. Because the microgrid has only one interconnection device, disconnection of the microgrid from the utility system is straightforward based on voltage and frequency measurements at the point of common coupling. Because of the size of the microgrid, the utility will likely require a transfer trip to open the microgrid intertie whenever the utility breaker opens so that the utility distribution feeder is not inadvertently islanded with the microgrid. When grid-connected, the microgrid generators must not try to actively regulate voltage; a fixed real power and power factor are common, possibly varying real power to track the facility load. To maintain suitable grounding when grid connected and when islanded, the microgrid generators should be effectively grounded.

*Overcurrent Protection.* Because this design has the main power source at the same location as the utility tie point, overcurrent protection within the campus is the same whether in islanded or standalone mode. The coordination of the substation circuit breaker should be checked to see that it doesn't inadvertently trip for faults on adjacent utility circuits from a backfeed of fault current from the generators at the campus.

*Synchronization.* Synchronization is relatively straightforward given one intertie point and generation in a central power station. Any of the modes of synchronization are possible: sync check, active, or open transition. An open transition is the least desirable because of the loss of voltage to the campus during the transition.

*Voltage Control and Power Control.* Because the campus power flows are the same in islanded and grid-connected operations, voltage control is relatively simple. For a seamless transition from a grid-connected mode to standalone operation, the real and reactive power supplied by the generators should closely match that of the loads.

*Metering and Monitoring.* No special metering is needed. All metering for basic microgrid operations and control can be done at the main power plant and the interconnection point.

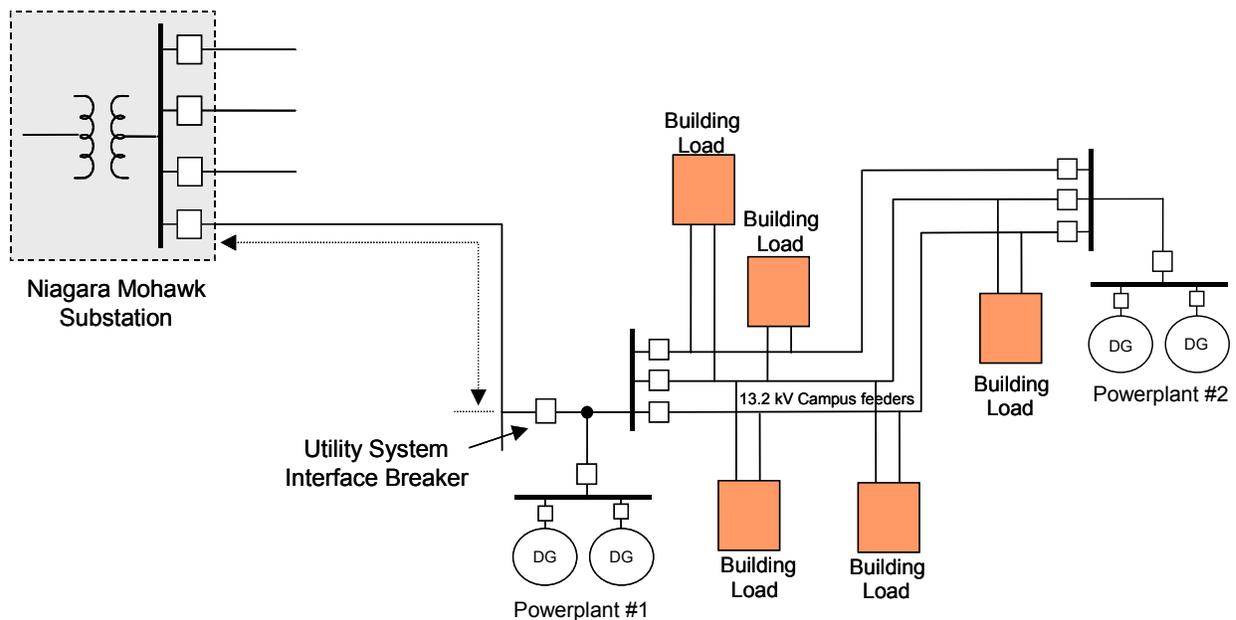
*Supplying Critical Infrastructure.* This microgrid arrangement can supply the whole campus with sufficient generation. If generators are not sized for this, or some are out of service, load shedding can be implemented. The crudest load shedding may be obtained by tripping one or two of the three main circuits feeding the campus. Because many buildings are fed from more than one of these sources, finding the right match between generation and critical loads within the campus may be difficult. Another option for load shedding is to have isolating switches at several buildings to trip less important loads.

*Black Starting.* Starts from the de-energized state should be possible if the generators support this. Having the main generation in one location should help. The generation can be brought online first, then the load can be energized in steps or all at once, depending on the capabilities of the generators and the load characteristics.

#### **5.4.1.1 Campus Style Variation: Multiple Generation Locations**

The integration and control of the campus microgrid in Figure 5-1 was made easier by having one location for generators. However, several issues arise if the microgrid had more than one location for generation (Figure 5-2).

**Figure 5-2. Variation of the campus microgrid example**



The microgrid with generators at multiple locations helps improve reliability, but operations and control are more difficult. The main complications are:

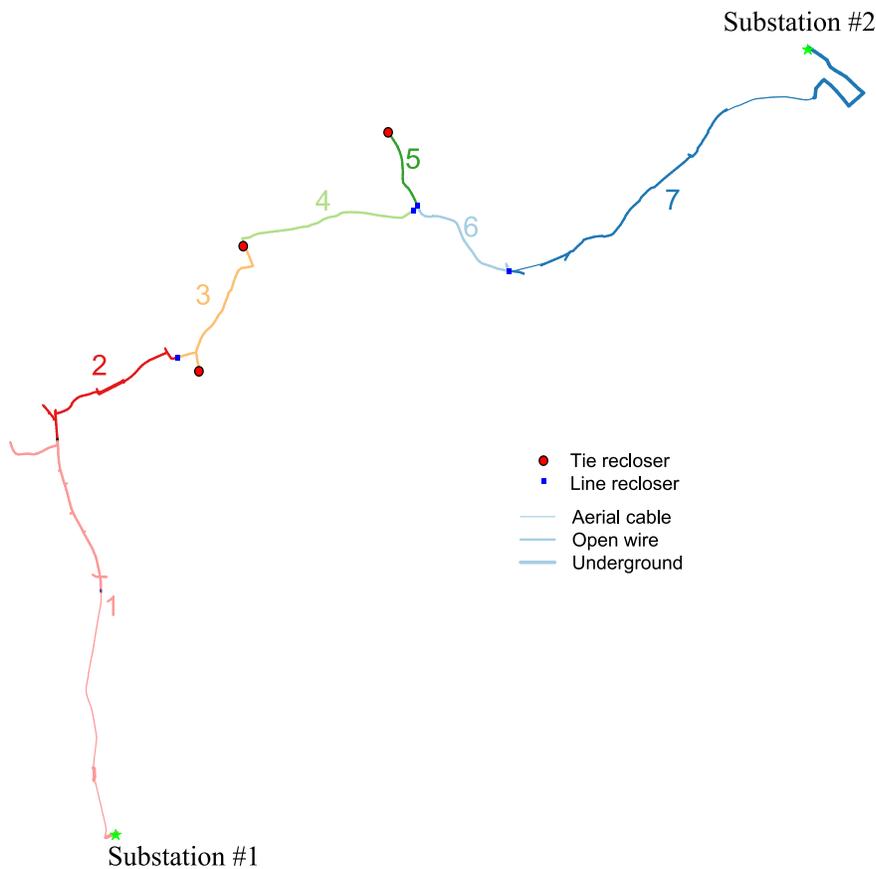
- *Voltage and power control*—With generators at multiple locations, control may require communications and backup control in case communications are lost. If dispersed generators are of different types (including those with inverters), control can be more challenging. If the bulk of the load is supplied with rotating generators, then they may be the main voltage and frequency source (like a swing machine).
- *IEEE 1547 Compliance*—Because there is still only one utility intertie, these issues are mainly the same. The important point is that the synchronization and disconnection requirements should apply at the interface breaker if any of the generators are online. Important control logic is that the disconnection relaying at the utility system interface breaker must change depending on the status of the generators, and some of these generators will be remote. If the generators are all offline, tripping the intertie breaker for a disturbance on the utility power system should be avoided. If any generators are online, the microgrid must be separated, or all generators must be tripped. If some generators lack effective grounding and they can be the only generation online, then they must be sized small relative to the minimum campus load, or an auxiliary grounding bank may be needed.
- *Overcurrent Protection*—Protection only becomes slightly more complicated. For a fault on the microgrid, feeder relays and overcurrent protection on the generators should suffice. Directional relaying on the feeder relays closest to power plant #1 may help coordinate, so they don't trip for utility-side faults.
- *Metering and Monitoring*—This is more complicated with generators at multiple locations as it increases the number of points that need to be monitored as well as increasing the distance between those points.

## 5.4.2 Suburban Looped System

A second major microgrid design environment is a looped system. Looped systems, often used on suburban circuits, can have high reliability because of redundant sources. In a major event, looped systems can still have significant outages because of how widespread the damage is or because of the loss of the sub transmission supply. Utility automation has greatly expanded in recent years. Automating loop systems allows faster sectionalizing and restoration of service. It also frees utility resources in major events to address other restoration efforts. Microgrids can provide additional resiliency support by maintaining service within a section of a looped system.

Figure 5-3 shows an example of two distribution circuits in a looped system with seven circuit segments divided by reclosers. In addition to the loop shown, the circuit also has ties through normally open reclosers to other circuits that are not shown. Figure 5-3 shows the three-phase mainline for these two circuits; lateral taps and secondaries are not shown. Any of the seven circuit segments may be candidates for microgrids. The following will discuss microgrid interconnection issues with the rest of the utility system.

**Figure 5-3. Looped circuits example**



*Safety.* Every segment in this looped design still has significant overhead exposure. In addition, multiple connection points to other circuits provide more opportunities and scenarios where infrastructure outside a microgrid zone is inadvertently energized. Because of the exposure, monitoring of microgrid status and communications to utility operation centers is critical as are procedures such as lockout-tag out to ensure safety of utility crews and the public.

*Reliability.* While microgrids in any of the segments of the circuits in Figure 5-3 should greatly improve reliability of the segments with microgrids, reliability will not be perfect. Each of the segments has overhead exposure, so in a major storm event, these lines could be damaged. Another consideration is the survivability of communications. In most designs like this one, communications are necessary for microgrid operations, so if the communication infrastructure is overloaded or otherwise compromised, the microgrid(s) may not be able to operate. A centralized controller for the system could decide whether to sectionalize portions of the circuit and/or whether to island microgrids for faults at different locations, including loss of both supplies. Another consideration with a looped system from different substations is that the utility may or may not allow true looped connections where a circuit is fed from two different substations without an open point. If true looped connection is not allowed, a microgrid/automation controller would have to prevent it.

*IEEE 1547 Compliance.* Complying with IEEE 1547 requirements may require complicated monitoring, measurements, and communications. Each microgrid segment has two or three interconnection points. Control of the generators and interconnection switches requires measurements at multiple locations, and for most designs will necessitate measuring voltage on both sides of each intertie switch. Another complication is segments with microgrids on adjacent segments. For optimal operations, a centralized control is best to coordinate sectionalizing of the automated system and operation of generators within each microgrid. With generators big enough to support one or more segments, effective grounding is important to limit overvoltages.

*Overcurrent Protection.* With generators big enough to support a whole section, overcurrent protection becomes more difficult. Coordinating multiple devices in series in an automated loop is already difficult. Addition of fault current from microgrid generators may cause miscoordination. If that occurs, miscoordination may be overcome by transitioning to islanding mode or other operations initiated by microgrid control. Another option is to use a pilot-wire type protection scheme that does not rely on coordinating fault currents for protection. This option would require reliable communications.

*Synchronization.* Synchronization is more difficult because of multiple tie points. Connections to different tie points may be at different phase angles and voltages. An open transition may be the safest transition if other methods become too complicated. It is also important that the microgrid controller knows the correct status of a microgrid. If a controller is trying to adjust voltage and/or frequency of a microgrid, but it is actually connected to an “infinite” utility supply, the generators on that microgrid may inject or absorb real or reactive power contrary to the needs of the system.

*Voltage Control and Power Control.* Power and voltage control within a microgrid in islanded mode should be similar to other microgrid controls. For grid-connected operation, the effect of these large generators may be significant and would require study. This particular circuit does not have additional voltage regulating devices, but if it did, it would further complicate utility voltage control.

*Metering and Monitoring.* Extensive metering and monitoring is likely to be needed because of multiple interconnecting switch locations.

*Supplying Critical Infrastructure.* This microgrid arrangement will normally supply the utility segment. In most cases, load shedding will be difficult. If utility customers have AMI meters with a remote disconnect option, those meters could be used to shed load in a microgrid area. When selecting a section for a microgrid implementation, the best benefits relative to costs will be for segments with the highest concentration of important infrastructure relative to the size of the overall section load and the overhead exposure on that section.

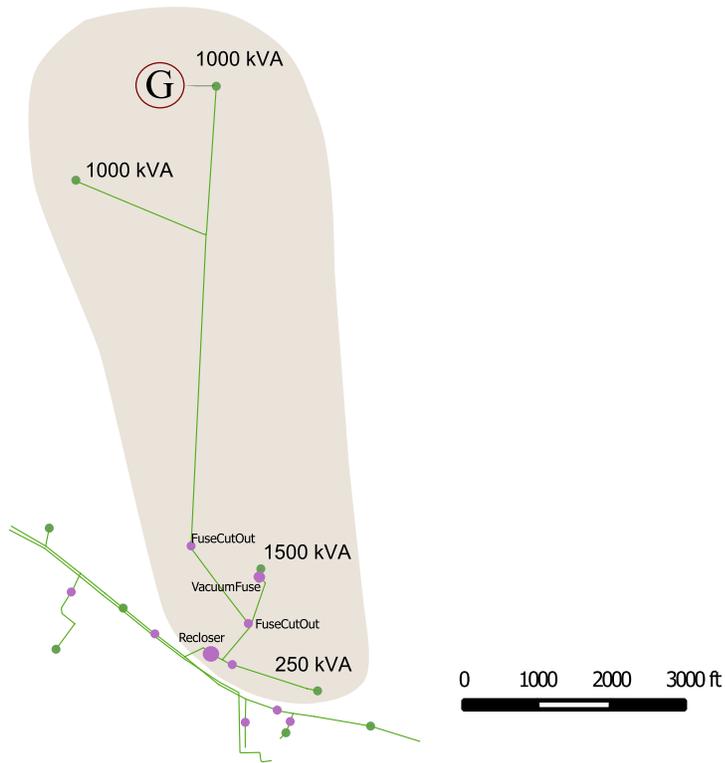
*Black Starting.* Starts from the de-energized state should be possible if the generators support them.

### **5.4.3 Neighboring Loads in a Utility Microgrid**

Another major microgrid design typology takes advantage of existing utility infrastructure to create a microgrid otherwise very similar to a campus style model. Utility infrastructure in many cases can be used for a microgrid. Figure 5-4 shows an example of a commercial plaza that is amenable to a microgrid. This example shows a generator connected at one location, but other options are possible.

This configuration is very similar to the campus microgrid. There is one connection point from the microgrid to the rest of the utility system. The main difference from a campus design is that much of the infrastructure is utility equipment. Because this arrangement so closely matches the campus microgrid model, it shares most of the benefits from the simplicity of a campus design. This arrangement also happened to have a recloser at the key interconnection point. For cases where this was not the case, a switch may need to be added to create a microgrid.

**Figure 5-4. Commercial park example**



The key points related to interconnection are discussed in the following paragraphs, particularly where there are differences with the campus design.

*Safety.* Same as the campus model, and has good safety features.

*Reliability.* Same as the campus model, and has good reliability features.

*IEEE 1547 Compliance.* The main challenge with this type of system is that the generator(s) are less likely to be at the interconnection point. This issue may require communications for tripping and synchronizing.

*Overcurrent Protection.* With generators big enough to support this section, overcurrent protection may be an issue on the rest of the feeder (although no more so than a distributed generator of the same size).

*Voltage Control and Power Control.* Same as the campus model.

*Metering and Monitoring.* Slightly more metering is needed for this configuration because the generator is not connected near the interconnection point.

*Supplying Critical Infrastructure.* Whether a utility system is suitable for a microgrid to supply nearby loads really depends on the arrangement of the utility supply. Many neighboring locations will not be suitable for this because they are supplied by parallel supplies. For example, it would be difficult to add one of the loads that was nearby this complex but not fed through the same recloser.

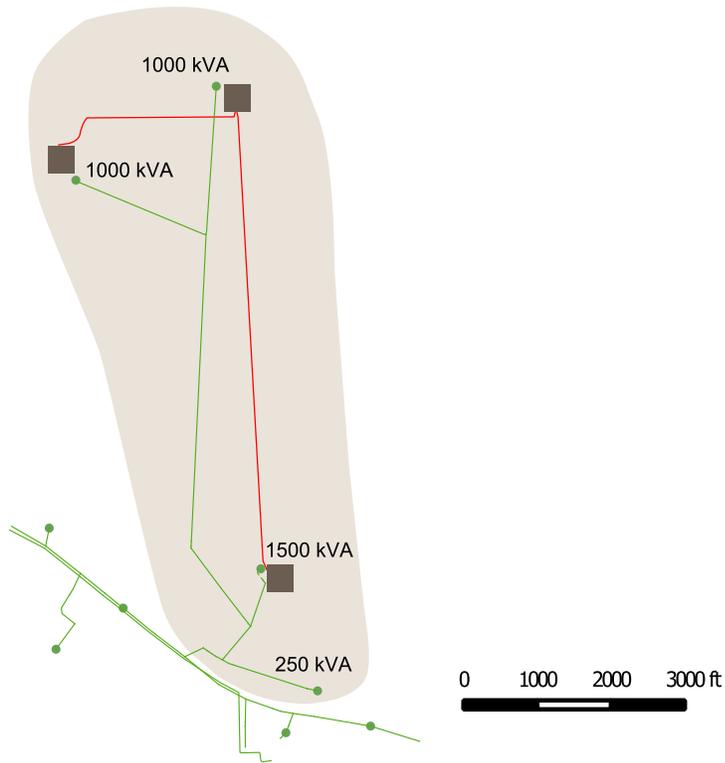
#### **5.4.4 Parallel Electrical System**

Another option for a microgrid to support neighboring facilities is to run a separate parallel electrical system. This option has several advantages over using existing utility and/or facility infrastructure:

- Flexibility—The microgrid can be arranged and designed to best match critical infrastructure with local generation. It does not rely on existing utility infrastructure. This includes system sizing, wiring arrangements, and choice of supply voltages. Even nonconventional microgrids such as a direct current (DC) microgrid may be preferable for some situations with significant electronic loads and inverter-based generation.
- Interconnection issues—Many interconnection issues can be avoided by being completely separate from the utility system.

Figure 5-5 shows an example microgrid connecting three facilities. The microgrid is connected by the electrical lines shown in red that are separate from the utility lines in green. The microgrid can be sized to support some or all loads in each facility, depending on the size of the generators and the capabilities of the interconnecting system.

**Figure 5-5. Parallel circuit example**



A key to the reliability and complexity of designs like this are how the microgrid is interfaced with the normal system. Various options are possible:

- *Isolated microgrid*—The microgrid could run full-time, and the loads supplied by the microgrid could be completely independent from the rest of the loads which are supplied by the utility system. This is unlikely as the reliability of the microgrid may be poor given the low availability statistics for most generation systems.
- *Open transition ties*—The microgrid can be operated separately from the normal system with open-transition tie switches. This option reduces the control complexity.
- *Parallel ties*—This arrangement is the most complicated because the microgrid provides a path between facilities that parallels that of the utility. The parallel paths greatly complicate interconnection. Even billing is complicated. Complexity reduces if only one tie switch is used as the interface between the microgrid and the utility-supplied system.
- *Transfer switches*—Loads can be transferred from the normal supply to the microgrid supply with transfer switches. Switches could be open transition or closed transition.

For all but the isolated microgrid, at tie locations, both the microgrid and the normal system must have compatible voltage and frequency.

*Safety.* With underground cables connecting facilities, exposure to energized conductors should be minimal for such designs. A key safety issue with this type of microgrid is establishing suitable guidelines for operations and control. The main complication is having electrical connections between different facilities, each with different ownership and oversight and each having separate employees, different work rules, and separate access to equipment. Even lockout and tagout of equipment may be complicated because of multiple organizations and ownership. The microgrid may add additional safety issues that facility owners may not normally encounter. For example if medium-voltage supplies ( $> 600$  V) are used between facilities, many facilities of this size are only normally familiar with and equipped to handle low-voltage equipment ( $\leq 600$  V).

*Reliability.* A separate microgrid should have good reliability. Many similar parallel designs will be energized only when needed. As such, they are susceptible to hidden failures. Consider the case where a cable between buildings is inadvertently broken by a backhoe. That fault may lay hidden until the microgrid is energized. Then, the microgrid fails when it is needed. Periodic testing, inspections, and maintenance help reduce the risk of hidden failures. See Section 6 of this report for additional information.

*IEEE 1547 Compliance.* The complexity of compliance depends on the types of interconnections between the microgrid and the utility system. With an interconnection in each building, compliance becomes quite complicated because measurements are required at multiple locations. Open-transition designs are easiest to accommodate. Parallel, connected operation of a separate microgrid would require extensive analysis to ensure proper grounding, voltage, and disconnection relaying.

*Overcurrent Protection.* Coordination and protection depend on the size of the microgrid relative to the local load and relative to the size of the utility system. The number and location of intertie points and generators also affect overcurrent protection for the microgrid and the local systems within each facility.

*Synchronization.* Using open transition connection is straightforward. Active synchronization or sync check are also options. Synchronization is more difficult if there are multiple tie points.

*Voltage Control and Power Control.* Power and voltage control within a microgrid in islanded mode should be similar to other microgrid controls. Parallel operation can be complicated, depending on the location of tie points and the size of the generators.

*Metering and Monitoring.* Extensive metering and monitoring is likely to be needed if there are multiple interconnecting switch locations.

*Supplying Critical Infrastructure.* This microgrid arrangement should be amenable to closely matching generation with only critical loads within a facility. A key caveat is that each facility must have infrastructure suited to easily separate or paralleled critical loads. If that is not the case, then the microgrid may need to be designed to supply larger portions of the facility.

*Black Starting.* Starts from the de-energized state should be possible if the generators support them.

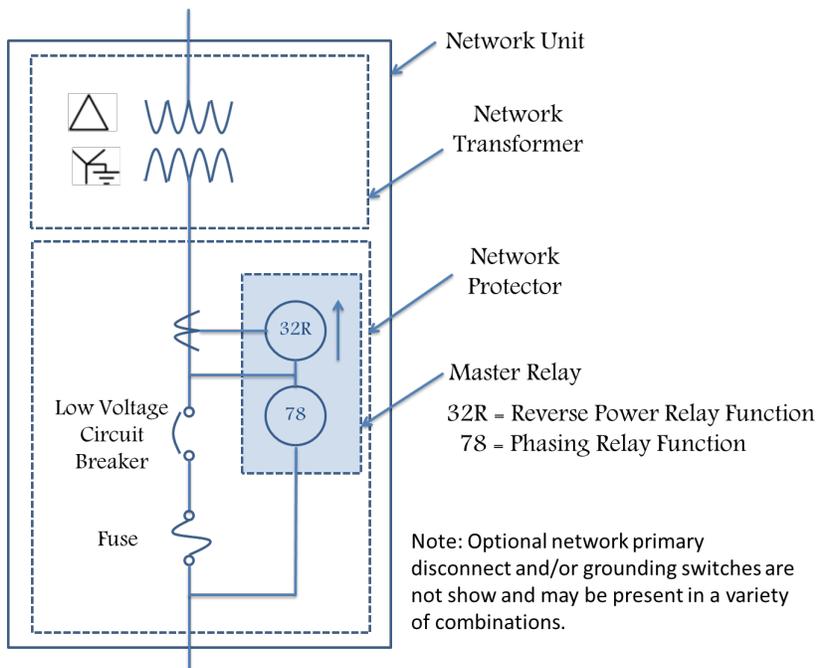
## **5.5 Urban Microgrid Arrangements**

Microgrids in urban environments usually conform to the requirements of spot networks and grid networks. Both of these types of networks are most easily distinguished from radial systems in that each customer is connected to multiple sources of power, each of which can supply their load. Therefore, urban distribution systems tend to be highly redundant – which provides good continuity of service – but also require more sophisticated protection. For example, network protectors may be required to detect when power flows in the wrong direction and isolate a transformer from the rest of the grid, typically allowing customers to be served by the several other redundant transformers in the area. These types of protection, however, require careful consideration in the microgrid context, particularly as concerns synchronizing power following an isolating event.

Grid and spot networks differ from the more common radial distribution systems by creating a secondary voltage AC network to serve concentrated load centers. Spot networks serve a limited number of customers at one location while a grid network serves many customers, potentially tens of thousands, over a dispersed area. The secondary grid system improves continuity of service for customers, since multiple sources are available to supply the load. A fault with any one supply is automatically isolated and does not interrupt service from the other sources.

Networks get their name from the fact that the secondary conductors are interconnected to form a low voltage supply network. Networks must be supplied by at least two primary feeders but are often supplied by more; large urban grid networks can have 30 or more primary feeder supply lines. Networks also have some specialized equipment to support their unique configuration. The term network unit is used to describe this equipment and one network unit consists of the network transformer, low-voltage circuit breaker, fuse, reverse power relay function, and phasing relay function as shown in Figure 5-6.

**Figure 5-6. Example of Network Unit Components**



Network transformers are often liquid-filled, air-cooled submersible units. Figure 5-6 shows a delta primary winding, but it may also be grounded wye. It is common for a manually operated primary oil switch to be mounted directly on the transformer. The oil switch has three positions – open, closed, and grounded. The network protector is also typically mounted directly on the transformer or in close proximity. Network secondary voltages are nominally 208Y/120 V and 480Y/277 V.

### 5.5.1 Network Protectors

Each network transformer is equipped with a network protector as shown in Figure 5-6. The network protector's main function is to sense reverse power flow and, when detected, disconnect its transformer from the network. In doing so, the network protector isolates faults on the primary feed from the network and enables continuity of service to the network customers. Under normal operations, all network protectors are closed, which places the network transformers in parallel thereby sharing the load across the network supply infrastructure. If one protector opens, the load is still supplied from the remaining network transformers and protectors that are still closed. The network relay is very sensitive with a reverse power pick-up on the order of 1-2 kW. The fuse inside the network protector acts as a back-up in case the protector fails to open for a fault on the upstream primary feeder (unless the primary winding is connected in delta in which case the fuse does not provide additional protection). The network relay also supervises closing of the network protector by measuring the voltages on both sides of the protector. The relay initiates closing when the transformer-side voltage is higher by about 1 V than the bus side voltage and the phase relationship is within the criteria specified in the relay settings.

When considering network microgrid applications, it is important to realize that most network protectors have several significant limitations (IEEE 1547.6-2011):

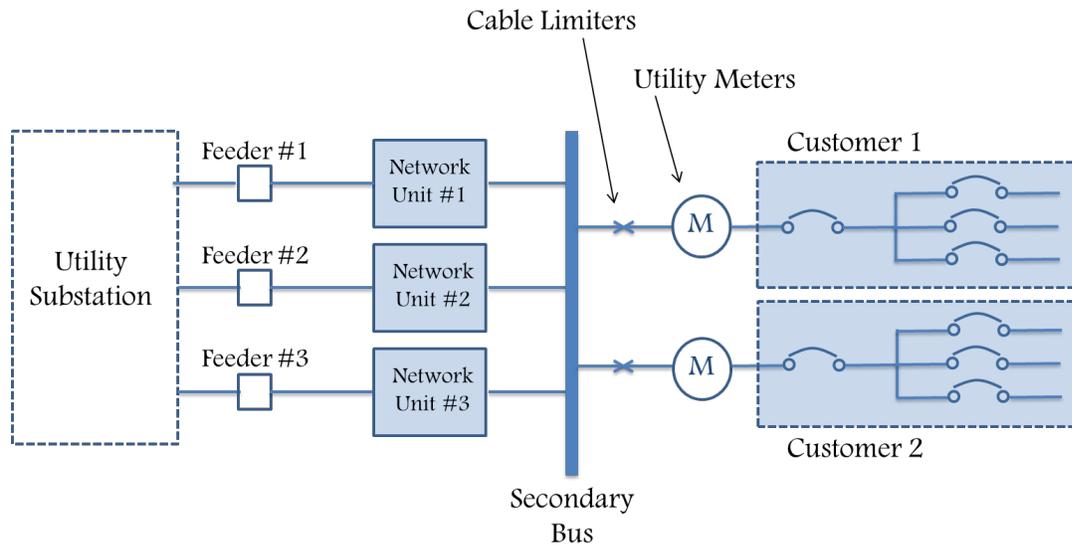
- Interrupting rating – many network protectors are not designed to separate generators from a fault, and the likely fault duty levels must be checked against the protector’s interrupting rating. The interrupting capability of the network protector breakers is designed for the fault current levels (magnitude and X/R ratio) ordinarily encountered in low-voltage network systems (X/R ratios typically in the range of 6–8). Breakers are designed for X/R ratios greater than 20. Concerns have been raised by utilities with underground network systems, such as Con Edison, about the ability of network protectors to successfully interrupt fault currents when distributed generation significantly changes the fault current magnitudes or X/R ratios.
- Separating dynamic sources – protectors may not be able to handle the recovery voltages present when the electrical systems on either side of the protector are not locked together in synchronism.
- Connecting dynamic sources – many network protectors do not have synchronizing capability. The supervising relay does not measure the system frequency on both sides of the open protector; it only checks voltage magnitude and phase angle relationships.

Network protector limitations are still being studied by the industry. Currently it is not clear if many of these limitations can be overcome by upgrading to a modern network protector and relay package like the Eaton CM52 protector and MPCV network relay package. Modern protectors offer somewhat higher interrupting ratings and may be able to handle the typical transient recovery voltage present on a network microgrid. However, even new protectors are not designed or rated for microgrid applications. A more robust solution is to add an additional relaying package and power circuit breaker to the low-voltage system, likely just downstream of the network unit. A modern relay package will offer all of the functions of the network protector plus synchronism capability. The power circuit breaker offers more robust fault current interrupting ratings and is better suited for this application.

## **5.5.2 Spot Network Microgrid**

Spot networks are often used to serve a single customer or multiple customers in close proximity to each other (commonly in a single building) that have large, concentrated electrical loads. Spot networks have at least two primary feeders and two transformers connected to a common low-voltage bus (Figure 5-7).

**Figure 5-7. Illustrative Spot Network Diagram**

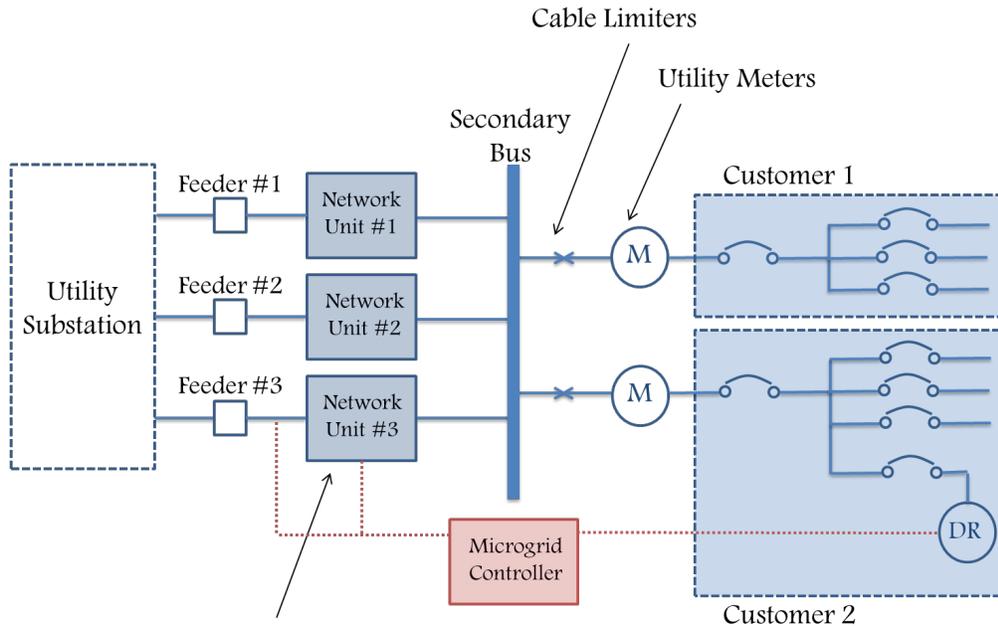


A spot network microgrid arrangement is more complicated than a basic radial system as there are multiple connection points to the utility system that are interfaced through network units. All electrical infrastructure downstream of the network unit is used for both grid-connected and standalone operation. Because most spot networks are relatively compact, the microgrid should have high reliability. Electrical lines feeding the customers in the network will normally be relatively short and likely underground rather than overhead. Shorter and underground lines have less exposure to faults, especially during major storm events.

The network system adds complications beyond that of a non-network microgrid. Having multiple interconnection points complicates many interconnection issues, including IEEE 1547 compliance, synchronization, overcurrent protection, monitoring, and control. There can be a variety of serious overvoltage, power quality, and reliability issues created if the microgrid does not properly coordinate with the upstream protection timing and tripping levels at both the network unit level and the primary feeder level.

Consider the microgrid in Figure 5-8 as the spot network microgrid base case. This microgrid is fed by multiple radial utility feeders and serves two customers. Distributed generation is located at one of the customers and is capable of serving the total load of the microgrid. The generation can be embedded within the customer facility as shown, or it can be connected directly to the secondary bus. If the generator is large enough to carry the full microgrid load and is embedded as shown, then there is the potential that the generator circuit wiring does not have a high enough ampacity to serve the entire microgrid. For this reason, it is better to directly connect a single large generator to the secondary bus in a spot network microgrid.

**Figure 5-8. Spot Network with Distributed Generation**



May require upgrading network protectors with full interrupting rating, synchronism capability, and reverse power flow detection. This may be accomplished with a new power circuit breaker and relay package.

This example microgrid also makes use of upgraded network protector units. As discussed in the previous section on network units, legacy network protectors and even new modern protectors may not be suitable for use in microgrid configurations. Reconnecting with the utility grid after islanded operation is particularly problematic for network protectors as they do not have any synchronism capability. The most likely approach for achieving synchronism is for the microgrid controller to ramp the microgrid generation to match the utility voltage and frequency and then close-in. It isn't clear if this approach can be achieved with modern network protectors or if they must be upgraded or if additional devices such as power circuit breakers or contactors added in series are necessary to handle this function.

The microgrid controller is responsible for managing the transition to islanded operation, optimizing generation and storage resource use, and managing the transition back to grid-connected operation. In reality, the microgrid controller shown in Figure 5-8 would have many more communication and control paths to enable these functions but they are omitted from the drawing for simplicity. The following describes various interconnection issues with this design.

*Safety.* Because spot networks are mainly underground and compact, exposure to energized conductors is negligible as long as an overhead utility supply is not inadvertently included in the island. The main concern with this application is an inadvertent island that includes one or more of the primary distribution feeders back to the substation. There are multiple interconnection points to the utility system. Even though the connections are interfaced through network protectors and should be very sensitive to reverse power flow, having multiple interconnection points increases the possibility of inadvertent energization beyond the microgrid. Because of the multiple interconnection points, monitoring of microgrid status and communications to utility operation centers is critical as are procedures such as lockout-tagout to ensure safety of utility crews and the public.

*Reliability.* A spot network microgrid will need to be carefully designed such that it enhances reliability and does not accidentally degrade reliability due to unintentional/undesirable transitions to an islanded state and the failure to carry the loads during such transitions. Perhaps the key function of the microgrid is that the generators can be used as emergency backup to enhance reliability during outages of all the primary feeder cables. Additionally, if there is an outage on one or more but not all of the primary feeds, the generation within the microgrid will reduce the stress that would normally be placed on the remaining feeds thus reducing the likelihood of a cascading failure. Even in the case of no failed feeds at all, the generation helps reduce loading that can reduce the chance of a failure and enhance reliability. There is the potential for a fault on the secondary bus or cables supplying the customer with the DG to interrupt service to the adjacent customer but those elements consist of multiple parallel conductors and may tolerate a single cable failure. The microgrid switchgear devices/controls that isolate it from the main utility system must be coordinated to make sure short duration reverse flows into network cables during remote transmission fault voltage sag conditions don't cause unintentional outages on the spot networks. With proper design, these problems can be avoided and the microgrid will enhance the reliability of the spot network.

*IEEE 1547 Compliance.* Complying with IEEE 1547 and IEEE 1547.6 requirements may require complicated monitoring, measurements, and communications. Control of the generation and interconnection points requires measurements at multiple locations, and for most designs will necessitate measuring voltage on both sides of each network protector. When grid-connected, the microgrid generators must not try to actively regulate voltage; a fixed real power and power factor are common, possibly varying real power to track the facility load. However, the generation must not export beyond the secondary bus as very small reverse power flow through the network protectors will cause them to open. IEEE 1547.6-2011 requires that the DG does not increase network protector operations, delay network protector opening, or separate or connect two dynamic systems. However, some functions and capabilities desirable on a microgrid may require adjustments to these IEEE operating criteria where it can be done without threatening normal system safety, reliability, power quality and operating criteria.

*Overcurrent Protection.* Overcurrent protection for the primary feeders supplying the network should not change substantially; substation relaying and the network protectors should isolate faults on the primary just like they normally do. But as mentioned earlier, some minor timing coordination changes may be desired to enhance reliability of the microgrid to avoid undesired islanding events that might accidentally drop the low voltage network. For example, it may be desirable to have logic that allows ride-through of the reverse power tripping functions of network protectors during transmission line faults but allows opening of the protectors during primary feeder faults. Microgrid generation also potentially increases fault levels when running in parallel with the utility, and the usual concerns associated with managing fault levels on networks that have little interrupting rating margin would apply. The impact of microgrid generation when operating as an island and also in parallel with the utility system must be considered on the customer's spot network fault levels and internal protection coordination. When in parallel, it may raise fault levels, and when islanded the fault levels may be lower depending on the amount of generation and its type. Inverter-interfaced generation generally offers much lower fault currents with very short durations and can be easier to coordinate in parallel with the utility than rotating machine DR. However, in an islanded state there may not be enough fault current to operate the protection properly without adjustments and modifications.

*Synchronization.* Synchronization of a grid network type microgrid is more difficult because of multiple tie points with the utility system. However, a spot network, while also having multiple primary cables feeding it, generally has all the connections (network units) at a single vault location making it somewhat easier to manage all the controls and coordination. Transition to/from islanded operation is complicated by the shortcomings of the network protectors previously discussed in this section. If the network protectors are not upgraded then an open transition (non-seamless transfer) may be the safest transition. A closed transition will likely require upgraded network protectors, possibly replaced with a power circuit breaker and enhanced relay package. With this upgraded intertie equipment in place, an advanced microgrid controller can control synchronization and slew the generation into synchronization with the utility.

It is also important that the microgrid controller knows the correct status of a microgrid. If a controller is trying to adjust voltage and/or frequency of a microgrid, but it is actually connected to an "infinite" utility supply, the generators on that microgrid may inject or absorb real or reactive power contrary to the needs of the system.

*Voltage Control and Power Control.* Power and voltage control within a network based microgrid in islanded mode should be similar to other microgrid controls. Generation would need to change from "voltage following" and "frequency following" operation in grid parallel mode to "voltage regulating" and "frequency regulating" mode when in an islanded condition. The power sources on the microgrid would need to have this functionality and the ability to supply adequate power quality to loads during the islanded state which means the ability to handle cycling loads (motors and motor starting), non-linear loads, and the usual load steps that occur.

*Metering and Monitoring.* Depending on design objectives of the microgrid, extensive metering and monitoring is likely to be needed. Spot network type microgrids will be much easier to implement in this regard than grid networks. The state of loading and generation will need to be carefully monitored in real time to implement control schemes that avoid reverse flow into the network protectors and also so that the controller can manage microgrid transitions to /from an islanded state. Extensive monitoring and control coordinating with the bulk dispatch center will also be useful for providing support in the form of “demand reduction response programs,” reactive power ancillary services, and other functions needed by the utility system as a whole.

*Supplying Critical Infrastructure.* This microgrid arrangement can supply the spot network with sufficient generation. If generators are not sized for the full load, or some generation is out of service, load shedding can be implemented. Load shedding may be obtained by tripping one or more of the customer breakers with a load-shed control scheme that manages load/generation balance on the island. When supplying critical infrastructure, the design decision of whether or not to use “seamless” versus “nonseamless” transition is extremely important. In a nonseamless operation, the loads may experience a brief power interruption during the transition to a microgrid operation. In a seamless design the transition occurs without any power interruption and has only as minor voltage perturbation. Many critical loads need the latter type of operation, but some may be satisfied with a brief interruption. The seamless transfer for the most critical and sensitive types of loads may require “UPS grade” power which typically has less than ½ cycle voltage sag perturbation during the transition to an island. This most advanced form of power quality may require solid-state static switches to implement, but mechanical switches can suffice if a few cycles of disturbance is allowable.

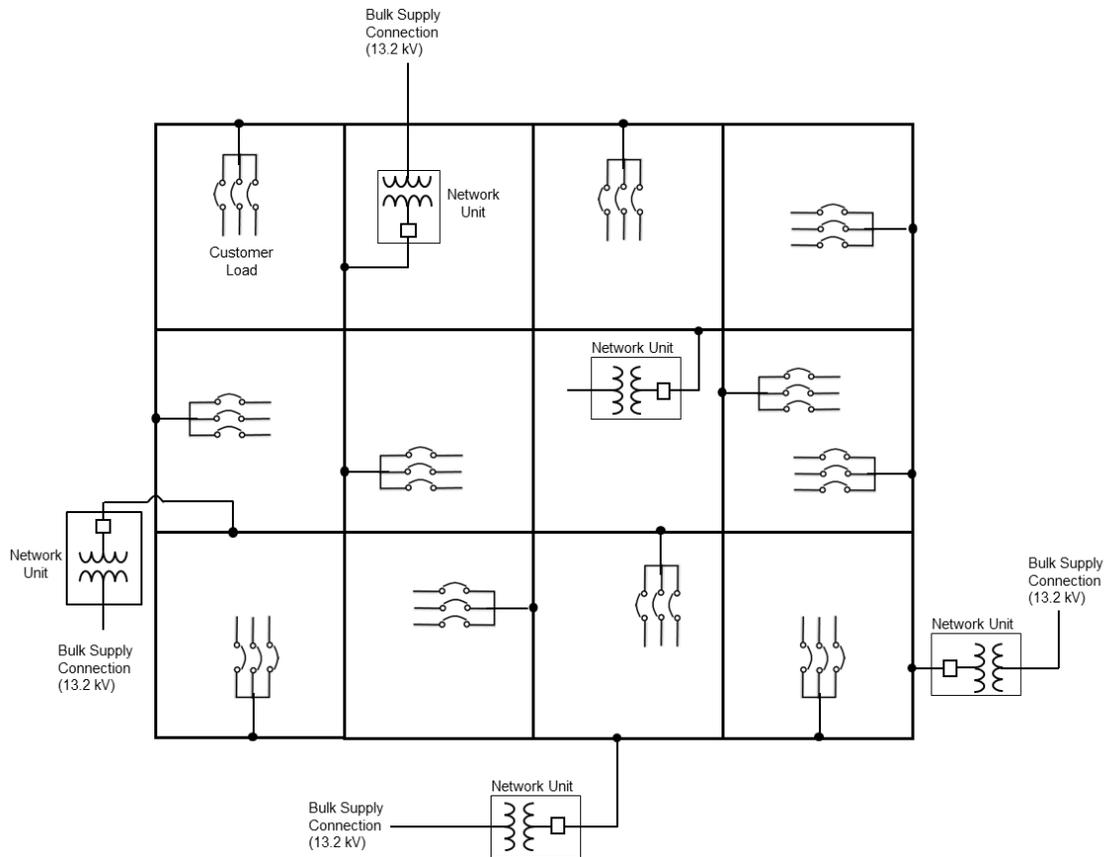
*Black Starting.* Starts from the de-energized state should be possible if the generators support them. Black start capability is important to maintain one of the key primary functions of the microgrid that is to supply emergency power to the local microgrid loads during a bulk utility system outage. Even for a seamless design, the microgrid may be accidentally dropped during the transition so there needs to be the option to recover from a fully de-energized microgrid state.

### **5.5.3 Grid Network Microgrid**

A grid network derives its name from its characteristic grid of interconnected secondary conductors as shown in Figure 5-9. The grid is energized by multiple primary feeders, each connected through a network unit (transformer and network protector). A large grid network in a dense urban area like New York City might be supplied by 30 primary feeders and serve 75,000 to 100,000 customers with a peak load of a few hundred megawatts.

Grid networks are often designed such that adjacent network transformers are supplied by different primary feeders. Customers are served directly from the secondary grid network. In large grid networks, there can be dozens of cables, called secondary mains, interconnecting the secondary buses. Grid networks provide very high reliability by creating multiple current paths from every primary interconnection point to every load; failure of any one path will not interrupt service. Secondary grid networks are either 208 Y/120 V or 480 Y/277 V.

**Figure 5-9. Illustrative Grid Network Diagram**



A grid network microgrid arrangement is more complicated than a typical spot network configuration discussed earlier. Grid networks often have many geographically distant connection points to the utility system, all interfaced through network units, and cover a much larger physical area. All electrical infrastructure downstream of the network unit is used for both grid-connected and standalone operation. Secondary grid networks have very high reliability and a grid network microgrid is expected to have the same benefit. Electrical lines feeding the customers in the network will normally be relatively short, and in most cases, these will be underground rather than overhead.

The network system adds complications beyond that of a non-network microgrid. Having multiple interconnection points complicates many interconnection issues, including IEEE 1547 compliance, synchronization, overcurrent protection, monitoring, and control. There can be a variety of serious overvoltage, power quality and reliability issues created if the microgrid does not properly coordinate with the upstream protection timing and tripping levels at both the network unit level and the primary feeder level.

Consider the microgrid in Figure 5-9 as a secondary grid network microgrid base case. This microgrid is fed by multiple radial utility feeders, serves many customers, and has multiple distributed generation and storage (DGS) resources embedded within the network. The DGS is capable of serving the total load of the microgrid. The generation can be embedded within the customer facility, or it can be connected directly to the secondary bus. The large electrical size and physical scale of a grid network microgrid necessitate that there be many smaller generation sources dispersed throughout the network; the secondary mains do not have the capacity to carry the current required to serve the entire network from just a few locations.

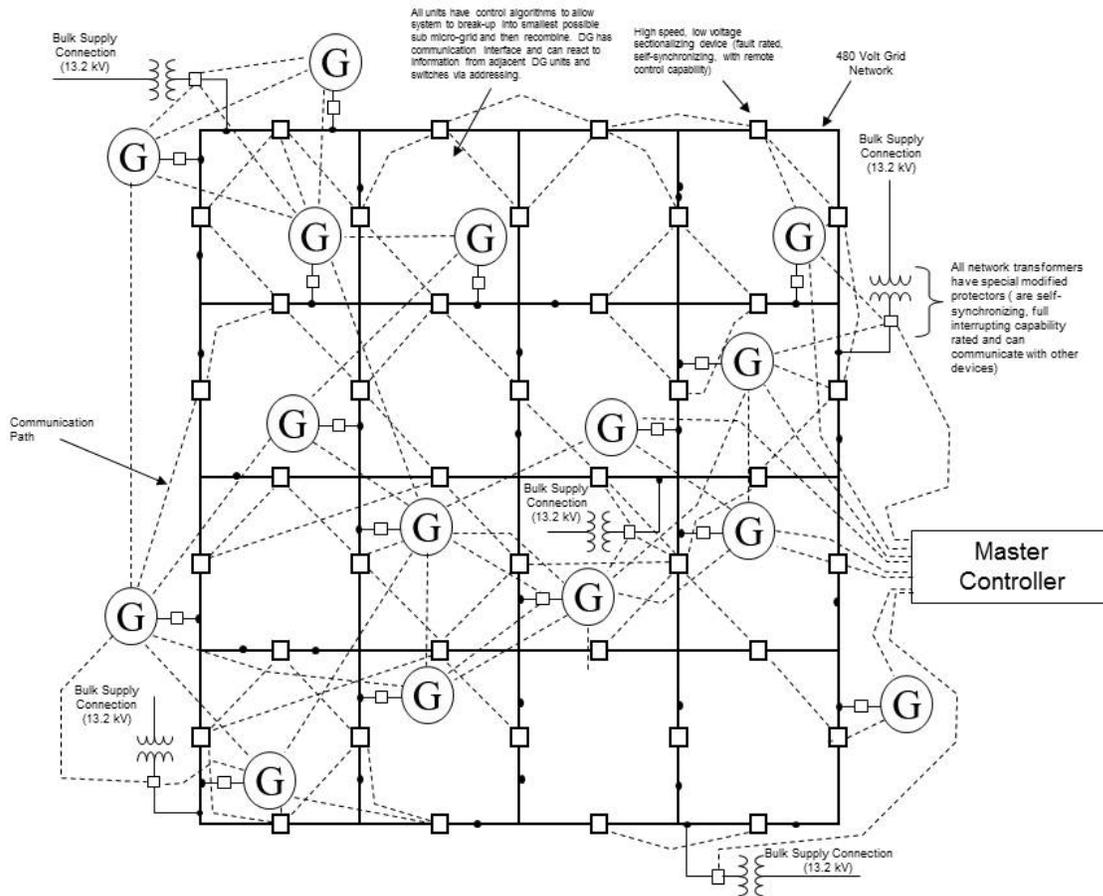
This example microgrid also makes use of upgraded network protector units. As discussed in the previous section on network units, legacy network protectors and even new modern protectors may not be suitable for use in microgrid configurations. Reconnecting with the utility grid after islanded operation is particularly problematic for network protectors as they do not have any synchronism capability. The most likely approach for achieving synchronism is for the microgrid controller to ramp the microgrid generation to match the utility voltage and frequency and then close-in. It isn't clear if this approach can be achieved with modern network protectors or if they must be upgraded or if additional devices such as power circuit breakers or contactors added in series are necessary to handle this function.

The microgrid controller is responsible for managing the transition to islanded operation, optimizing generation and storage resource use, and managing the transition back to grid-connected operation. In reality, the microgrid controller shown in Figure 5-10 would have many more communication and control paths to enable these functions but they are omitted from the drawing for simplicity. For example, the controller will need visibility to customer breakers in order to accomplish load shedding and coordinated load pick-up to facilitate transitions to/from islanded operation.

A microgrid in an urban secondary grid network has almost all of the same interconnection issues as the spot network microgrid. The complexity is magnified by several factors:

- *Synchronization.* Synchronization of a grid network type microgrid is more difficult because of multiple tie points with the utility system. A grid network typically has many more primary feeds that are dispersed over a much large area. It can be difficult to achieve robust communication links in underground systems and this is made more complicated by the relatively large geographic area covered by many grid networks in dense urban environments. The communication backbone is a vital part of ensuring accurate synchronization across the many intertie points which makes synchronization a significant challenge for microgrid operations on grid networks. Transition to/from islanded operation is complicated by the shortcomings of the network protectors previously discussed in this section. If the network protectors are not upgraded, then an open transition (nonseamless transfer) may be the safest transition. A closed transition will likely require upgraded network protectors, possibly replaced with a power circuit breaker and enhanced relay package. With this upgraded intertie equipment in place, an advanced microgrid controller can control synchronization and slew the generation into synchronization with the utility.
- *Voltage Control and Power Control.* The microgrid is likely to contain numerous generation and storage sources, especially for a large grid network, which may require a complex communication and control infrastructure with visibility to each DGS source.
- *Metering and Monitoring.* Depending on design objectives of the microgrid, extensive metering and monitoring is likely to be needed as shown in Figure 5-10. Grid network metering and monitoring is going to be more complex and difficult to implement when compared to a spot network.
- *Reliability.* Because customers on grid networks supplies already have outstanding reliability, the backup supply capability of the microgrid would rarely be called upon. That means that the microgrid communications and control system would rarely be tested in islanded mode. Hidden failures would be a main concern in designing the control system.

**Figure 5-10. Grid Network Microgrid with Dispersed Generation and Robust Communication**



Given the complexities and the amount of equipment that would need to be upgraded, the grid network microgrid is one of the more experimental and futuristic design concepts.

## 6 Microgrid Operations During Emergency Situations

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### **Findings**

**Finding 6.1:** Microgrids may be susceptible to many of the same problems that cause interruptions in service from the local utility. For example, microgrid circuits with overhead exposure may be susceptible to storm damage. In areas affected by flooding, damage to non-submersible underground equipment may occur. Just like the local utility, a microgrid can experience faults/failure; there is no guarantee that it will function as intended, especially if aspects pertaining to its resiliency were not adequately designed and maintained.

**Finding 6.2:** Providing enough power to meet all critical loads while islanding may entail installing redundant generation to protect against the failure of one or more generators. This redundancy will allow the microgrid to provide adequate generation to serve critical loads even if a generator fails or is out of service.

**Finding 6.3:** Inadequately designed or implemented microgrids can introduce additional safety hazards during storm events, particularly from live, downed conductors and potential reverse electric power flows.

### **Recommendations**

**Recommendation 6.1:** Facilities should develop regular testing procedures to ensure that all equipment associated with the microgrid is adequately maintained and operates as intended.

The Legislation required that the Project Team determine:

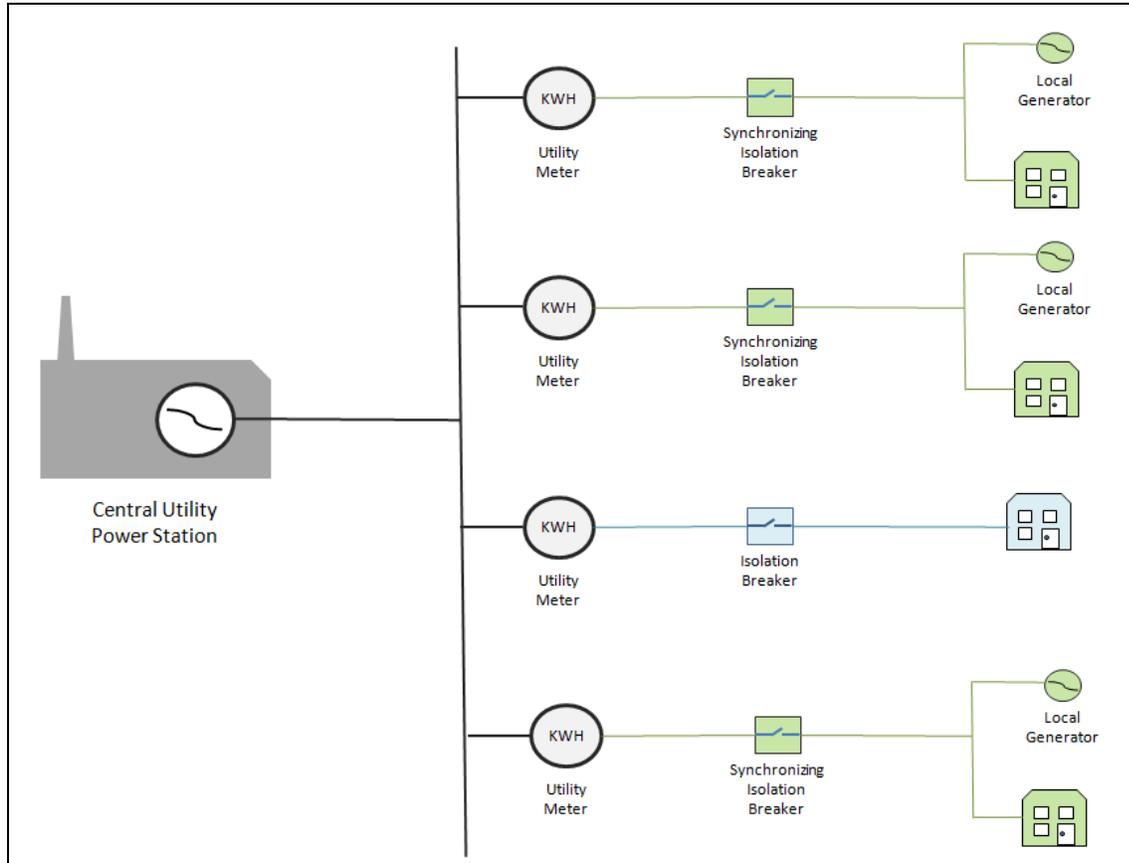
- The adequacy of a microgrid system to operate in emergency situations and that proper protections are in place to ensure operation in the event of an emergency situation.

Microgrids can positively impact response and recovery actions during emergencies. They can also reduce the amount of back-up generation that is required. In a simple, isolated region supported by a single 1,000-MW generator, a second 1,000-MW generator would be required to provide back-up when the primary generator was unavailable. Without power from the second generator, there would be a region-wide blackout. If that same region were supported by ten 100-MW generators, the loss of any one generator would cause smaller, more localized problems. If planned maintenance outages were coordinated between generators, only a few 100 MW generators would be required as standby generation for the entire region. Although utility transmission and distribution systems are intentionally networked with redundancy to minimize risks, the use of microgrids can improve resiliency and the impact on critical public safety and security infrastructure.

Having generating assets spread diversely over a large area reduces the risk of common-mode failures due to environmental events or intentional attack.

**Figure 6-1. Power delivery in the absence of microgrids**

Without microgrids, if utility power delivery is interrupted, there can be a regional emergency. If one or even two smaller microgrids fail, there may be local inconvenience, but problems are more localized and reduced in scale.



## 6.1 Who owns and operates microgrids today?

Typical microgrid owners and operators include: fixed military bases, university campuses, corporate research facilities, hospitals, airports, industrial plants, hotels, municipalities, shopping centers, and planned residential communities. The reason each of them invests in the components of a microgrid is that they find the cost of owning and maintaining it is lower than the cost of service interruptions. When CHP and thermal energy storage are included, complete microgrid assets can often be justified through energy savings alone.

With the growing frequency of severe weather events causing grid disruption and power outages, more industries are investing in microgrids to mitigate business interruption losses, particularly in mission critical facilities housing research, emergency functions, production facilities, and medical services.

## 6.2 What features are necessary for continuity of service, reliability, and resilience in a microgrid?

### 6.2.1 Generating Capacity Required Within a Microgrid

When operating in isolation, a microgrid no longer enjoys the benefits normally provided by the utility: diverse energy sources and the perception of an unlimited supply of power. Thus the microgrid operator needs to either install more generating capacity than the amount of power needed in any conceivable emergency, or the microgrid must perform load shedding during emergencies and turn off enough noncritical load that the remaining critical loads add up to less than the internal generating capability. Here are three examples:

- **Example 1:** A microgrid with a load that varies between 10 MW during the day and 6 MW at night should include at least 10 MW of generating capability. If 3 MW of the peak load could be considered noncritical and could be shut-off indefinitely without constraining core operations, then only 7 MW of generating capacity would be required. This could be supplied by one 7 MW generator, or multiple smaller generators that could operate in parallel.
- **Example 2:** A microgrid with 3 MW of noncritical load and 7 MW of critical load needs at least 7 MW of generating capability within its boundaries. But if that were in the form of a single 7-MW generator, there would still be a reasonable risk that the 7 MW generator would be out of service at the time of utility failure. In that case, the entire critical and noncritical load would be lost. To provide N+1 reliability, three 3.5-MW generators could be provided. Maintenance activities would be scheduled without overlap so at least 7 MW (two 3.5MW units) of generation was available at all times. If utility power supply failed during a maintenance activity, the critical loads could still be met. If utility power failed when all three microgrid generators were available, both critical and noncritical loads could be met.
- **Example 3:** It is important to note that for a microgrid with a 3-MW noncritical load and 7-MW critical load, a generator combination of 4 MW + 4MW + 2.5 MW = 10.5 MW is not equivalent to three 3.5-MW generators equaling 10.5 MW. With either of the 4-MW generators out of service, only 6.5 MW of capacity remain. For N+1 reliability, the largest generator must be able to be removed from service and all critical loads met by the remaining generators.

Depending on the negative consequences associated with failure of critical service, generator configurations of N+1, N+2, 2N, or more are sometimes specified.

As a minimum, each microgrid needs at least one generator “behind the meter.” However, all mechanical equipment requires maintenance. Even the most reliable, well-maintained equipment can fail. Both planned and unplanned maintenance can make equipment unavailable for days or even weeks. Thus, to provide high reliability, redundancy is required. A common basis of design is called “N plus One Redundancy.” This design means providing enough generators to meet peak loads even when the largest generator is out of service.

Depending on the electrical characteristics of loads served by the microgrid, additional generating capacity may be required beyond the simple summation of load nameplates. “Resistive” loads such as incandescent lighting and electric heaters can simply be added together to determine the total required generating capacity. Motor loads can vary dramatically and must be carefully evaluated for the demands they may impose during outages. Loads that include motors (fans, pumps, cranes, mills, mixing equipment, etc.) can draw up to six times more current during their start-up transient than during steady-state operation. The impact of motor loads on a generator can be more or less significant depending on whether all motors could be called on to start at the same time and what portion of the total load is made up of motors. It is particularly important to identify motor loads that are set-up for automated operation because they can rapidly increase demand and cause an islanded microgrid to shut down. One strategy to mitigate the impact of motor loads is to maintain all critical rotating equipment in continuous operation to avoid the demand spike caused by their initial start-up (this obviously comes with a cost of additional energy). Another is to include variable-speed drives in the system rather than “across-the-line” motor starters. A careful electrical engineering load study is required to determine the additional generating capacity required by motor loads.

## **6.2.2 Identifying Critical Loads**

Even with redundancy built into the generating system, industry best practice includes evaluating and prioritizing customer loads for “load shedding” during interruptions. If only a portion of the generating capacity is available, it is important to identify which loads are most critical to serve and which ones must go without power.

A university, hospital, military base, or other microgrid community would identify their own "mission-critical" facilities as "must-run" and develop a cascading list of buildings or services in declining priority so as to manage load during interruptions. The highest priority is inevitably any equipment that is required to maintain operation of the microgrid generators themselves. This includes equipment such as fuel and lubricating oil pumps, air compressors, control systems, boiler feed pumps, cooling water pumps, combustion air fans, and starting motors for gas turbines. Automated power distribution circuit breakers also require power to operate. Equipment required for life safety, safe egress from buildings, and communication between first responders is in the top tier. Each microgrid needs to impose its own priority structure when developing a load-shedding list. Mission critical demands involve continuity of the most basic services to customers and avoidance of large losses. An example in a hospital would include power to operating rooms. In a research facility, it might include power to cold storage or animal facilities. In a data center, power to the white space servers would be highest priority. “Back office,” administrative, and all other deferrable services are usually the first to go without service.

More subtle load-shedding decisions involve services that can be scaled-back rather than simply turned off. For example, noncritical building temperatures can be allowed to drift outside normal comfort range while still being occupied. Fresh air recirculation rates can be cut back. Controllable lighting can be cut back. Data center white space conditions can be allowed to move from the ASHRAE “recommended” zone, where most are operated, into the ASHRAE “allowable” zone. All of these decisions should be made in advance of an emergency.

### **6.2.3 Maintaining Uninterrupted Service**

Some loads can tolerate brief interruptions of power with minimal consequences. Many commercial buildings have emergency generators that start up automatically on loss of utility power and can carry all loads within a few seconds. Most building codes allow a few seconds of power outage while emergency generators start. Small commercial or residential applications may only require manual-start generators and manual load transfer upon loss of utility power. Other applications such as data centers, hospital operating rooms, security systems, and critical process equipment control cannot tolerate any out-of-service time without severe consequences.

For continuous service, an automatic transfer switch must be included between the microgrid and the incoming utility. It will detect and open up the failed utility power circuit and transfer all load to the microgrid power system in less than 1/10th of one second. Most electronic equipment can ride through this transfer period without problem. But, for continuous service applications, this transfer cannot be performed manually.

To maintain uninterrupted service, at least enough generating capacity within the microgrid must be operating prior to a utility service interruption. There must be enough capacity to accept the entire microgrid load immediately upon loss of utility power without tripping the microgrid's generator(s). Alternatively, enough energy storage capacity (uninterruptible power supply or UPS) must be included within the microgrid so that the entire microgrid load and the added electrical demands of starting a generator can be met by the UPS system until the generator can take over. A third option is to provide UPS protection for critical loads and "automatic load shedding" of noncritical loads and loads that exceed the on-site generating capacity.

A microgrid best practice is to commence operation of behind-the-meter generators and control their net power output level to match the microgrid load in advance of a storm or imminent weather event so that when a utility service failure occurs, adequate capacity is already proven and carrying the load. By remaining synchronized but moving the microgrid's generators to a net-zero energy flow across the utility boundary, the microgrid generators will experience the least amount of stress and least likelihood of failure if outside utility service should fail. With experience, microgrid operators can learn that certain environmental conditions are likely to result in utility service interruptions. Ice storms and extremely high winds often result in failure of overhead power cables. In that case, a decision can be made in advance to preemptively separate the microgrid from the utility and operate as an island. This strategy has the benefit of avoiding variations in utility power quality that might trip the microgrid's generators. It has the drawback of losing the reliability normally provided by the utility company.

Properly designed generator systems include protective relays that will shut them down rather than allow them to fail due to excess load. For continuous service, microgrids with loads that can exceed their generator's capacity must include the ability to shed load. As previously described, there must be a pre-determined load shedding process established to maintain power continuity to critical loads and allow less critical loads to lose power rather than the microgrid shutting down due to excessive demand. Just like an automatic transfer switch, the load-shedding system must automatically open breakers carrying excess load in approximately 8 milliseconds of utility service failure. For continuous service, this process must be automated.

Load-shedding systems involve software that implements the microgrid operators' pre-established load shedding processes. The system continuously monitors the available generating capacity that is currently operating behind the meter to the loads that are currently operating behind the meter. The system monitors the utility power supply just outside the microgrid isolation breaker. When utility service fails, the load-shedding system will open enough breakers to noncritical loads within the microgrid that the microgrid generators have more than adequate capacity to support the remaining (higher priority) loads.

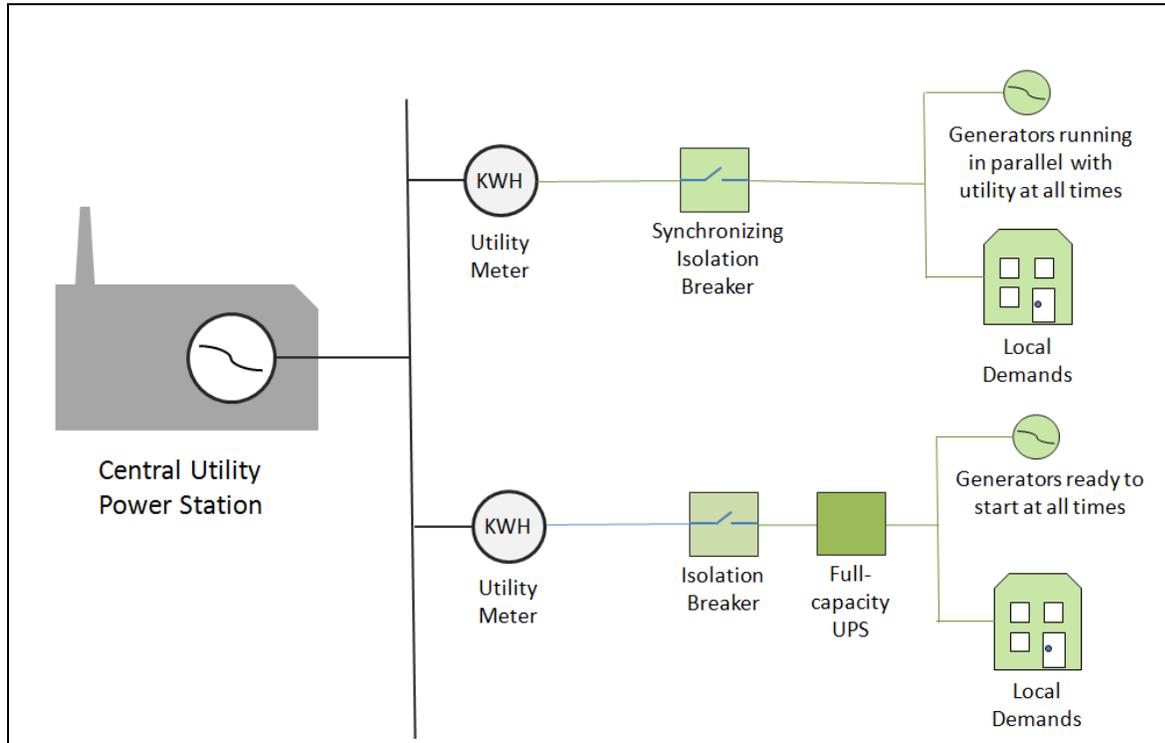
Two sets of breakers need to open near-instantaneously at the moment of utility service failure: the microgrid isolation breaker(s) at the utility service entrance and the breakers that serve lower-priority loads within the microgrid. Specialized fast-acting relays must be located inside all of these breakers and high-speed communications must be maintained between them and the load shedding system. These breakers must be "pre-armed" by the load shedding system so they will operate fast enough when called on. Since generating capacity can vary based on environmental conditions and maintenance requirements, and loads can vary based on environmental conditions and customer desires, the set of electrical services that need to be shed will not necessarily be the same in every event.

There are events that can cause utility service to degrade rather than fail altogether. These events can result in multi-millisecond power interruptions or variations in power factor, frequency, or voltage supplied to the power users. These power quality events rarely cause problems to typical users of electricity. However, some high-speed electronic equipment used in alarm and security systems, research equipment, and advanced computing systems require high power quality as well as continuity of service. Needs for power quality that are higher than "utility grade" must be identified and addressed on a customer-by-customer basis. Protection of these systems often involves the use of UPS systems.

Batteries and flywheels are commonly used for energy storage in UPS systems. Continuous utility-synchronized operation is common in CHP applications while UPS systems are typical of emergency-only generator systems.

**Figure 6-2. Requirements for uninterrupted service**

To provide uninterrupted service, either a full-capacity generator must be running synchronized with the utility at all times, or a full-load uninterruptible power supply must be provided.



A gasoline or diesel-fueled reciprocating engine or aero-derivative gas turbine may start and carry its rated load within a few seconds. Large solid-fueled steam-turbine-generator combinations may require 12 or more hours to start-up from cold.

### **6.2.3.1 Understanding Synchronous vs. Induction Generators**

Normally, the utility is responsible for maintaining a stable voltage, frequency, and waveform at the microgrid service connection. Without the utility, microgrids must perform these services themselves. At least one generator in a microgrid must be a synchronous generator having the ability to run in isochronous mode, i.e., it must be able to maintain a stable output voltage and frequency without connecting to any other generation sources. Induction generators do not have this characteristic. Induction generators can be made by rotating an AC motor faster than the synchronous speed on the grid they are connected to. Induction generators are commonly used in mini-hydro plants, wind turbines, and some backpressure steam turbines due to their ability to produce power at varying rotor speeds.

Induction generators are simpler and more rugged than other generator types, but they cannot be the first or only generator running, i.e., they do not have isochronous capability. Similarly, solar electric systems cannot usually run in isolation. They can only act as a supplement. Renewable energy sources alone should not be considered reliable sources of emergency power. Their output varies based on forces of nature, not the microgrid load. However, with careful design that includes energy storage, renewable energy can be used as a supplement to reduce the rate of fuel use by other generators.

#### **6.2.4 Black Start Capability for the Microgrid**

Due to the demanding performance conditions for automatic transfer and load-shedding systems, provision should be made for occasional failures. Black start capability is strongly recommended for each microgrid. At least one of the generators within a microgrid must be coupled with a starting system that requires no external power. The stored energy used to start this generator is commonly a set of batteries. Black-start battery sets are a standard feature of emergency diesel generators but compressed air, compressed nitrogen, or other mechanical means may also be used.

There is not a standard rating of black start capacity per MW of generating capacity but between 2% and 5% of a gas turbine's rated output may be required to support its initial starting sequence. A solid fueled, steam driven, boiler-steam-turbine generating system may require considerably more. More importantly, enough energy storage must be included in the black start system to make multiple starting attempts since generators that have not been running recently often require much more energy to warm up and come to stable operation than machines that were recently shut down.

It is not uncommon for gas turbines and steam-driven generators to rely on their own small, dedicated, black-start diesel generators for starting power.

Along with all emergency equipment, all components of black start systems should be part of a well-documented preventative inspection and maintenance system. Even batteries take maintenance and have finite service lives. The service life of batteries can be affected by the battery charger characteristics, electrolyte maintenance practices, the number of charge-discharge cycles, and the environmental conditions they are subject to. Well-maintained batteries will last many years.

Black start systems should be demonstrated to be fully functional at initial commissioning and on an ongoing basis thereafter. Annual testing is typical. As the cost of downtime increases, microgrid operators may choose to test black start systems monthly or even weekly. Provisions for this testing should be made at the time of initial system design so that testing of the black start system equipment does not require actual outages of mission-critical components. It is common for mission-critical systems such as data centers to include electrical "load banks" that are used as proxy loads for use in black start and emergency generator testing.

The term “black start” can also be used when a microgrid uses its own operating equipment and available capacity to assist a utility or nearby microgrid to re-start equipment outside the boundaries of the operating microgrid. This can be done as a pre-arranged contracted grid service or on a volunteer basis during an emergency. Pre-planned scenarios have a much higher likelihood of success than ad-hoc attempts to solve a problem under time pressure. The planning of interconnecting generating equipment and loads is an activity that should be undertaken only by experienced electrical power engineers. Errors with large energy systems can be costly and dangerous.

### **6.2.5 Load Restoration**

An initial automatic load-shed event may involve dropping more noncritical load than necessary so that critical loads are not disturbed. Once the isolated microgrid has reached stable operation and if there is still remaining generating capacity, it may be desirable to restore service to a few noncritical loads as well. This restoration can be done remotely or through direct manual operation of breakers. If performed manually, real-time, explicit communications must be established between key personnel involved in generator operation, load monitoring, and the load breakers. This may involve telephones, radios, computer-based communications, or human messengers if other communications systems are out of service. But it must be done by skilled technical personnel who have complete familiarity with the loads, generator characteristics, and safe power breaker operation as safety must be the highest priority.

Planning for load-restoration is highly system-specific and involves documentation of the loads that will be connected and the available generator capacity. Best practice involves maintenance of electrical “single-line” drawings showing the current configuration of the microgrid power distribution system. Ideally, a microgrid operator will maintain records of not only the maximum loads that a subsystem may carry, but also the typical loads and the patterns of these loads through daily, weekly and seasonal variations.

A typical sequence of load-restoration within a microgrid involves:

1. Identifying the total load that will be restored when a particular breaker is re-closed. This process involves understanding what devices will use power immediately and what additional loads may re-start automatically after breaker re-closure. If possible, it is helpful to review operating records of these loads from moments just prior to load shedding. Best practice involves data collection, trending, and archiving of power demands from all power breakers within a microgrid that may be part of a load-shedding strategy. This operation can be done manually or can be fully automated.
2. Confirming the generator operating within the microgrid has adequate remaining generating capacity -- with additional margin for unanticipated changes.
3. Confirming the generator has adequate “block load acceptance” capacity, i.e., it will not trip due to the size of the step-change the new load will impose on it.
4. Verifying all loads to be restored are in a safe condition and that restoration of those loads will not cause an unsafe condition. It is particularly important to communicate with anyone who may have performed maintenance on any equipment while it was out of service.
5. Communicating with the microgrid generator operator.
6. Re-closure of the load breaker.

Once utility service is available following a service interruption, most microgrids require a planned re-synchronization with the utility. This process involves use of specialized synchronizing equipment to adjust and confirm that the microgrid generator output matches the utility system output in frequency, voltage, and phase angle.

### 6.2.6 Underground Power Distribution

For both reliability and aesthetics, many microgrid owners choose to use underground power distribution. Underground cables are more expensive to install than pole-mounted cables but they are rarely subject to vandalism, damage from storms, animals or vehicular contact. They can be damaged due to careless landscaping, flooding or construction activities but these have the slight mitigating characteristics of usually taking place during the day, on weekdays and during better weather when most repair crews are available and the location and cause of damage is often quite obvious.

Careful consideration should be given to the volume of fuel stored for each generator and the length of time that critical loads can be supplied without fuel deliveries. Natural gas is typically supplied by utility pipeline while liquid or solid fuels are usually delivered in advance of use and stored on site. For example:

- **Example 4:** How much diesel fuel is needed to support a steady 2-MW load with no fuel deliveries for a seven-day period?
  - $2 \text{ MW} \times (1,000 \text{ kW/MW}) \times (3412 \text{ Btu/kWh}) = 6.824 \times 10^6 \text{ Btu/hour}$
  - $(6.824 \times 10^6 \text{ Btu/hour}) \times (24 \text{ hours/day}) \times (7 \text{ days}) = 1.146 \times 10^9 \text{ Btu.}$
  - Diesel fuel has a lower heating value of 128,450 Btu/gallon. A modern diesel engine may be 40% efficient.
  - $(1.146 \times 10^9 \text{ Btu}) / (128,450 \text{ Btu/gallon}) / (40\%) = 22,312 \text{ gallons.}$

### 6.3 What could render stored fuel unusable?

Liquid fuels have a shelf life, i.e., the fuel can degrade or support biological growth over time. Liquid fuels commonly used by microgrid generators primarily include biodiesel, #2 oil, #6 oil, kerosene, and propane. These fuels may be stored in tanks that are buried or above ground and can accumulate water and sludge in them. With proper storage, commercial diesel fuel will maintain its quality for over a year while biodiesel has a shorter shelf life. Either fuel will last longer with the proper use of biocides. Liquid fuel should be used within a year of delivery. If not, it should be periodically tested to confirm it will not foul the engine when used. Testing every one to three months is common.

## **6.4 Fuel Purchasing and Inventory**

Fuel storage capacity should take into account the longest credible period that a microgrid might need to operate autonomously and the likelihood of fuel delivery interruption during emergencies. Best practice involves contracting in advance with fuel suppliers for deliveries during regional emergencies. Emergency fuel service contracts should involve both certification and verification that supplier inventories and delivery equipment vehicles are maintained at all times. If a fuel supplier is relied on for emergency service, they must have adequate emergency power capability to transfer and load fuel.

## **6.5 What are best practices to maintain high availability and reliability?**

### **6.5.1 Establish a Preventive Maintenance Program**

Equipment manufacturers provide recommendations about periodic maintenance activities to keep equipment in good running order. This will include chemical testing of water and lubricating fluids, vibration testing at each bearing, acoustic and thermal image testing, and routine replacement of consumable parts such as filters. Periodic operating-time-based inspections are also common. Preventative maintenance programs can be performed by trained in-house personnel or contractors. All maintenance and repair activities for each machine should be tracked in a searchable database. Whenever equipment fails to perform as designed, the maintenance logs should be reviewed as a part of the troubleshooting and repair sequence.

In addition to the manufacturer's guidance regarding maintenance, it is recommended that operators of new equipment consult with other operators who have experience with the same equipment.

Mature generating technologies such as reciprocating engines, gas turbines, and steam-turbine-generators usually have very predictable service lives when maintained properly and preventative maintenance programs can be planned well in advance.

Preventative maintenance and inspection events are typically based on both the number of operating hours and number of starts a piece of equipment has been subject to as well as fixed seasonal maintenance. It is common for engine inspection and maintenance programs to involve daily monitoring of instrumentation while equipment is in service, brief monthly or quarterly inspection of equipment while out of service, multi-day semiannual or annual boroscope inspections, and extended partial disassembly and replacement of some components after 20,000 to 45,000 hours of operation, and full overhaul every 40,000 to 75,000 hours of operation.

Some of the more common operations and maintenance activities performed by equipment operators involve checking oil levels, monitoring operating temperatures, inspection and replacement of fuel, air and water filters, vibration monitoring, infra-red temperature monitoring, and cleaning of heat exchangers. More complex maintenance involves inspection and calibration of instruments and control valves, checking and adjusting piston clearances on reciprocating machines, and internal inspection and component replacements in gas turbines.

## **6.5.2 Operations and Maintenance Training and Manuals**

The initial purchase of all major equipment should include complete training for all operations and maintenance staff. Training should include both classroom theory and hands-on operation and maintenance of the equipment. All training should be performed on fully-commissioned equipment. A training session is insufficient if the equipment is only partially functional. There is a big difference in training effectiveness between saying, “when this green light comes on, the shaft should rotate -- once everything is hooked up,” and “notice that when this light comes on, the shaft has begun to rotate.”

Manufacturers should be required to provide at least one paper and one searchable digital copy of Operations and Maintenance manuals. If generic manuals are provided that apply to more than one equipment model number, all differentiating aspects of the relevant model must be boldly noted in both paper and digital versions.

Manufacturers and installation contractors should be required to provide “as-built” drawings for their respective scopes of work. It is best for equipment owners to have AutoCAD copies of all equipment drawings reflecting the “as-built” condition following commissioning. Drawings must be maintained based on operating experience, new program requirements, and changes in codes and permits. In particular, it is often necessary to modify and update piping and instrumentation, controls, and wiring diagrams throughout the life cycle of the equipment. Without current drawings that accurately reflect the existing configuration of systems, troubleshooting problems can be extremely challenging. Best practice is to require that changes are documented immediately when made, one set of hand-marked drawings is left on file with the microgrid operating personnel, and a duplicate set is submitted for formal AutoCAD update. Revision-controlled document sets are updated as soon as the revised drawings are available. A log of drawing revision numbers is maintained and periodic audits are performed of all revision-controlled document sets.

If critical documentation for troubleshooting microgrid problems is only available in digital form, the systems that provide that documentation need to be part of the first tier of power availability. Alternatively, hard physical copies of critical documentation can be maintained – but these must be kept up-to-date.

### **6.5.3 Consumable Supplies and Specialized Tools**

At least one year of consumable parts should be purchased with all new equipment. Manufacturers should also provide a complete list of all spare parts with prices valid for at least one year. Consumable parts typically include air, oil, fuel and water filters, gaskets, O-rings, and fuses. A best practice is to identify the lead-time involved in delivering all subcomponents of a system and to stock all items that have unacceptably long lead times or contract the manufacturer or local supplier to stock these items and provide them on a just-in-time basis.

Specialized tools should be purchased as required for equipment maintenance performed by operators or in-house maintenance personnel.

### **6.5.4 Fully Commission Complete Systems**

All systems should be completely tested under realistic conditions. Testing all individual components does not constitute commissioning of an integrated system. Commissioning tests must be run to demonstrate all capabilities that will be expected during emergency conditions. After all systems are “working,” an additional 18 months of observation may be necessary to have confidence that a system is fully tested. Extremes of weather conditions must be observed and deficiencies addressed and re-tested.

### **6.5.5 What does commissioning involve?**

Commissioning equipment is more than just demonstrating that it operates. Full commissioning involves not only operation of equipment at its design capacity, but verifying and fully documenting that its efficiency, emissions, and other operating characteristics meet the original design intent under all conditions that have been specified and/or guaranteed. Generator performance characteristics are often measured at 25%, 50%, 75%, and 100% output. Confirmation of efficiencies involves measuring fuel flows and energy outputs as well as parasitic loads and cooling requirements. If a system must start and run automatically, then commissioning must demonstrate that. A best practice is to perform a true “pull-the-plug” test to demonstrate that all automated systems will actually perform as intended.

New equipment should not be accepted or fully paid for by the end user until full commissioning is complete.

### **6.5.6 Equipment that runs is more reliable than equipment that sits idle**

Microgrid owners who operate generators that continuously carry real loads while synchronized to the utility grid can much more readily identify performance problems than those who only test equipment periodically under simulated conditions and only fully-load their equipment during emergencies. Operators of continuously running equipment learn how frequently fuel, oil, and air filters become fouled. They also become more familiar with basic maintenance and troubleshooting. Continuous parallel operation is especially cost-effective in CHP systems.

### **6.5.7 Regularly retest everything that is not continuously operated**

Equipment components can fail even with limited use. Emergency-only generators do not usually include emissions controls so they are limited by state emissions permit to less than 500 hours of operation per year. These generators must be tested regularly to confirm they are still fully functional and will perform as expected. Weekly surveillance tests are typical, including synchronizing and carrying load. The root cause of even small deficiencies should be determined and resolved as soon as possible.

### **6.5.8 Multiple fuel options are desirable**

Fuel supplies can be interrupted for various reasons. During very cold conditions, natural gas may be interrupted and standby fuel operations will be essential. Cold fuel oil storage may require pre-treatments, in-tank heaters, or controls adjustments for viscosity changes. The price per Btu of different fuels can change due to various market conditions. Generating assets that can operate on different fuels diversify these risks. Providing multiple fuel options could involve use of separate generators that run on different fuels. Boilers, gas turbines and reciprocating engines can be outfitted with dual fuel capability. This is usually a combination of natural gas and liquid fuel but other combinations are possible.

Some systems are capable of switching fuels on demand without interruption of service. Due to its complexity, dual fuel equipment is more costly to buy and maintain. In addition, dual fuel controls are more complex and troubleshooting can be more challenging when problems occur.

### **6.5.9 Practice with emergency response teams periodically and plan for human needs**

Just as equipment must be tested under real operating conditions, so must the people who are expected to support operations during an emergency. Emergency plans should consider the following issues/questions:

- What is the minimum number of people required to operate microgrid equipment?
- What troubleshooting and maintenance activities is the minimum staff capable of?
- What proportion of the operations and maintenance staff will need to prioritize their families over a work assignment during a regional emergency?
- Where will an emergency operations center be established if most of the power is out? What if the planned location is unavailable?
- Is the team dependent on Internet service, telephones, or radio?
- How will emergency response personnel communicate with their families and report to the rest of the organization?

- Where will people sleep? Where will food come from if roads are impassable? Will they be able to shower?
- What events could lead to an interruption of the municipal water supply?
- Who is capable of leading an emergency response team and making competent decisions in a stressful, evolving situation?
- What authority and resources will they have?

Emergency response teams will be successful in direct proportion to how well their needs are planned for and how realistically and regularly they are exercised during nonemergency conditions.

### **6.5.10 All mechanical equipment requires periodic maintenance**

Operators should start by following an equipment manufacturer’s recommended schedule for replacement of consumable parts, routine maintenance, and overhauls. After several years of familiarity with equipment, calendar-based maintenance intervals can be converted to longer “on-condition” based maintenance. This switch usually takes place after the equipment warranty ends. Ideally, it should be done in collaboration with the equipment manufacturer. Other owners of similar equipment can be useful sources of experience and best-practice recommendations as well.

All energy systems require monitoring and maintenance to assure that they will perform as anticipated when they are called on. Good record-keeping and prompt resolution of problems are at the heart of all proper maintenance programs. The following are descriptions of generally good practices, but are not intended as comprehensive lists of all maintenance activities for specific systems. Maintenance can either be performed by trained in-house personnel or contracted out to manufacturers, distributors, or dealers under service contracts.

#### **6.5.10.1 Solar Electric (PV) Systems**

Solar electric (also known as photovoltaic or PV) systems convert a portion of the energy in light into electricity. PV cells absorb photons and release electrons. When these electrons are captured, a small electric current results that can be used as electricity. By connecting PV cells together in both series and parallel, large voltages and currents can be produced. PV cells produce direct current (DC) electricity. To connect the output from a photovoltaic array to grid electric systems, the electricity needs to be “inverted” to alternating current (AC) and often stepped-up in voltage. To produce 1 megawatt of AC electricity, the output of over 3,000 photovoltaic panels must be combined. One can easily imagine that this combination involves tens of thousands of individual electrical wiring connections. For increased power output, many commercial and utility-scale PV systems include mechanisms that tilt long rows of panels so they are oriented directly toward the sun – tracking its daily path in the sky from east to west. The panels are tilted back to face the eastern horizon during nighttime hours. To monitor and document performance from the system, power metering and telemetry needs to be included.

Maintenance activities for photovoltaic arrays begin with monitoring their output and comparing it to the output of an ideal or “reference” cell, then troubleshooting and correcting any deficiencies. Reasons for degradation can include panel coverage from snow, leaves, vegetation shadows, dust, hail or other impact-damage. In most regions of the country, rain and snow are enough to keep the panels clean. In particularly dusty areas or in systems located near construction or farming activities, it may be necessary to wash the panels periodically to restore design performance. Vegetation must be maintained low enough so it does not cast shadows on the panels at any time during the day. Small areas of shade cause disproportionately large degradation in power output. Electrical connections must be kept dry and tight to prevent corrosion. As a minimum, inverters and transformers should be given an annual check to confirm proper performance. Tilting motors and linkages should be checked at least annually for proper movement and lubricated, if required by the manufacturer.

### **6.5.10.2 Battery Systems**

Although batteries appear passive, they involve a continuous chemical process. They degrade over time and require maintenance. The following types of tests should be undertaken to ensure the continued operability of battery systems:

- Each individual cell within a new battery system must be checked with a digital voltmeter.
- Specific gravity and liquid-level readings should be made of each cell’s electrolyte fluid. These should be recorded and plotted over time. By documenting the periodic test results, degradation of any individual cell can be compared to its peers and to the manufacturer’s design data. Ideally, battery systems should include a panel meter where operators can monitor and document float voltage each shift, or at least daily.
- Periodic adjustments to the liquid level and float voltage may be required to maintain the design charge.
- Monthly, checks should be performed for general cleanliness of the battery, mounting rack, and battery room.
- Checks should be made for electrolyte leaks and cracks in cells, and corrective action taken if any are found.
- Checks should be made for corrosion at terminals, connectors, racks, and cabinets.
- Checks should be made of the ambient temperature and verification that ventilation devices (fans and vents) are operable.
- Checks and corrections should be made for all the electrolyte levels.
- Checks should be made for availability and condition of all safety equipment and operation and cleanliness of body wash station.
- Check for a class C fire extinguisher and check that it has been inspected and tested.
- Check for availability of insulated tools.
- Check the hydrometer for cleanliness and cracking of rubber parts.
- On a quarterly basis, all cells should be checked with a digital voltmeter and 10% of the cells should be checked for specific gravity and temperature.
- On an annual basis, all connections’ resistance should be checked and the panel voltmeter should be calibrated with a certified calibration digital voltmeter.
- Every five years it is appropriate to perform a capacity discharge test. If the five-year test shows less than 90% capacity, the capacity test frequency should be increased to annual.

### **6.5.10.3 Fuel Cells**

A fuel cell is a device that produces electricity and heat by electrochemically reacting a fuel (generally hydrogen or hydrogen-rich) with oxygen. Unlike a conventional prime mover, it does this without burning the fuel and can therefore be more efficient and cleaner. A fuel cell essentially consists of an electrolyte sandwiched between two electrodes with connectors for collecting the generated current.

Fuel cells are related to batteries in that both produce DC current through an electrochemical process without direct combustion. But they have important differences. A battery is a closed system that generates electrical energy from the conversion of its stored electrolyte. Once the electrolyte is fully converted, the battery is depleted and must be either recharged or replaced. A fuel cell, can be continually provided with fuel and oxygen from external sources and can therefore produce power for the rated lifetime of the cell. Waste heat from fuel cells can be captured to improve overall efficiency as part of a Combined Heat and Power (CHP) system. Heat is generally recovered in the form of hot water or low-pressure steam (<30 psig), but the quality of heat is dependent on the type of fuel cell and its operating temperature. Generally, the heat recovered from fuel cell CHP systems is appropriate for low temperature process needs, space heating, and potable water heating.

Fuel cell systems designed for DG applications are primarily natural gas or LPG fueled systems. Each fuel cell system consists of three primary subsystems: 1) the fuel cell stack that generates direct current electricity; 2) the fuel processor that converts the natural gas into a hydrogen rich feed stream; and 3) the power conditioner that processes the electric energy into alternating current or regulated direct current.

Maintenance costs for fuel cell systems will vary with the type of fuel cell, and the size and maturity of the equipment. Some of the typical costs that need to be included are replacement parts and material such as air and fuel filters, reformer igniter or spark plug, water treatment beds, flange gaskets, valves, electronic components, and consumables such as sulfur adsorbent bed catalysts and nitrogen for shutdown purging. Recommended service is comprised of routine short interval inspections and adjustments with periodic replacement of filters at intervals of 2,000 to 4,000 hours of operation. Major overhauls include catalyst replacement every three to eight years. The largest and most expensive maintenance activity is the catalyst replacement. This maintenance requires substantial down-time and is a very high proportion of the life-cycle-cost of the fuel cell system.

#### **6.5.10.4 Flywheel Energy Storage**

Flywheels absorb and discharge energy to an electric grid, effectively smoothing the output of more variable renewable energy sources such as solar and wind. Flywheels can be used within uninterruptible power systems (UPS). Flywheels don't use toxic chemicals, and can come online and vary power output very quickly. They need little maintenance over a 20-year period so they will incur lower lifetime maintenance costs, and are very energy efficient. Flywheels work by accelerating a rotating mass to a high speed and maintaining energy in the system as rotational energy. Flywheels typically spin at tens of thousands of revolutions per minute. Advanced systems operate at over 100,000 rpm. A flywheel system consists of a rotor suspended by bearings inside a vacuum chamber to reduce friction. It is connected to a combination electric motor and electric generator. Best practice includes continuous vibration monitoring of the rotating mass. If the system is not fitted with full magnetic bearings, the bearings are typically replaced about every five years. Sealed vacuum systems with magnetic bearings may only require brief shutdowns for maintenance inspection every five years.

## 7 Microgrid Funding Mechanisms

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### **Findings**

**Finding 7.1:** Microgrid developers may pay a risk premium for finance capital as there is limited microgrid performance data to inform potential investors.

**Finding 7.2:** A microgrid developer's ability to secure long-term revenue streams is critical in assuring their investment.

**Finding 7.3:** Some microgrid revenue streams cannot be captured by nonutility microgrid owners. For example, there are presently no mechanisms to compensate microgrid or distributed generator owners for distribution-level ancillary services and transmission and distribution investment deferral. This may result in the underutilization of otherwise economically feasible options and reduces the potential revenue streams that could be used to fund investments in microgrids. These issues are being examined by the Public Service Commission under the Reforming the Energy Vision (REV) proceeding.

**Finding 7.4:** A typical feasibility study for a potential microgrid project commonly exceeds \$50,000 and takes approximately six months to complete.

### **Recommendation**

**Recommendation 7.1:** The State should evaluate public-private partnerships to enhance microgrid economics through economies of scale and collaborative procurement.

The Legislation required that the Project Team determine:

- Funding mechanisms that should be considered in order to pay for the establishment, operation, and maintenance of such microgrids.

Several different ownership models exist that may be employed in the development of microgrids. Ownership models are an important component in the consideration of funding mechanisms for microgrids because the models describe how various entities may monetize additional benefits resulting from a microgrid in addition to the societal benefits of supplying critical infrastructure with more resilient power. By capturing additional benefits in the form of various revenue streams and other value propositions, the cost of microgrids may be fully or partially self-funded thereby reducing the need for public assistance. Microgrid ownership models were studied with the purpose of identifying ownership models that could provide the incentive for different entities to invest in microgrid development and the barriers that may inhibit such ownership models.

## 7.1 Overview of Ownership Models and Funding Mechanisms

Microgrid ownership models describe how the costs and benefits resulting from a microgrid are distributed across all entities that are affected by the project. Microgrid costs and benefits will directly accrue to several distinct entities—the microgrid owner, microgrid user, the utility, and society.<sup>84</sup>

The microgrid owner refers to the entity or entities that retain ownership of the infrastructure within the defined boundaries of the microgrid system. This infrastructure includes the distribution facilities and distributed energy resources (DERs) within the microgrid system. The microgrid owner may be a single entity or multiple entities depending on the microgrid ownership and service model. The microgrid users refer to the different entities that are connected to and served by the microgrid system. This report focuses on microgrids that include users providing essential public services including hospitals, first responder headquarters (such as police and fire stations), emergency shelters, schools, water filtration plants, sewage treatment plants, municipalities, and certain commercial and non-profit organizations. The utility refers to the local distribution utility that owns and operates the macrogrid distribution facilities to which the microgrid may interconnect. Because all expenditures by a utility are ultimately passed on to the utility's ratepayers (excluding those passed on to the microgrid owner), the utility, in this context, also serves as a proxy for the utility's ratepayers. Finally, society refers to all entities outside the boundaries of the microgrid that enjoy certain benefits or bear some cost that is associated with the operation of the microgrid. An example of such a societal benefit would be offering relief to the public during an extended loss of power affecting a city or region by operating a facility that provided power, heating or cooling for the duration of the emergency event.

Microgrids can be owned and operated by a utility, a governmental entity, a nonprofit organization or a for-profit entity. However, the net benefits and costs accruing to all entities of any given microgrid are constant irrespective of who owns and/or controls the microgrid. For example, if a microgrid is sited in an area of the distribution network whereby it reduces peak demand on the system and helps avoid the need to invest in new utility assets to serve that area, the microgrid creates a benefit to the utility by reducing capital expenditures necessary to meet the utility's required level of service reliability. This benefit will be the same whether the utility or another party owns the microgrid because the peak demand reduction is independent of ownership.

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<sup>84</sup> The “direct” accrual of microgrid costs and benefits to different entities identifies to whom the costs and benefits of the microgrid accrue to in the absence of any economic transaction that transfers a cost or benefit to a different party. For example, a utility may directly accrue a cost from a microgrid development if the microgrid requires the utility to upgrade facilities on its distribution system. In practice, this cost will likely be transferred to the microgrid owner as a requirement of interconnecting with the utility.

The ability to monetize the benefits created by microgrids will be influenced by who owns and operates the microgrid. To continue the example above, if current utility planning and regulation fails to account for the value of utility asset investment deferral created by microgrids owned and operated by a nonutility entity, then only utility ownership would allow these microgrid benefits to accrue to microgrid owners. If the microgrid is owned and operated by a nonutility entity, the benefit to the utility would still be created, but it would not be monetized and accounted for in an economic and financial analysis from the perspective of a nonutility microgrid owner in the absence of markets or other mechanisms that compensate for benefits provided to the utility. For a potential microgrid owner, the ability to monetize these benefits is critical to the development of microgrids.

The disconnection between benefits created by a microgrid and the ability of the microgrid's owner to monetize the benefits is an important issue in addressing the design and the efficacy of various ownership models to support investment in microgrids. If the ratio of social benefit to private benefit is high, and if the State desires to encourage investment by the private sector into the development of microgrids, then there may be a need for State incentives to insure that the costs incurred by the private entity are recovered with a sufficient return to attract investment in microgrids.

## **7.2 Benefit Accrual**

Microgrid benefits can be grouped into five main categories: energy, reliability, power quality, environmental, and public safety, health, and security benefits.

- Energy benefits, including energy cost savings and reductions in the cost of expanding or maintaining energy generation or distribution capacity.
- Reliability benefits, which stem from reductions in exposure to power outages that are considered to be within the control of the local utility.
- Power quality benefits, including reductions in the frequency of voltage sags and swells or reductions in the frequency of momentary power interruptions.
- Environmental benefits, such as reductions in the emissions of air pollutants.
- Public safety, health, and security benefits, which include reductions in fatalities, injuries, property losses, or other damages and costs that may be incurred during prolonged power outages. Such outages are generally attributable to major storms or other events beyond the control of the local utility.

These benefits would directly accrue to the microgrid users, the utility, or society in general (see Table 7-1).

**Table 7-1. Microgrid Benefit Accrual**

<b>Benefits</b>	<b>Users</b>	<b>Utility</b>	<b>Society</b>
<i>Energy benefits</i>	☑	☑	
<i>Reliability benefits</i>	☑	☑	☑
<i>Power quality benefits</i>	☑	☑	
<i>Environmental benefits</i>			☑
<i>Safety, health and security benefits</i>	☑		☑

### **7.2.1 Energy Benefits**

Energy benefits include any reduction in the variable costs in electricity production and/or the displacement of heating and cooling costs via combined heat and power (CHP) systems, resulting in energy cost savings; the provision of ancillary services both to the microgrid and macrogrid; and the potential deferral of otherwise necessary expansion/upgrading of energy generation, transmission, and distribution systems resulting in capacity-cost savings. Energy-cost savings will accrue directly to the microgrid users, and additional energy cost savings may be passed along to utility customers if the microgrid results in lower locational-based marginal prices (LBMP). The utility will also receive a benefit where grid operational services are provided to the macrogrid reducing the need to procure these services elsewhere. Finally, the utility would directly receive a benefit if the additional generation capacity installed within a microgrid helps defer investment in the macrogrid elsewhere by reducing generation, transmission, or distribution capacity constraints.

### **7.2.2 Reliability Benefits**

Reliability benefits include the valuation of the total monetary and non-monetary benefits that occur as a consequence of the reduced probability and shorter duration of power outages. This benefit will accrue to private entities, the utility, and society as a whole.

Microgrid users will benefit from the increased reliability the microgrid provides through its internal energy generation and/or storage capacity and the ability to island from the macrogrid in cases of macrogrid disruption.

The utility may also realize benefits if the microgrid improves the overall reliability of the wider system. For example, during the aftermath of Superstorm Sandy, the Long Island Home in Amityville, NY remained islanded from the macrogrid for 15 days at the request of the Long Island Power Authority (LIPA) helping to reduce the overall strain on the local area's macrogrid and allowing LIPA to provide power to over 400 homes in the area.<sup>85</sup> Lastly, society as a whole will receive benefits from improved reliability when the microgrid can continue to provide energy services that would otherwise be unavailable during macrogrid outages.<sup>86</sup>

### **7.2.3 Power Quality Benefits**

Power quality benefits include reductions in the frequency of voltage sags and swells or reductions in the frequency of momentary power interruptions. Power quality is becoming increasingly important in today's economy with the increased utilization of highly sensitive electrical devices that may be damaged by suboptimal power quality. Industries like data centers and financial services providers particularly are vulnerable to even momentary interruptions.

### **7.2.4 Environmental Benefits**

Environmental benefits account for the potential net reduction in pollutant emissions if the microgrid energy supply is associated with less emissions than the energy that would otherwise be consumed from the macrogrid. This could result from the utilization of renewable sources of energy such as wind and solar or from the utilization of more efficient fossil-fueled generation, such as CHP, which can drive higher efficiency and less net pollution than separately fueled electrical and thermal supplies. These benefits will directly accrue to society through a reduction in health and ecological damage commensurate with the reduction in pollutant emissions.

### **7.2.5 Safety and Security Benefits**

Safety, health, and security benefits capture the value of maintaining services that are critical to health and safety. These services include fire response, emergency medical service response, hospital services, police response, wastewater treatment, safe water supply, and electric power for other critical services. The provision of these services will, in general, accrue to society as a whole.

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<sup>85</sup> Robert D. Chester. "The Long Island Home Co-generation CHP". April 3, 2013. [http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp\\_enabling\\_resilient\\_energy\\_infrastructure.pdf](http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_enabling_resilient_energy_infrastructure.pdf)

<sup>86</sup> These services do not include services deemed critical to health and safety, which are covered under safety and security benefits.

## 7.3 Cost Accrual

Microgrid costs can be broadly grouped into four categories: project planning and administration, capital investments, operation and maintenance, and environmental. Under current financial incentive programs, regulations, and utility practices, the majority of these costs will be directly borne by or easily passed onto the microgrid owner. Some costs, however, may still be incurred by the utility to which the microgrid interconnects or by society. Table 7-2 lists the cost elements of each cost category and ascribes to whom these costs may accrue.

**Table 7-2. Microgrid Cost Accrual**

Costs	Owner	Utility	Society
<i>Project planning and administration costs</i>			
Project design	<input checked="" type="checkbox"/>		
Building and development permits	<input checked="" type="checkbox"/>		
Efforts to secure financing	<input checked="" type="checkbox"/>		
Marketing the project	<input checked="" type="checkbox"/>		
Negotiating and administering contracts	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
<i>Capital investment costs</i>			
Energy generation equipment	<input checked="" type="checkbox"/>		
Energy storage equipment	<input checked="" type="checkbox"/>		
Energy distribution infrastructure	<input checked="" type="checkbox"/>		
Upgrades to macrogrid		<input checked="" type="checkbox"/>	
<i>Operation and maintenance costs</i>			
O&M for generation and storage equipment	<input checked="" type="checkbox"/>		
O&M for distribution infrastructure	<input checked="" type="checkbox"/>		
O&M for dedicated utility infrastructure		<input checked="" type="checkbox"/>	
<i>Environmental costs</i>			
Capital costs of emissions control equipment	<input checked="" type="checkbox"/>		
O&M of emissions control equipment	<input checked="" type="checkbox"/>		
Emission allowances	<input checked="" type="checkbox"/>		
Human health and ecological damage			<input checked="" type="checkbox"/>

### **7.3.1 Project Planning and Administration Costs**

The costs associated with project planning and administration include the labor and other expenses associated with project design, building and development permits, efforts to secure financing, marketing the project, and negotiating and administering contracts. Most of these costs will be directly borne by the microgrid owner, but there may be costs borne by the utility due to the expenses associated with negotiating and administering contracts that govern the interaction between the utility's distribution system and the microgrid. In many cases, the costs borne by the utility will likely be passed on to the microgrid owner. For example, the New York State Standardized Interconnection Requirements (SIR) state that applicants are "responsible for payment of the utilities' costs as provided for" in the rest of the document. For many applicants, their cost responsibility will include the utility's expenses associated with processing the application and contract.

### **7.3.2 Capital Investment Costs**

Capital investments include the cost to purchase and install distribution infrastructure, energy generation and storage equipment, and any necessary upgrades to the utility's distribution system resulting from interconnecting with the microgrid.<sup>87</sup> The majority of capital investment costs will likely be borne by the microgrid owner. Some capital investment costs may accrue to the utility if upgrades to the macrogrid are needed to accommodate interconnection with the microgrid such as higher capacity transformers. Again, many of these costs are likely to be passed on to the microgrid owner by the utility. For example, the standardized contract provided with the SIR includes provisions stating that the applicant is responsible for any incremental capital costs resulting from the interconnection.<sup>88</sup>

### **7.3.3 Operation and Maintenance Costs**

Operation and maintenance (O&M) costs include the labor, fuel, and other material costs associated with operating and maintaining the microgrid's infrastructure including energy generation and storage equipment, distribution infrastructure, and any dedicated facilities within the macrogrid resulting from the microgrid's interconnection. The microgrid owner will bear the O&M costs of the energy generation and storage equipment and distribution infrastructure within the microgrid, while additional O&M costs for the macrogrid resulting from interconnection with the microgrid would accrue to the utility. Like other costs incurred by the utility, utility O&M costs would likely be passed along to the microgrid owner through the provisions of a standby rate or similar mechanism.

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<sup>87</sup> If a CHP facility is part of the project, investments in heat recovery and distribution equipment will be required.

<sup>88</sup> The SIR includes some exemptions for applicants' capital cost responsibility including limits on cost responsibility for dedicated transformers and other safety equipment resulting from the interconnection of net-metered generation of certain sizes.

### 7.3.4 Environmental Costs

Environmental costs include the cost of purchasing, installing, operating, and maintaining emission control equipment; the cost of purchasing any emission allowances for regulated pollutants; and any costs associated with health and ecological damage caused by pollutant emissions. With the exception of health and ecological damage costs, all environmental costs will likely be borne by the microgrid owner. Health and ecological damage costs will accrue to society as a whole.

## 7.4 Monetizing Benefits to Recover Costs

Potential microgrid owners are unlikely to pursue microgrid development if they are unable to recover the costs incurred in building and operating a microgrid and realize some return on their investment. To recover their costs, microgrid owners will seek to monetize and capture the various benefits resulting from the microgrid and accruing to the microgrid users, utility, and society. This implies that the amount of potential cost recovery is linked with the amount of benefits generated by the microgrid. Microgrid owners, therefore, will strive to develop microgrids that minimize costs and maximize the benefits that they are able to monetize and recover.

Accordingly, it is important for policymakers and those charged with delivering emergency services to recognize “high value” attributes that can minimize costs and maximize the benefits that can be monetized for microgrid serving critical infrastructure. For example, incorporating a diverse set of users within a microgrid can allow internal generation assets to be sized more efficiently or run more often allowing for more economic utilization of the asset. According to Pace Energy and Climate Center:

Consider the example of a commercial center next to a large residential area. As illustrated in [Figure 7-1], the commercial building is used intensively between the hours of 8 AM and 5 PM, with demand increasing and decreasing quickly during the morning and evening, respectively. The adjacent residential area complements this load profile because it demands more electricity during early mornings and late evenings. The pair of users provides a combined daily demand profile that is steady. This complementary demand profile can be paired with a generator such as a CHP unit and ensure that the generator’s capacity will be utilized consistently.<sup>89</sup>

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<sup>89</sup> Pace Energy and Climate Center. 2013. “Community Microgrids: Smarter, Cleaner, Greener,” [//energy.pace.edu/publications/community-microgrids-smarter-cleaner-greener](http://energy.pace.edu/publications/community-microgrids-smarter-cleaner-greener).

### Figure 7-1. Complementary Load Profiles

Complementary users combine to form a single high and steadier demand profile, meaning microgrid generators are less likely to sit idle or run inefficiently.

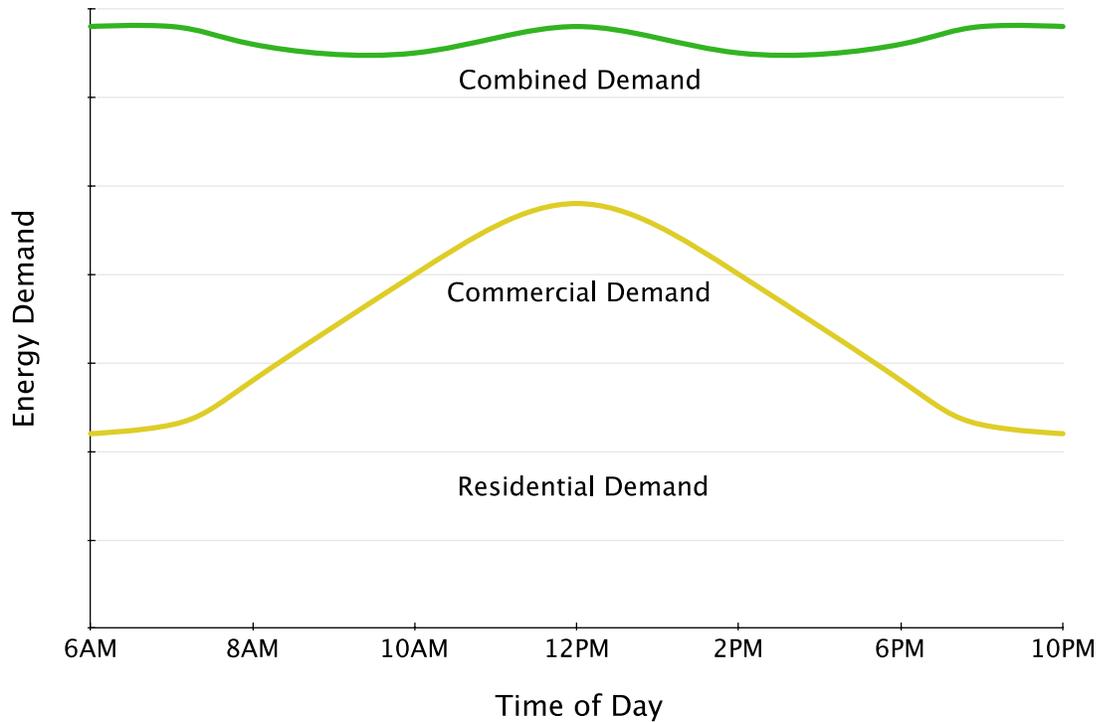


Table 7-3 lists several more examples of attributes favoring successful microgrid projects. The extent to which these attributes are sought, however, will depend on the microgrid owner’s ability to benefit from them. For example, a microgrid owner will prefer a microgrid site in an area of the grid experiencing capacity limits to another site (everything else being equal) if the owner can benefit from that attribute through some form of compensation. If the microgrid owner is unable to monetize the benefit resulting from this attribute, it will be less likely that the microgrid would be developed in that location. These benefits may be captured through a variety of mechanisms depending on the ownership model employed and the legal permissibility, economic viability, and/or implementation practicality of the mechanism. Enabling and employing microgrid ownership models that allow for the greatest degree of benefit monetization will incentivize the development of microgrids that create the most value for private entities, utility, and society.

**Table 7-3. Attributes Favoring a Successful Microgrid Project**

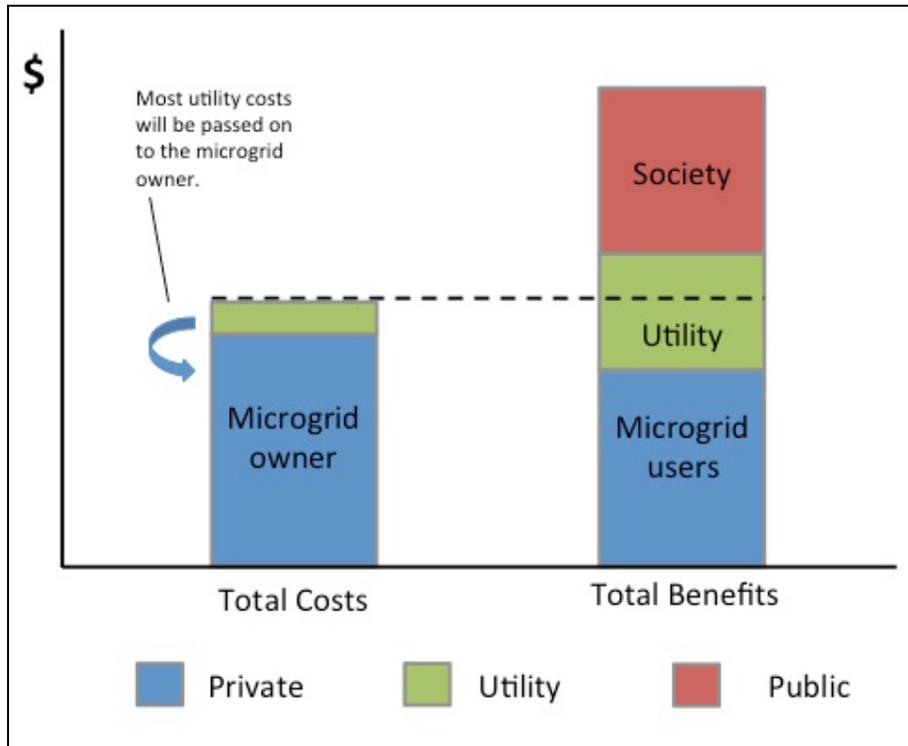
Attribute	Advantage
Clustering of CI sites in close proximity	Reduced infrastructure costs
Existing electric or thermal distribution infrastructure that can be re-utilized	Reduced infrastructure costs
A consistent and significant need for electrical energy	High degree of asset utilization improves economic return (e.g., generators never sit idle)
A significant demand for thermal energy (heat, hot water, cooling) that occurs when the power is being generated	Overall system efficiency improvements generating energy savings
Capacity limitations in the zone or network area of the microgrid	Demand (capacity) savings that benefits the macrogrid
Requirement for distribution capital expenditures that can be deferred or avoided by this microgrid	Distribution utility capital expenditure savings
The ability of the microgrid to provide ancillary services (NYISO market)	Lowering the capital and operating costs of the transmission system
The ability of the microgrid to provide distribution level services (voltage control, feeder loading relief)	Lowering the capital and operating costs of the distribution system

Figure 7-2 portrays the accrual of a hypothetical microgrid’s costs to the microgrid owner—including any costs passed on to the microgrid owner by the utility or environmental regulations—and the direct accrual of benefits to the microgrid users, the utility, and society.<sup>90</sup> In this example, the microgrid imparts significant benefits to the utility and society. The microgrid owner is only able to monetize the benefits that accrue to the microgrid users. In this example, the net benefits available to the microgrid owner to realize a return are negative. The level of owner costs exceeds the level of user benefits (blue boxes). Although the total benefits, including societal (red box) and utility (green box) are far greater than total costs, the private owners return will be negative, as they cannot charge for and collect the societal or the utility benefits. The dotted line indicates that this hypothetical project is not attractive for a private or nonprofit entity.

<sup>90</sup> Any costs accruing to the utility or society that are *not* passed on to the microgrid owner are assumed to be negligible.

**Figure 7-2. Distribution of Microgrid Costs and Benefits**

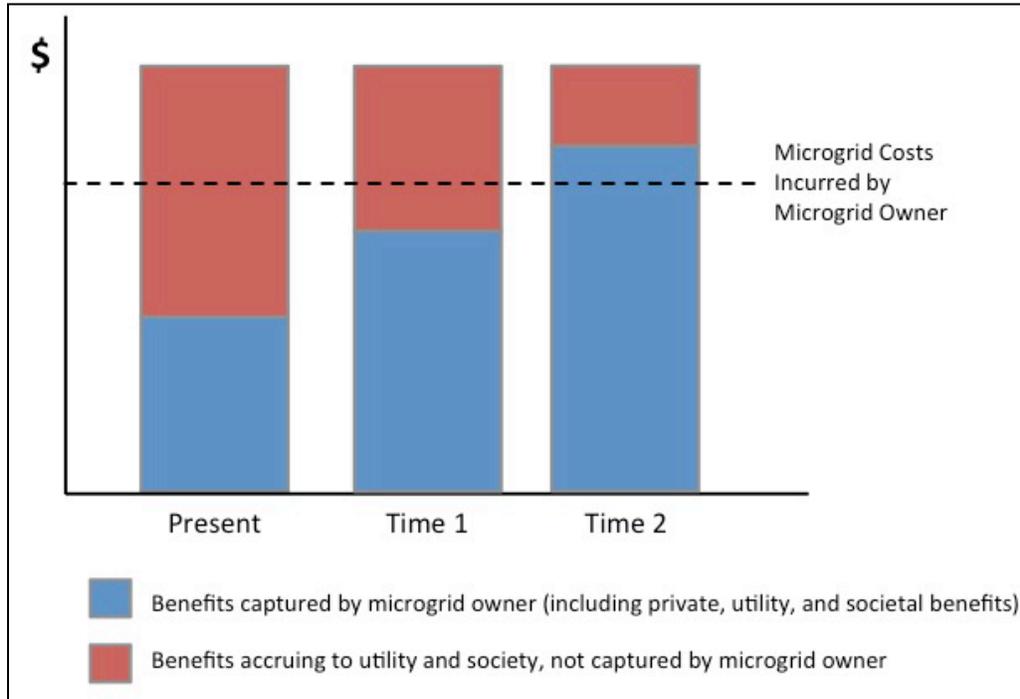
Well-designed and strategically sited microgrids may offer significant private, utility, and public benefits that far exceed costs. However, if the microgrid owner is not able to capture enough of these benefits to recover the private costs of the microgrid, then it is unlikely that the microgrid will be developed.



However, either by shifting some of the societal benefits to the owner (e.g. by incentives, grants, other public payments) or shifting some of the utility benefits (e.g. new or expanded markets for providing transmission and distribution level services) there is possible room to compensate the owner and encourage investment in microgrids that provide safety and security benefits. The ideal scenario is one where, over time, mechanisms are created that allow the benefits produced by microgrids to be captured by the microgrid owner to incentivize the development of microgrids that provide these and other benefits (see Figure 7-3). When the full range of benefits created by the microgrid can be largely monetized, the private or nonprofit sectors are far more likely to find the investment attractive. In this case, society may be able to reap the benefits of a high level of reliability of essential public services, without the need to make a large public investment with government resources.

**Figure 7-3. Shifting the Value of Microgrid Benefits to Microgrid Owners**

At present, many of the benefits produced by microgrids may not be easily monetized and captured by the microgrid owner. With the creation of new markets for these benefits (e.g. for utility benefits) or through government subsidy programs (e.g. for societal benefits), the value of these benefits may be transferred to the microgrid owner.



## 7.5 Microgrid Ownership Models

When delineating the various types of microgrid ownership models, a variety of relevant factors come into consideration. An important first-order consideration is ownership of the microgrid’s distribution facilities. Are the distribution assets used owned by the existing electric utility or are distribution assets going to be privately owned? Contingent on the resolution of this factor, other relevant parameters need to be considered. If the utility owns the distribution facilities, the next relevant consideration is ownership of the distributed energy resources (DERs) within the microgrid. If the utility both owns the distribution and the generation assets, it is referred to as a full utility microgrid, whereas if the utility owns the distribution assets but a nonutility owns the generation assets it is referred to as the “hybrid” utility ownership model.

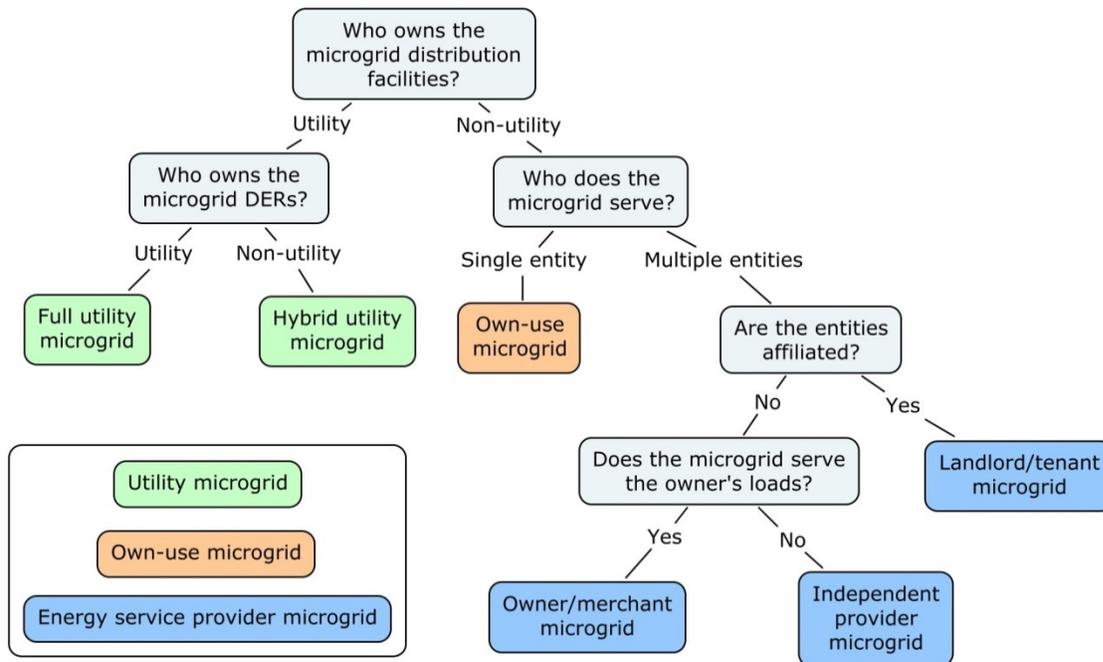
On the other hand, if a nonutility owns the distribution assets then the next set of relevant parameters consider whether one or many entities are served by the microgrid. For microgrids that serve multiple entities, the affiliation of these multiple entities is relevant. For example, microgrid users who have an existing landlord-tenant arrangement may find that some terms of a power purchase agreement are impacted by pre-existing contractual relationships between the parties, such as the kinds of financial assurance required, whereas parties without a pre-existing relationship may contract differently or require different or greater kinds of financial assurance. Finally, if the multiple entities are unaffiliated, the last relevant parameter is whether or not the microgrid serves the microgrid owner's loads in addition to the other unaffiliated entities.

Depending on these parameters, microgrid ownership models can be described as:

- Utility microgrids.
  - Full utility microgrid.
  - Hybrid utility microgrid.
- Own-use microgrid.
- Energy service provider microgrids.
  - Landlord/tenant microgrid.
  - Owner/merchant microgrid.
  - Independent provider microgrid.

Figure 7-4 maps the parameters that differentiate these different models.

**Figure 7-4. Ownership Model Typology**



## 7.5.1 Utility Microgrids

The utility ownership model describes a microgrid where the microgrid distribution facilities are owned by the service area's regulated electric distribution utility. Utility-owned microgrids may offer several advantages over nonutility owned microgrids. First, utility-owned microgrids would not need to contend with franchise issues. Nonutility owned microgrids that cross public rights-of-way will likely be confronted with a host of legal and regulatory hurdles, including the need to qualify its distribution infrastructure as "related facilities" within the meaning of the qualifying facility exemption, or the granting of a franchise or lesser consent from the presiding municipal authority.<sup>91</sup> These procedures are time-consuming, costly, and can be cumbersome if not successful. Second, utility-owned microgrids may be able to avoid significant capital investment costs by utilizing existing distribution facilities.

Additionally, because utilities have intimate knowledge of their distribution system, utility owned and operated microgrids may be better situated to maximize benefits that directly accrue to the utility. Utility operation of the microgrid will permit that utility to fully control it and thereby maximize its performance as a component of its overall system. If the microgrid provides services to the utility but is not under full ownership and control of the utility, there is some level of performance risk for the utility's operation of the macrogrid. There is a risk premium in a service obtained from a contractual agreement with an outside party that does not exist when the services are provided by assets under the full ownership and control of the entity receiving the service. Finally, utility-owned microgrids may benefit from the existing institutional capacity within distribution utilities to construct, operate, and maintain electrical systems like microgrids.

The ownership of the DERs within utility- owned microgrids may influence how the microgrid is impacted by current regulations. For this reason, utility-owned microgrids can be categorized into two distinct models: full utility model and the hybrid utility model.

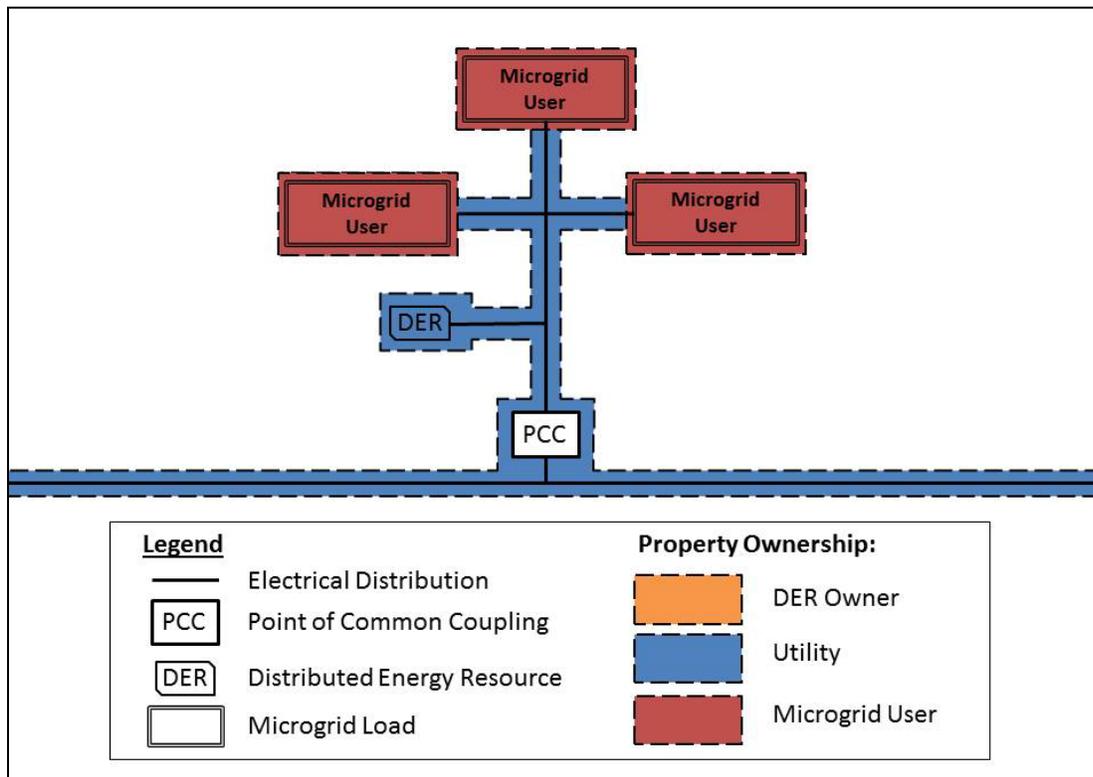
### 7.5.1.1 Full Utility Model

The full utility model describes a microgrid where the distribution facilities and internal DERs are owned by the utility (see Figure 7-5). Under this model, the utility would fully bear all costs related to the microgrid development including any costs incurred by the macrogrid because the microgrid owner and utility are the same entity.

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<sup>91</sup> See Section 4 of this Report for more detail on microgrid regulatory models.

**Figure 7-5. Full Utility Microgrid Ownership Model Example Diagram**



Full utility microgrids offer certain distinct advantages. Under this model, microgrid operation and control would be less complex than the hybrid utility model because the utility will own and control the individual components that influence the internal and external dynamics of the microgrid. From the utility perspective, possessing operational control over the assets comprising the microgrid assures the utility that the microgrid will not negatively impact the macrogrid. Additionally, the full utility model may be particularly suited to maximize benefits that accrue to the macrogrid because of the longer potential timescale of hybrid microgrid development. For example, if a utility desires to develop a microgrid that provides, among other things, the deferral of otherwise necessary distribution system upgrades, the time needed to prompt the development of customer-owned DERs (e.g., capacity bidding processes) may be too long to address the distribution system’s deficiencies. Full utility microgrids may be able to be deployed faster to address capacity constraint concerns while providing other benefits than the hybrid utility model. Please see the Denning microgrid example (in box) for more information on Central Hudson Gas & Electric’s ownership of DERs in order to improve reliability in the Catskills region. In Michigan, Detroit Edison has dispatched mobile DG units to congested distribution networks to defer costly distribution upgrades, and in Massachusetts, National Grid has installed solar electric arrays as part of their Congestion Relief Pilot.

### **Full Utility Microgrid Example**

**Denning Microgrid.** The Town of Denning, NY, is in the middle of Catskill Park. Central Hudson Gas & Electric (Central Hudson) developed a microgrid system in Denning to serve an electric load center located more than 14 miles from the distribution substation after an evaluation of the electric service reliability of the area found service to be unacceptable.<sup>92</sup> Due to its rugged and remote terrain, additional transmission and distribution investments were not comparably cost effective, as well as being an environmentally inferior option (running new transmission 10-15 miles through the park would require cutting down large swaths of trees). The microgrid's internal DER consists of a 1,000-kVA diesel engine—owned and operated by Central Hudson—which is capable of serving the total peak load of the feeder. The microgrid is able to island from the macrogrid at an automated point of isolation established through a series of automatic transfer switches within switchgear compartments, which allows Central Hudson to continue to serve the community when the feeder line to the distribution substation is down due to weather or servicing.

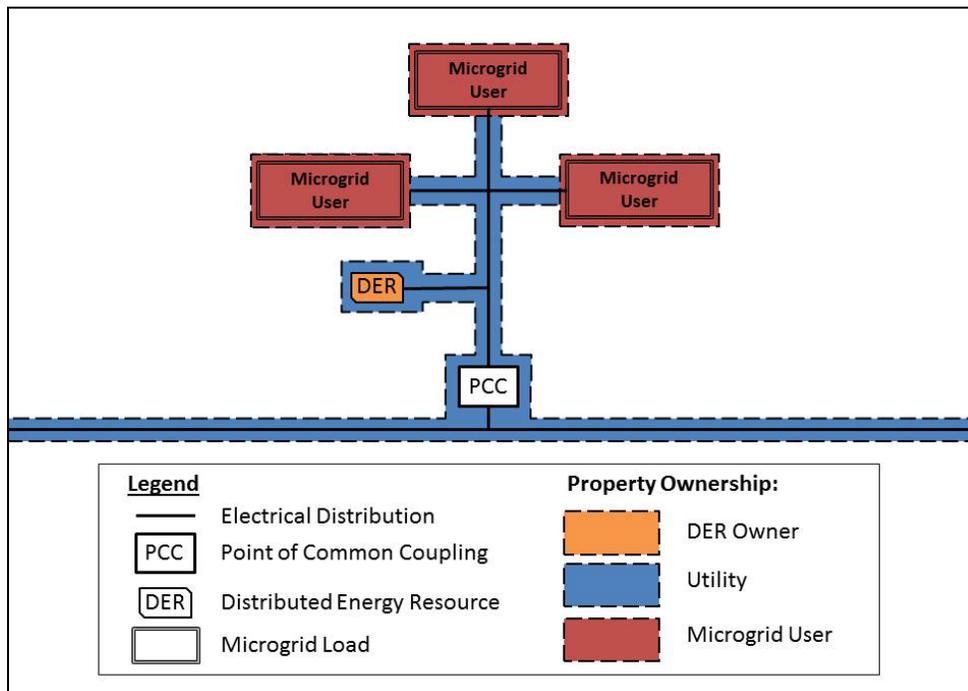
#### **7.5.1.2 Hybrid Utility Model**

The hybrid utility model describes a microgrid where the distribution facilities are owned by the utility but at least some of the microgrid's internal DERs are owned by a nonutility entity (see Figure 7-6). This nonutility entity could be a participating customer or a third-party energy service provider. Likewise, participating customers or third parties will also incur the associated costs resulting from ownership of DERs within the microgrid.

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<sup>92</sup> Central Hudson Gas & Electric EPTD 1208 Program Proposal

**Figure 7-6. Hybrid Utility Microgrid Ownership Model Example Diagram**



The hybrid utility model can avoid any potential hurdles resulting from utility ownership of DG if nonutility DERs within the microgrid are sufficient. In scenarios where the utility is not able to show substantial ratepayer benefits with market power mitigation measures for DG ownership, the hybrid utility model would be the only viable option that incorporates the utility. This model may also be a method of encouraging customer-owned, clean distributed generation by providing additional benefits to the DG owner (i.e., increased reliability). With states including New York encouraging customer investment in solar electric, fuel cells, and other forms of advanced clean distributed generation, hybrid utility microgrids may help advance this goal.

The primary challenge of the hybrid utility model is the likely higher degree of coordination and interaction that will be needed between the utility and DER owners within the microgrid as opposed to a single DG customer interconnecting with the utility. The utility will likely operate or direct the microgrid control system, and possibly use a control scheme that can accommodate the interests of multiple DER asset owners (i.e., one that enables and can integrate multiple agents, or customers, acting on their own behalf). In this model, the utility would be an active partner with customers and generators to facilitate and manage the aggregation of loads and the deployment of generation on the microgrid.

### Hybrid Utility Microgrid Examples

**Parkville Microgrid.** As part of Connecticut’s Microgrid Pilot Program, the City of Hartford has proposed a microgrid development in Hartford’s Parkville neighborhood. The proposed microgrid will incorporate a school with an attached senior center and library and an adjacent supermarket and gas station. The school will serve as a “center of refuge” for up to 500 people during emergency events and power outages. A 600kW natural gas reciprocating engine will be sited at the school to provide electricity to the microgrid users as well as thermal energy to the school. New distribution facilities including underground wiring will be constructed, owned, and maintained by the local distribution utility—Connecticut Light & Power (CL&P)—while the microgrid’s internal generation will be owned and maintained by a third-party energy provider.

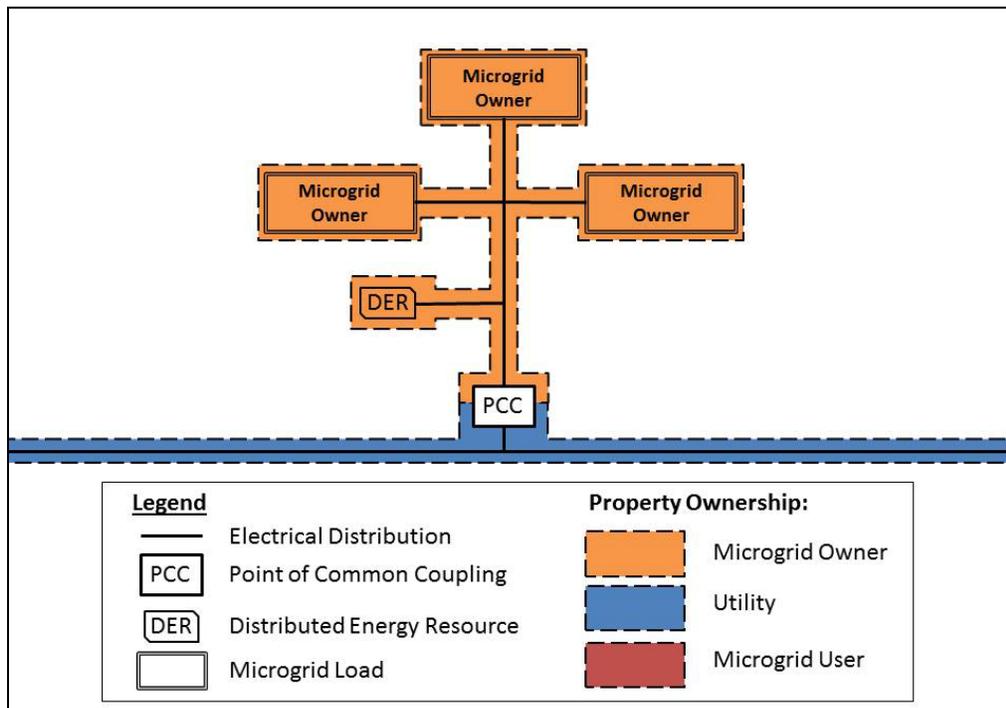
Both full and hybrid utility models can be employed to provide safety and security benefits through the provision of more resilient power to critical services, as evidenced by the Parkville Microgrid. However, this microgrid benefits from substantial government funding.

The majority of the project planning and capital costs of the distribution facilities owned by CL&P were covered by funds from the Connecticut Microgrid Pilot Program. Nevertheless, the generation assets will be financed by a third-party because it believes it will be able to recoup its costs through selling energy to the City of Hartford. The relatively small generation capacity of the microgrid (600 kW) precludes it from producing other significant benefits for which it could be compensated. However, as part of a hybrid microgrid model, the Parkville Microgrid plans to leverage energy benefits resulting from the microgrid to help partially recover the costs of the development instead of full reliance on external funding sources.

### 7.5.2 Own-Use Microgrids

Own-use microgrids describe microgrids that are fully owned by (both distribution infrastructure and DERs) and serve the same single entity (see Figure 7-7). This model is typically employed in the MUSH (military, universities, schools, and hospitals) sector because these organizations are more likely to own clusters of buildings with favorable load profiles and have the institutional capacity to own and operate a system like a microgrid. For example, universities that maintain large campuses will often have their own staff and equipment to maintain the campus infrastructure including electrical and thermal generation and distribution facilities. Additionally, because large campuses will often feature building loads that serve a diverse set of uses including residential, retail, and energy intensive research purposes, DERs can often be sized and operated in configurations that maximize efficiency.

**Figure 7-7. Own-Use Microgrid Ownership Model Example Diagram**



Own-use microgrids can offer several distinct advantages over utility-owned microgrids and energy service provider microgrids:

- Ability to tailor technology solutions to specific campus requirements, growth, e.g., enhanced reliability/power quality.
- Costs associated with using local utility distribution facilities are not an issue.
- Potentially capture a larger share of the economic benefits of the microgrid as compared to a model where a third party owns and operates the microgrid.

Because the distribution facilities within own-use microgrids are owned by private entities, any own-use microgrid that intends to cross a public right-of-way may encounter utility franchise issues. For example, during an expansion project, Cornell University considered expanding their microgrid to include a shopping plaza that it owns. However, to reach the shopping plaza, the university would have had to construct distribution facilities that crossed a public road. Ultimately, Cornell opted against incorporating the shopping plaza in order to avoid utility franchise issues.<sup>93</sup> However, at their Washington Square Campus, New York University (NYU) has developed a microgrid that serves multiple university-owned buildings across several public rights-of-way.

<sup>93</sup> See NYSERDA. 2010. “Microgrids: An Assessment of the Value, Opportunities and Barriers to Deployment in New York State.” Appendix A..

## Example of Microgrids That Serve Single Entities

**Cornell Microgrid.** Cornell University owns, operates, and maintains an extensive microgrid that serves the school's various buildings located on its Ithaca, NY, campus. Cornell does not provide service to unaffiliated customers and the microgrid does not cross a public right of way to deliver energy to any of the campus buildings. Many of the campus buildings house advanced research facilities with a need for highly reliable electricity services. Loss of energy to labs for even relatively short periods could result in loss of research with significant financial consequences. The microgrid contains a diverse array of DERs, but the main generation assets are two 14.7 MW dual-fuel combustion engines with heat recovery for combined heat and power.

**NYU-Washington Square Microgrid.** New York University owns and operates a microgrid at its Washington Square campus in New York City. The microgrid provides electricity to 22 buildings and thermal energy to 37 buildings. The microgrid is powered by a 13.4 MW natural-gas fired cogeneration plant. The microgrid's distribution facilities cross public streets to deliver both electric and thermal energy to interconnected buildings, but it does not provide service to any unaffiliated customers. NYU owns all of the property, on both sides of the street, to which energy from the microgrid is delivered. The only exception is the underground vault where the cogeneration plant is located, which the University leases from the New York City Department of Transportation.

The own-use microgrid model can provide safety and security benefits to the extent that the microgrid owner also owns critical infrastructure within the confines of the microgrid. For many large institutions, this may be true. For example, an own-use microgrid serving a hospital complex would provide valuable safety and security benefits through the provision of resilient energy for the critical services offered by the hospital. Other large institutions such as universities may have many critical services that can serve the wider community during emergency events including medical clinics, police, and other buildings that can serve as centers of refuge. However, as the model is defined, any critical services not owned by the microgrid owner would be excluded from receiving service from the microgrid.

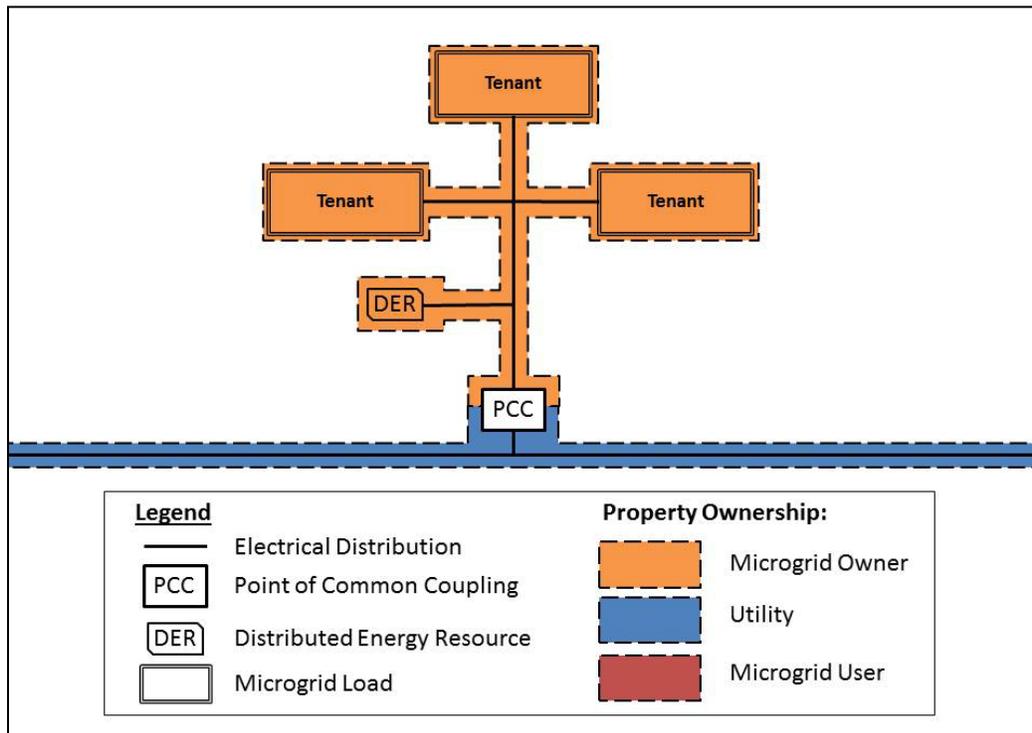
## 7.6 Energy Service Provider Microgrids

The energy service provider model describes microgrids that are owned by a nonutility entity and that provide energy services to multiple entities. These microgrid users may include the microgrid owner, previously affiliated entities of the microgrid owner (e.g. tenants of the microgrid owner), and/or previously unaffiliated entities of the microgrid owner (e.g. neighboring but not contractually linked entities). The fundamental difference between energy service provider microgrids and the own-use microgrid is that the former engages in the sale of energy services to nonutility entities, while the latter primarily produces energy for their own consumption with any excess sold back to the grid—not another energy consumer directly.

### 7.6.1 Landlord/Tenant Microgrid

The landlord/tenant microgrid model describes a microgrid where the microgrid owner and the microgrid users (that are not the owner) are affiliated with the owner through leases or other tenancy arrangements (see Figure 7-8). The microgrid may or may not serve the microgrid owner. A conceptual example of this model could be an industrial or commercial park where a sole entity (the landlord) owns the property and leases building space to other entities. As part of the lease agreement, the landlord would provide energy services—in this case energy via a microgrid—to their lessees.

**Figure 7-8. Landlord/Tenant Microgrid Model Example Diagram**



A key advantage of this model is the exemption provided by the PSL for landlord/tenant energy service arrangements. The PSL sets out a specific exemption for microgrids that provide service only for their own use or the use of their tenants. That is, in addition to the exemption provided for renewables and cogeneration distributed at or near a project site, the definitions of “gas corporation,” “electric corporation,” and “steam corporation” each exclude energy distributed by the maker on or through private property solely for its own use or the use of its tenants and not for sale to others.

## 7.6.2 Owner-Merchant Microgrid

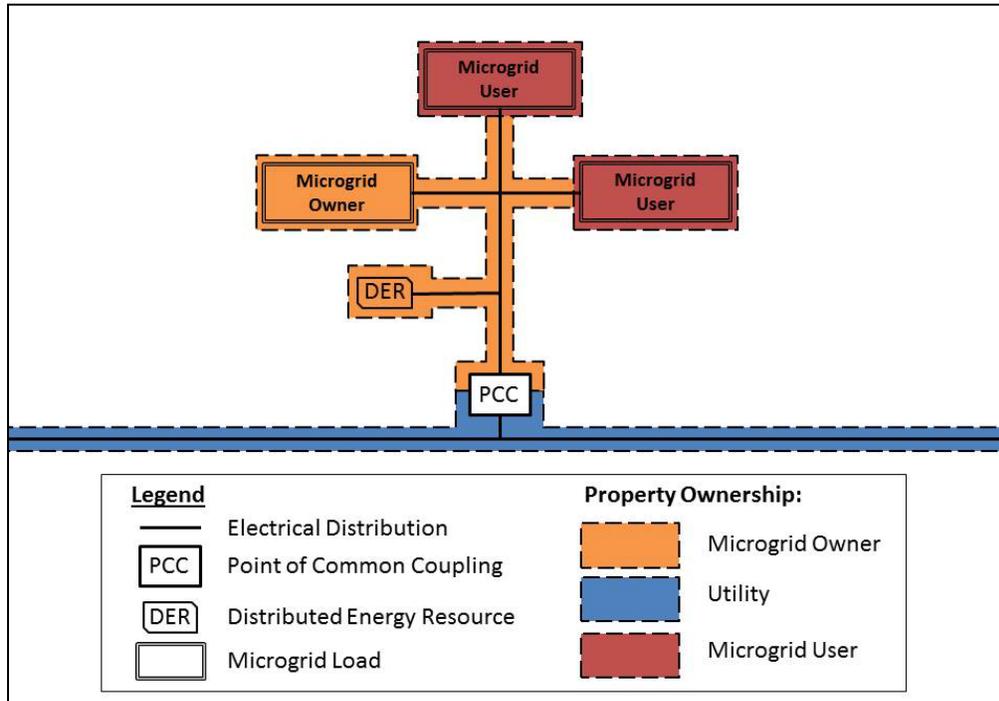
The owner-merchant microgrid model describes a microgrid that serves the owner and other microgrid users who do not have an affiliation other than via the microgrid (see Figure 7-9).

The owner-merchant microgrid model may result from a project champion interested in the benefits provided by a microgrid who then seeks out neighboring energy users to be incorporated into the microgrid. For the project champion, incorporating additional energy users into the microgrid can significantly improve the economics of the project by producing a combined energy load profile that better matches thermal and electrical demand and/or allows for a higher utilization rate of generation assets throughout the day and year.

### Landlord/Tenant Microgrid Example

**Eastman Business Park Microgrid.** Located in Rochester, NY, the Eastman Business Park Microgrid serves the Eastman Business Park (formerly known as Kodak Park), which is a large manufacturing and industrial complex. Originally constructed by the Kodak Corporation to serve its own business needs, the complex includes a network of utility facilities to provide gas, electric, steam, and water distribution services to support the high-quality utility service needs of its complex industrial and manufacturing activities. As part of Kodak's 2012 bankruptcy proceedings, Kodak's business unit that provides utility services within the park was sold to Recycled Energy Development (RED). RED will continue to supply energy and other utility services to the park. As part of the process of transferring ownership of the utility system to RED, Kodak and RED have petitioned the PSC to transfer the previously granted Certificates of Public Necessity to RED. At the time of the petition, Kodak reported that it was providing utility services including electricity and steam to 35 independent businesses within the park. The utility facilities include a tri-generation system that produces electricity, heat, and cooling and is currently powered by coal, although RED plans to convert it to natural gas. The system has approximately 125 MW of electricity generation capacity, 940 tons/hr steam generation capacity, and 64,000 tons of chilling capacity, as well as a 41 MW bi-directional interconnection to the macrogrid. In previous proceedings, Kodak has reported that it has traded electric energy and capacity it produces with Rochester Gas and Electric (RG&E), obtaining about 20% of the Park's electrical requirements from RG&E. Electric and natural gas service is taken from RG&E through discrete interconnection points, from which Kodak then distributed electricity and gas throughout Kodak Park.

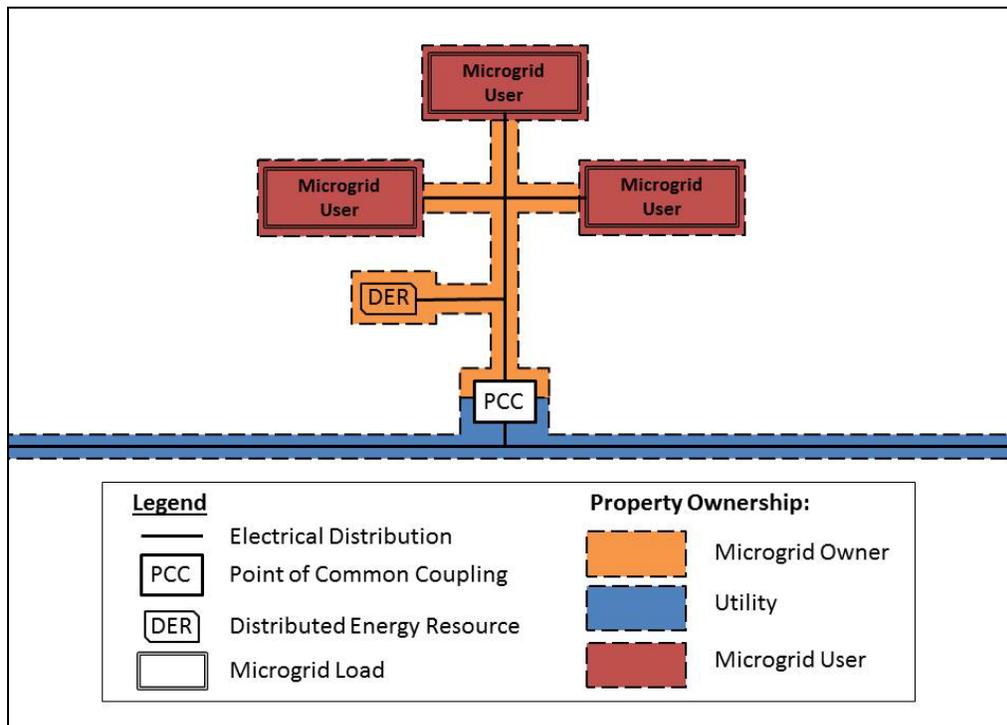
**Figure 7-9. Owner-Merchant Microgrid Model Example Diagram**



### 7.6.3 Independent Provider Microgrid

The independent provider microgrid model describes a microgrid where the microgrid owner and the microgrid users are previously unaffiliated entities (see Figure 7-10).

**Figure 7-10. Independent Provider Microgrid Model Example Diagram**



Independent service provider microgrids can allow an organization with the expertise and resources to safely and reliably build and operate the microgrid without requiring one of the microgrid users (whose principal line of business may not be energy related) to acquire the expertise internally. Additionally, this ownership model can allow the microgrid project to benefit from government incentives that might otherwise be unavailable if one of the microgrid users served as the microgrid owner. For example, a municipality seeking to develop a microgrid may use a third party to own and operate the microgrid infrastructure allowing for the utilization of federal tax credits and other incentives that are available to private entities but not available to the municipality.

### Example of Independent Provider Microgrid

**Burrstone Microgrid.** The Burrstone Energy Project is a microgrid in Utica, NY, that serves three distinct entities—Utica College, Faxton-St. Luke’s Hospital, and St. Luke’s’ Nursing Home. The distribution and generation facilities are independently owned by Burrstone LLC, which is a special purpose entity incorporated for the purpose of financing the microgrid infrastructure. The microgrid utilizes private underground distribution facilities and four natural gas fired reciprocating engines (total of approximately 3.6 MW) configured to cogenerate electric and thermal energy and designed to operate as baseload. Two of the engines provide electricity to the hospital, another one to the nursing home, and a final one to the college campus. The thermal energy from all four engines serves the hospital only.

Energy service provider microgrids are particularly well suited for providing safety and security benefits because they can combine various microgrid users including critical infrastructure facilities regardless of who owns and operates the microgrid. This characteristic can, for example, allow critical infrastructure facilities to be paired with other facilities that can make the overall load profile more advantageous for DER applications as well as distribute the costs of the system over multiple entities instead of just one entity in the case of a standalone DER.

## **7.7 Cost Recovery Issues Affecting Ownership**

Microgrid development is unlikely to occur if the microgrid owner is unable to capture enough of the benefits resulting from the microgrid to justify the costs incurred to build and maintain it. There are a variety of cost recovery mechanisms that microgrid owners can employ to capture and monetize many of the microgrid benefits accruing to the microgrid users, the utility, and society. The mechanisms that are used will differ based on the ownership model employed. In some ownership models, some microgrid benefits may not be easily monetized by the microgrid owner under current regulations and practices. The remainder of this section details the different cost recovery mechanisms that may be employed within the various microgrid ownership models and notes the challenges to capturing certain benefits through different ownership models under current regulations and practices.

### **7.7.1 Utility Cost Recovery**

As government-granted monopolies, distribution utilities are subject to regulation through PSL and the PSC regarding the amount of money they are allowed to earn. The PSC makes the final determination on the rates utilities are allowed to charge their customers and is tasked with ensuring these rates are just and reasonable for the customers (i.e. non-monopolistic/competitive prices). These determinations are made through regular rate cases where the utility must present their total revenue requirement including prudent operating expenses and capital investments, as well as a reasonable rate of return on their capital investments. Rates are then set by the PSC to allow the utility to collect their total revenue requirement. To recover the costs associated with development of either a full or hybrid utility microgrid, the utility will need to seek cost recovery approval from the PSC through a rate case. If approved, cost recovery may be realized by one of several methods, i.e., inclusion in the general rate base, through an alternative tariff, or through a supplemental delivery charge. The method by which cost recovery is realized by the utility is likely to depend on the services provided by the microgrid.

#### **7.7.1.1 General Rate Base**

Cost recovery for a microgrid through the general rate base would entail adding the costs incurred from microgrid development to the utility's total revenue requirement thereby allowing the utility to recover the costs through the collection of their standard tariffs and effectively distributing the cost of the microgrid across all ratepayers. The utility would likely seek approval for cost recovery via the general rate base if the microgrid assists the utility in

fulfilling their mandate to provide safe and reliable service to their customers at just and reasonable rates. In other words, the utility may seek to distribute microgrid costs across all ratepayers if the microgrid is deployed as an “alternative service delivery model” that is more cost effective than traditional solutions, because all ratepayers would presumably benefit from the overall reduction in capital infrastructure costs.

Microgrids can provide several different benefits that may be considered as an alternative service delivery model including enhanced reliability, ancillary services, and T&D deferral. For example, a utility may pursue a microgrid to provide more reliable service to an area receiving relatively unreliable service. This same microgrid may also defer distribution system upgrades upstream from the microgrid through the reduction of the localized peak demand resulting from the microgrid’s internal generation capacity. Without the microgrid, the utility would have to invest in the system upgrades and the cost of these upgrades would be distributed among the utility’s ratepayers. Additionally, if the utility’s assets within the microgrid are able to provide ancillary services for the utility’s wider grid, the resulting reduction in the amount of ancillary services the utility would otherwise need to purchase from the open market would reduce the overall burden on all ratepayers as well. To the extent that the microgrid provides any of these services, the utility may find it more appropriate to seek recovery from all ratepayers.

Approximately half of the costs associated with the development of the Denning Microgrid were included in the general rate base, while the other half was covered by research grant funds from NYSERDA.<sup>94</sup> Central Hudson proposed and developed the microgrid on the argument that it would increase service reliability to acceptable levels at least cost for its customers served by the microgrid. After the utility evaluated electric service reliability in the area of concern and determined it was below acceptable standards, Central Hudson developed a comprehensive corrective action plan to improve reliability that evaluated four different options with their respective costs.<sup>95</sup> One option evaluated was the microgrid proposal and the other three options involved more traditional measures that included rebuilding miles of electric distribution lines. Due to the rugged and remote terrain of the area in the Catskills park, these options were both more costly than the microgrid solution, as well as environmentally inferior (building 10-15 miles of new transmission wires through the park would have required cutting down large swaths of trees). From their analysis, Central Hudson concluded that developing the microgrid would be the most cost effective solution due to the high costs of new distribution line construction and maintenance. In addition to being the lowest cost, Central Hudson also argued that the microgrid would provide more reliable service than the other three options given the topography of the area’s electric system, which made any options that relied on additional distribution circuits still prone to outages. See Table 7-4.

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<sup>94</sup> Central Hudson Gas & Electric EPTD 1208 Program Proposal at 1.

<sup>95</sup> Central Hudson Gas & Electric EPTD 1208 Program Proposal at 7.

**Table 7-4. Central Hudson’s Proposed Options to Improve Reliability to Denning, NY Load Pocket**

Source: Central Hudson Gas & Electric EPTD 1208 Program Proposal

Option	Description	Cost
1	Create a distribution microgrid in the Town of Denning, utilizing a diesel engine powered generator as an alternate energy supply.	\$800,000.
2	Relocate the off-road portion of the circuit 3091 onto the road; 5 miles.	\$900,000; utilizing \$150,000 per mile for new distribution line construction, \$15,000 per mile for extensive tree removal and tree trimming.
3	Create an alternative circuit path (approximately 5.4 miles) that would be used as an alternate feed in a conventional Automatic Load Transfer (ALT) scheme.	\$940,000; utilizing \$80,000 for an ALT, \$150,000 per mile for new distribution line construction; \$10,000 per mile for tree trimming.
4	Create a three-phase distribution-circuit tie between the 3091 and the NYSEG circuit along County Route 47 in the Town of Denning, 10 miles.	\$1,650,000; utilizing \$150,000 per mile for new distribution line construction, \$15,000 per mile for extensive tree removal and tree trimming.

For the Borrego Springs Microgrid, the costs incurred by the utility that were not covered by funds provided by the Department of Energy (DOE) or California Energy Commission (CEC) were included within San Diego Gas and Electric (SDG&E) general rate base. The microgrid was primarily developed as a “proof-of-concept” demonstration project for the deployment of technologies to make the grid more efficient and amenable to intermittent renewables. The investments required for these technologies were approved by the California Public Utility Commission (CPUC) for addition to the general rate base under the argument that they help contribute to the achievement of California’s energy policy goals.

#### **7.7.1.2 Alternative Tariff**

A more appropriate cost recovery mechanism for utility microgrids that provide energy services above and beyond normal standards may be an alternative tariff assessed to those that directly receive the benefits resulting from the microgrid. In this scenario, the microgrid users would be the beneficiaries of a premium energy service that other utility customers do not necessarily receive. The utility would effectively monetize and capture this reliability benefit accruing to the microgrid users through the alternative tariff, which could then be used to offset the additional costs of providing the premium service. While the project team did not identify any utility microgrids that provide this premium service and utilize an alternative tariff structure for participating customers, Detroit Edison has employed an analogous model for DG. Through their Premium Power Service program, Detroit Edison offers customers the option to host utility-owned standby DG on the customer’s property for a monthly per kilowatt-hour service charge in exchange for the more reliable electric service provided by the DG.

An alternative tariff would likely be more applicable to a full utility microgrid model since the reliability benefit results from the coupling of DERs with island-able distribution facilities. However, for any full utility microgrid where an alternative tariff would be appropriate, the utility is more likely to encounter obstacles in obtaining permission to own generation assets because the provision of premium services would likely be viewed negatively under the market power mitigation measures test.<sup>96</sup>

### **7.7.1.3 Supplemental Delivery Charges**

Supplemental delivery charges may be appropriate for utility cost recovery in some hybrid utility microgrids. The underlying idea behind these charges would be to obtain payment for distribution services to offset the revenue requirements to provide that service. The charge could be assessed in through different arrangements including through a “microgrid wheeling charge” or through a “buy/sell” arrangement.

A microgrid wheeling charge would be some combination of charges assessed to the nonutility energy seller, buyer, or both. Wheeling charges are generally assessed by multiplying the quantity of energy transported over distribution lines in megawatts (“wheeled”) by some price. In theory, these charges would be structured to cover the revenue requirement of providing distribution services within the microgrid including the cost of developing and maintaining the necessary distribution facilities to provide microgrid capabilities. In a buy/sell arrangement, the nonutility DER owner would sell power directly to the utility’s grid at a specified rate (e.g., a “buy back” tariff). The utility would then separately provide energy services to the other microgrid users at another specified rate. If appropriately set, the difference between these two rates would accrue to the utility and act very similar to a microgrid wheeling charge—allowing the utility to recoup their costs associated with the microgrid.

The key difference between a buy/sell arrangement and a microgrid wheeling charge is that under a buy/sell arrangement, the energy seller would only enter into an agreement with the utility, while a wheeling charge would allow the energy seller to develop a separate and independent agreement with the other microgrid users. For the seller, a microgrid wheeling charge may be preferable to the buy/sell arrangement because it allows more flexibility in negotiating favorable terms for both the energy producer and consumer. However, while utilities must provide open access to wheeling services over their transmission facilities for qualifying facilities under FERC requirements, there is no such requirement for distribution level facilities. In this case, entering into such an agreement with an energy seller within the microgrid would be at the utility’s prerogative.

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<sup>96</sup> See Section 4.1.1 for more information on the Vertical Market Power Policy, which contains a test on mitigating market power for utilities that own DERs.

## **7.7.2 Nonutility Cost Recovery**

Cost recovery by nonutility microgrid owners may take a variety of forms including the net present value (NPV) of self-provided energy services, selling energy services, and compensation for benefits provided to the macrogrid.

### **7.7.2.1 Net Present Value of Self-Provided Energy Services**

For microgrids that provide service to the microgrid owner themselves, some or all of the cost of the microgrid may be recovered through any energy cost savings associated with the self-generation of electrical and/or thermal energy and the additional reliability provided by the microgrid's islanding capabilities. This may include the hybrid utility microgrid model where the nonutility DER owners within the microgrid supply themselves energy or the own-use, landlord/tenant, or owner-merchant microgrid models.

Energy cost savings may be realized if the levelized cost of the self-generated energy (both electric and thermal) is less than the price that would otherwise be paid for energy from the grid to provide the same services. For qualifying facilities, net metering arrangements could help maximize a DER owner's energy cost savings for systems that import and export energy from the grid when DER energy supply is less or more than energy demand by crediting net excess energy generation to the DER owner's next energy bill. This procedure can be further extended to multiple facilities under virtual net metering (VNM) arrangements where net excess energy generation can be credited to the energy consumed by loads separate from where the generation is sited. The amount of time required for these savings to recover the costs associated with the DER is referred to as the payback period assuming no other value streams are recovered from the DER.

In addition to energy cost savings, microgrid owners may also realize some cost recovery via the increased energy reliability provided by the DER. For the microgrid owner, the provision of highly reliable energy can be ascribed some value. For some entities (e.g. data centers, high-tech industrial processes), the value of highly reliable energy may be greater than other entities. Regardless, the additional value of reliable energy would likely be considered by a potential microgrid owner as contributing to the recouping of their costs.

### **7.7.2.2 Selling Energy Services**

For any energy services that are not self-consumed, the microgrid owner will likely seek to sell these energy services to other entities either within the microgrid or outside it. There are three main ways a nonutility microgrid owner (including a nonutility DER owner within a hybrid utility microgrid) may sell energy services that are not self-consumed. The microgrid owner could sell energy back to the grid either to the utility or the wholesale commodity market at the applicable Buy Back Service Tariff or market price. Or alternatively, the microgrid owner could contract energy services directly to another entity through a power purchase agreement (PPA).

The arrangement by which energy services are sold will be influenced by the relevant regulations and utility procedures controlling the sale of energy and could have a significant impact on the overall economics of microgrid (or DER) ownership for a nonutility entity. For many microgrids, the sale of energy services will be the primary revenue stream. For this reason, the ability to sell energy services at rates that produce returns required by the microgrid owner at an acceptable level of risk is vital for the overall economic viability of the microgrid project.

### **Power Purchase Agreement**

A PPA is a contractual agreement between two parties: an energy producer and an energy purchaser. Typically, the PPA will define all terms for the sale of electricity between the two parties including payment rates, when the commercial operation will begin and terminate, and duration. The contractual term will typically last anywhere between five and 20 years. For the microgrid owner, a PPA may be a central component for securing external financing for the generation assets because the PPA defines and secures the asset's revenue terms over a fixed period of time that allows for the microgrid owner's cost recovery. In the context of a microgrid, a PPA will likely be between the microgrid owner and either the other microgrid users or with the utility depending on the microgrid ownership model. Each option has advantages and disadvantages.

A nonutility microgrid owner would likely have to seek PPAs with the individual microgrid users in microgrid ownership models that utilize private wires and serve other entities besides the owner (i.e., landlord/tenant, owner/merchant, and independent service provider microgrids). For these microgrids, the PPA will ideally be structured to allow the microgrid owner to recoup their costs within an acceptable time frame with an acceptable amount of risk. Because these costs include the cost of providing islanding capabilities, the value of the more reliable energy services would be built into the PPA.

In a landlord/tenant microgrid model, the microgrid owner (i.e., the landlord) will likely include the PPA as part of the lease agreement.<sup>97</sup> The landlord would install submeters for each tenant to measure the amount of energy consumed. In New York, if a single property owner wishes to provide utility power to his tenants through a submetering arrangement, the owner may need to seek PSC approval. Submetering requirements vary depending on whether the tenants are residential or nonresidential, and if residential, what type of property is being submetered. In a 2013 Order, the PSC deregulated commercial submetering. New commercial property submetering arrangements,

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<sup>97</sup> The provision of energy services in a landlord/tenant model could be incorporated into the lease agreement as part of the rental price. This method would make payment for energy services a fixed price for the tenants regardless of the amount of energy consumed in a given billing period. This method may not be preferable to a PPA that charges (at least partially) based on energy consumption as the former method does not incentivize the tenants to conserve energy.

therefore, do not need to receive PSC approval. In the residential context, 16 NYCRR §96, recently revised under a 2012 PSC Order, provides regulations on what an applicant must show to be approved for residential submetering. Common requirements include notice to residents, consumer protection measures, and a PSC determination and order approving such submetering as in the public interest and consistent with the provision of safe and adequate electric service to residents.

In the owner/merchant and independent service provider models, the microgrid owner will need to negotiate individual PPAs or a collective PPA with the other microgrid users for the provision of energy services. In the Burrstone Microgrid, for example, Burrstone LLC entered into PPAs with Utica College, Faxton-St. Luke's Hospital, and St. Luke's' Nursing Home for the provision of electricity and with the hospital for the provision of thermal energy. The cost of the new electric generation and distribution facilities financed and installed by Burrstone LLC are included in the PPA over its 15-year contract horizon.

In a hybrid utility model, two potential PPA arrangements could be utilized by the nonutility DER owners within the microgrid. First, the DER owner could seek to enter into a PPA directly with the other microgrid users hereafter referred to as the "individual PPA contracting model." As previously mentioned, distribution utilities are not required to allow the direct sale of energy services across their distribution facilities and may only do so at their own prerogative under current regulations. Second, the DER owner could enter into a PPA directly with the utility hereafter referred to as the "central procurement contracting model."

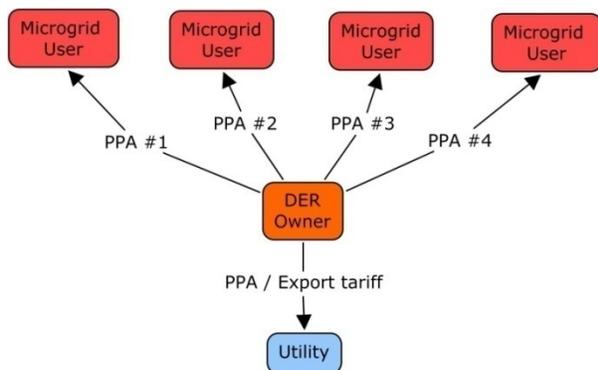
Under an individual PPA contracting model, the DER owner would negotiate PPAs with the individual microgrid users. For any surplus power produced, the microgrid owner would need a separate arrangement with the utility for energy export. The utility would likely levy some form of microgrid wheel charge to recoup their costs for microgrid distribution services. For the DER owner, the ability to enter directly into a PPA with other microgrid users may be a preferable arrangement than selling excess energy to the utility because of the additional flexibility a PPA can afford the DER owner and the energy purchaser in negotiating mutually beneficial terms.

Under a central procurement contracting model, the DER owner would only need to negotiate a single PPA with the utility for provision of energy services to the microgrid. The utility would then interface with the individual microgrid users who would be charged for energy services under their applicable tariff. The tariff charged by the utility could be the normal tariff assessed to the customers in a nonmicrogrid setting or an alternative tariff that incorporates the utility's incremental costs for the provision of more reliable power.

The preference of nonutility DER owners will likely depend on a variety of factors including the number of other users participating in the microgrid and the energy service terms that could be attained through either PPAs with each unaffiliated microgrid user or through a single arrangement with the utility. As an example, consider a hybrid utility microgrid with the internal DERs owned by a nonutility third party that serves four unaffiliated microgrid users. In an individual PPA contract model, the DER owner would need to negotiate four separate agreements with the users as well as work with the utility to export any excess generation to the macrogrid if needed (see Figure 7-11). The negotiation and execution of each contract will require resources and time to secure.

### Figure 7-11. Individual PPA Contracting Model

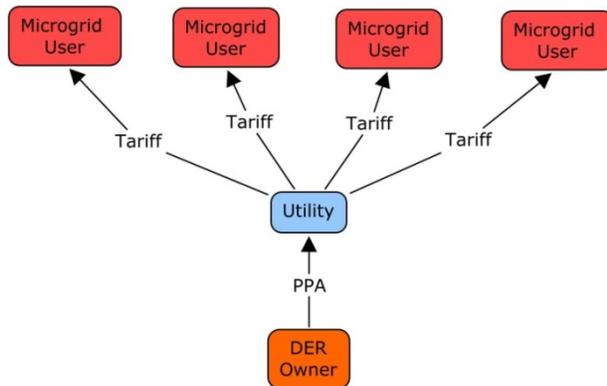
Under the individual PPA contracting model, the DER owner would enter into PPAs with each individual entity served by the microgrid, thereby incurring the costs associated with negotiating and executing each individual contract.



In a central procurement contracting model, however, the DER owner would enter into a PPA with only the utility (see Figure 7-12). Even if the terms the DER owner could secure with the individual microgrid users are more favorable than what could be secured from the utility, the additional cost of negotiating multiple contracts could negate the benefit of more favorable terms. The issue becomes more pronounced as more microgrid users are included with the system. For the utility, however, the additional cost of interfacing with the microgrid users will likely be little since the utility already has bill and customer support procedures in place and would need to bill these customers in the absence of a microgrid as well.

**Figure 7-12.- Central Procurement Contracting Model**

Under the central procurement contracting model, the DER owner would enter into a PPA with the utility for the sale of energy services. The utility would then charge the microgrid users for energy services under an applicable tariff.



The central procurement contracting model would likely result from a process initiated by the utility. For example, as of this writing the Long Island Power Authority (LIPA) has a Request for Proposals (RFP) issued for New Generation, Energy Storage, and Demand Response Resources. Accepted proposals for this particular RFP will enter into a 20-year PPA with LIPA for the provision of the requested services. A similar procurement strategy could be envisioned for hybrid utility microgrids whereby the utility issues an RFP for DG to serve within a microgrid configuration. Proposal winners would enter into long-term PPAs with the utility to provide energy services to the microgrid.

In hybrid utility microgrids where neither an individual PPA contracting model or central procurement contract model are possible, net metering or virtual net metering policies may allow a third-party DER owner to contact a larger portion of energy production to a microgrid user if the DER is located at the microgrid user's site, i.e., energy will not be distributed via utility wires to the microgrid user's facilities. The Parkville Microgrid will also employ a buy/sell arrangement for the hybrid utility microgrid in addition to utilizing virtual net metering. The net excess energy produced by the reciprocating engine in the school that is not credited to another municipal account via virtual net metering will be purchased by the utility at applicable buy-back rates. The other microgrid users (i.e., the supermarket and gas station) will continue to buy their energy from the utility at their normal tariffs.

Net metering and Virtual Net Metering (VNM) rules, however, may allow a third-party DER owner sited on a customer's property to maximize the amount of energy services provided through a PPA even if contracting with other energy users is not possible. For example, the Parkville Microgrid plans to use a PPA arrangement between the City of Hartford and the third party that will own and operate the 600-kW reciprocating engine located in a school owned by the City. The PPA will require that the school purchase its electricity and thermal energy from the third party for a defined period of time thereby guaranteeing a secure revenue stream for the DER owner. The generator, however, has been sized to meet the full loads of the other users on the microgrid—a grocery store and a gas

station—and therefore will produce more energy than will be consumed by the school alone. The third party cannot enter into a PPA with the grocery store and gas station because the microgrid’s distribution facilities are utility-owned. However, the City of Hartford and the third party are awaiting the Public Utilities Regulatory Authority’s (PURA) approval of recently approved legislation (CT Public Act 11-80) that extends VNM rules to allow municipalities to VNM “Class III CHP generation assets” to other municipal accounts. Under these new rules, the Parkville Microgrid will be able to credit any generation beyond what is consumed by the school to up to five other municipal accounts within the same service territory. If approved by PURA, this will effectively allow the third-party DER owner to expand the PPA with the city to include the provision of energy services to other municipal buildings at the rate agreed upon by the third party and the municipality.

### **Buy Back Tariff or Wholesale Commodity Market**

Microgrid owners may also sell energy services through the NYISO wholesale commodity market or through applicable “buy back” tariffs that require utilities to purchase excess generation from qualifying facilities. Both methods will typically provide highly variable rates to the microgrid owner for energy services. Microgrids or DERs interconnected at the transmission level may be able to bid into the NYISO wholesale energy markets for the sale of power where rates fluctuate hourly. Under a buy back tariff, the utility typically buys generation from the participating customer at the LBMP, which reflects the wholesale price of energy through NYISO’s bulk power markets at the transmission level.

From the standpoint of the nonutility microgrid owner, selling relatively large amounts of energy produced via a buy back tariff or through the wholesale power market would likely not be a preferred arrangement due to the uncertainty of the revenue stream resulting from the fluctuating wholesale price of energy. While models exist that attempt to predict future energy prices, they remain highly uncertain. The economic viability of generation built to sell energy on the whole sale market may falter if energy trends push the wholesale price to below the operating costs of the already built generation. The magnitude of the risk associated with this uncertainty is a constant issue in the wholesale energy markets. For the DERs likely to be used in microgrids, this level of risk and uncertainty can seriously hamper their economic viability.

Selling energy back to the utility via a buy back tariff may be a viable option for microgrid owners if used as a secondary means of receiving compensation for energy services. This may be particularly salient for microgrid systems that provide thermal energy through CHP systems where the system is operated to follow thermal demand. In these instances, there will be times where electric generation exceeds electric demand. When this occurs, the grid can serve as a destination for the surplus power produced. In addition, the ability to receive compensation for this energy through a buy back tariff creates an additional revenue stream for the microgrid and can help the overall economics of the project. Selling surplus energy in a similar manner though the wholesale commodity market would not be as advantageous to the microgrid owner. For microgrid systems where a large portion of the electric

generation follows thermal load, the amount of surplus energy will be highly variable depending on weather conditions and other factors influencing thermal demand. Under NYISO rules, this variability would increase the risk of the microgrid owner incurring under-generation penalties if they bid into the market. For this reason, FERC has ruled that the Cornell Microgrid qualifies for NYSEG's buy back tariff after the utility argued that the microgrid should not be considered a qualifying facility.

The ability to sell surplus energy via the buyback tariff also provides the option for microgrids to export intentionally to the grid when the Locational based Marginal Pricing (LBMP) is at favorable rates. For example, while the Burrstone Microgrid has established a PPA with each microgrid user that covers most of the energy produced, the microgrid sells surplus power to National Grid at the LBMP. To operationalize the microgrid's interaction with the wholesale power market, Burrstone developed an algorithm that governs the microgrid control system. Using market prices fed into the algorithm, the microgrid control system provides signals to the units indicating when to run and when not to run. It also checks the NYISO's day-ahead prices and compares them against hourly data and a forecast load profile to determine the strategy the units will operate under. Burrstone's algorithm makes hourly operational decisions that are automatically implemented by the Energy Management System.

### **Selling Excess Power Back Via Buy Back Tariff: Cornell Microgrid Example**

Cornell submitted its notice of self-certification of its cogeneration facility as a “qualifying facility” (QF) under the federal Public Utilities Regulatory Act (PURPA) on October 6, 2009 (Docket No. QF10-13-000).<sup>98</sup> Cornell sought QF certification for its cogeneration system so that it can sell excess power, when available, to NYSEG.

On December 18, 2009, NYSEG applied to FERC to terminate its obligation to enter into new power purchase obligations for energy and capacity from QF facilities with net capacity greater than 20 MW.<sup>99</sup> This request follows changes made to PURPA by the Energy Policy Act of 2005, which provides for the termination of such utility purchase requirements if FERC finds that the QF has nondiscriminatory access to wholesale electricity markets.

In Order 688, FERC found that the markets administered by the New York Independent System Operator (NYISO) satisfied the criteria of the relevant PURPA section (210(m)(1)(A)). Accordingly, FERC’s regulations established a “rebuttable presumption” that large QFs interconnected to the NYISO system have “nondiscriminatory access” to wholesale markets where they can sell excess power, obviating the need for the utility purchase requirement.

On January 15, 2010, Cornell submitted a protest of NYSEG’s application and requested that FERC exclude its facilities from any termination of the purchase obligation it might grant.<sup>100</sup> Cornell’s request was based on two facts that it claimed allow it to rebut the presumption of nondiscriminatory access. First, because the amount of electricity produced is tied directly to steam production, which is driven by weather conditions, Cornell’s facilities have operational characteristics that are highly variable and unpredictable. Second, NYISO rules, namely penalties for facilities that undergenerate compared to what they bid into the market, discriminate against intermittent resources such as Cornell’s. On March 18, 2010, FERC issued its order granting NYSEG’s application for a service area wide termination of its PURPA QF purchase obligation with the exception of Cornell. FERC found that Cornell persuasively explained the connection between its electric output and variable steam production and how that limited its ability to economically participate in the NYISO energy markets. FERC observed that because NYISO exemptions to penalties for undergeneration provided to solar and wind resources are not extended to cogeneration units such as Cornell’s, it was “effectively denied non-discriminatory access to NYISO markets.”<sup>101</sup> The effect of this decision was that NYSEG had to purchase Cornell’s excess electricity in accordance with the terms and conditions set forth in its QF buy-back tariff (see NYSEG’s Tariff, PSC No. 120, Leaf No.’s 275-281).

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<sup>98</sup> Cornell University, Notice of Self-Certification of Qualifying Facility Status of a Cogeneration Facility, filed with FERC on October 8, 2009.

<sup>99</sup> NYSEG and Rochester Gas and Electric Corporation, Application of NYSEG and RG&E Requesting Termination of Their Obligation to Purchase from Qualifying Facilities with Net Capacity Greater than 20 MW, filed with FERC on December 18, 2009.

<sup>100</sup> Cornell University, Answer and Protest of Cornell University to the Application of NYSEG and RG&E Requesting Termination of their Obligation to Purchase from Qualifying Facilities with Net Capacity Greater than 20 MW, filed with FERC on January 15, 2010.

<sup>101</sup> 130 FERC 61,216, Docket No. QM10-3-000, Order Granting in Part and Denying in Part the Application to Terminate Purchase Obligation (March 18, 2010), <https://www.ferc.gov/whats-new/comm-meet/2010/031810/E-25.pdf>.

### **7.7.2.3 Macrogrid Benefits Compensation**

#### **Ancillary Services Payments**

Depending on their configuration, size, and interconnection point, the DERs within a microgrid may be able to provide ancillary services at the transmission or distribution level.<sup>102</sup> The NYISO administers markets for ancillary services at the transmission level including regulation, voltage support, and black-start service, while utilities manage ancillary services at the distribution level. The ability of a microgrid owner to participate in the ancillary services markets provides an opportunity to generate an additional revenue stream that can further improve the economics of the microgrid. For example, Princeton University monitors ancillary service price information in the Pennsylvania, New Jersey and Maryland (PJM) ancillary services markets and provides ancillary services when the operational state of their campus microgrid is such that these services can be provided at a financial net benefit for the university.

For the microgrid owner, however, the possible revenue resulting from the provision of ancillary services must be weighed against the cost of modifying microgrid operations and equipment and the opportunity cost of using generation capacity for ancillary services that could otherwise be serving load. For relatively small capacity microgrids, the transaction costs of participating in ancillary service markets such as any required equipment (e.g., telemetry equipment with redundant relays and communication lines) could negate the additional revenue that could be earned through these markets. For this reason, few microgrids or DERs in New York “have been designed with the communication and control equipment necessary to allow the [DERs] to serve grid operational needs.”<sup>103</sup> Nevertheless, ancillary services payments could be a potential revenue stream in certain microgrid scenarios where it is financially beneficial to the owner. The case study in Appendix C discusses this option in some detail.

Microgrids that are interconnected with the distribution system and not technically or financially able to participate in NYISO ancillary services markets may still be able to provide ancillary services to the utility’s distribution system. Currently, there are not established markets for the provision of distribution level ancillary services and direct procurement of ancillary services by utilities from nonutility microgrids is unlikely due to utility and customer risk aversion. It is therefore unlikely that nonutility microgrid owners will be able to obtain compensation for these services.

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<sup>102</sup> The proper design of a DG system in order to provide grid benefits depends on careful coordination between the DG host site and the utility, as well as markets that give owners value for the benefit rendered.

<sup>103</sup> Pace Energy and Climate Center. 2011. “Valuing and Supporting the Expanded Deployment of Grid-Connected Distribution Generation in New York State.” <http://energy.pace.edu/sites/default/files/publications/RPIReportCompleteDraft07JULY11.pdf>.

## Demand Response Payments

A microgrid may also be able to earn revenue through participation in various demand response programs administered by the NYISO or individual utilities.

The NYISO has four Demand Response programs: the Emergency Demand Response Program (EDRP), the ICAP Special Case Resources (SCR) program, the Day Ahead Demand Response Program (DADRP) and the Demand Side Ancillary Services Program (DSASP). The NYISO's Day-Ahead Demand Response Program (DADRP) allows energy users to bid their load reductions, or “negawatts,” into the Day-Ahead energy market, just as generators do. Like generators, DADRP participants will also receive the market-clearing price for generation. To participate in this program, an account must be capable of reducing load by at least 1 MW.

### **Control, Risk, and Liability Issues with Third-Party Provision of Distribution Ancillary Services**

The provision of distribution level ancillary services by third parties may produce issues of risk for the utility that the utility may be unwilling to bear as explained in a 2011 report by the Pace Energy and Climate Center:<sup>104</sup>

[T]here are issues of control, risk and liability that need to be resolved. For example, utilities are responsible for providing reliable electric service within a narrow range of acceptable voltages. Relying on a third party (the DG owner) for voltage regulation services puts utilities in the untenable position of being responsible to provide services they cannot directly control. If voltages are not well regulated and damage to customers' property results, the utility may be liable for this damage. Thus, to manage risk and liability, and to ensure delivery of important services, utilities will prefer to use generation units they can directly control.

DG unit owners, for their part, are unlikely to want to cede control of their systems to the utility, because the utility may make demands on the DG unit at times when the DG owner needs to devote the unit's full capacity to serving the local load. This conflict of interest is inherent in the system so long as the DG unit is owned and operated by an entity whose core business is not the sale of electricity and related services. Because small DG units are often owned by entities for which the provision of such services falls well outside their core business, there is considerable inertia on the provider side as well.

This is the status quo. However, it is likely that the status quo will shift due to technological advances and regulatory initiatives. Emerging smart grid technology promises to improve the ability of grid managers to monitor and control conditions throughout the grid. At the same time, public policy commitments to renewable energy deployment and highly efficient natural gas-fueled combined heat and power (CHP) and fuel cell systems continue to increase the number of distributed generators throughout the electric power system. And new tools, such as the RPI test bed, are giving researchers the ability to better evaluate the balance of costs and benefits presented by expanded DG development and grid penetration.

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<sup>104</sup> Ibid.

The Emergency Demand Response Program “allows wholesale electricity market participants to subscribe retail end users able to provide Load Reduction (Demand Side Resources) by curtailing Load or by shifting Load onto a Local Generator when called upon by the NYISO during emergency conditions.”<sup>105</sup> The NYISO’s Emergency Demand Response Program specifically indicates that owners of on-site and emergency generators may participate in this program, along with end use customers reducing or disconnecting load, if the generators meet program requirements. These requirements include the ability to respond within two hours’ notice, to reduce at least 100 kW of load, and to provide hourly interval metering data to validate their performance.

The NYISO Emergency Demand Response Program also includes the Special Cases Resource (SCR) program that offers end-use loads and on-site generators incentives to commit capacity during system emergencies. The NYISO describes special case resources as “Demand Side Resources whose Load is capable of being interrupted upon demand at the direction of the ISO, and/or Demand Side Resources that have a Local Generator, which is not visible to the ISO’s Market Information System and is rated 100 kW or higher, that can be operated to reduce Load from the NYS Transmission System or the distribution system at the direction of the ISO.”<sup>106</sup> Participating resources receive capacity payments for pledging to deliver capacity during system emergencies, and additional compensation for the energy delivered when such an emergency request is executed. The ISO prioritizes bids put forward by each SCR resource reflecting the payment terms that they will require when called to contribute. SCR program participants are penalized if they fail to provide the promised capacity during SCR events.

Individual utilities also administer load management programs that address short-term emergency capacity shortages on their distribution networks. Con Edison, for example, administers its Distribution Load Relief - Tariff Rider U Program, that offers financial payments for load reductions during critical demand periods.

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<sup>105</sup> NYISO, Emergency Demand Response Program Manual, Oct. 2013, at 2.1, [http://www.nyiso.com/public/webdocs/markets\\_operations/documents/Manuals\\_and\\_Guides/Manuals/Operations/edrp\\_mnl.pdf](http://www.nyiso.com/public/webdocs/markets_operations/documents/Manuals_and_Guides/Manuals/Operations/edrp_mnl.pdf).

<sup>106</sup> NYISO Tariffs, New York Independent System Operator, Inc., at 370 (Feb. 27, 2014).

## **Transmission & Distribution (T&D) Investment Deferral Compensation**

The generation capacity of DERs within a microgrid may help the utility defer otherwise necessary T&D capacity upgrades elsewhere on their system. Compensation for T&D deferral may be embedded in a utility-driven procurement process (i.e., issuing RFPs for generation), but for customer initiated DERs, the ability to receive compensation for contributing to T&D investment deferral on the wider system may not be possible under current procedures. Since 2003, Con Edison's Targeted Demand Side Management program has solicited investments in energy efficiency and DG to provide distribution load relief.<sup>107</sup> Nevertheless, due to stringent physical assurance requirements and short lead times, the program has not supported DG and it appears unlikely that a new microgrid would be able to participate. As a result, the indirect T&D deferral benefits associated with microgrid investments are likely to remain uncompensated utility benefits for nonutility-owned DERs.

## **7.8 Reducing Barriers to and Creating Opportunities for Various Microgrid Ownership Models**

The extent to which microgrid ownership models allow microgrid owners to capture the benefits created by their microgrids will significantly influence the amount of private or utility resources that can be leveraged to provide microgrids with safety and security benefits. Several actions may ease the ability of certain ownership models to be employed.

### **7.8.1 Allow Utility DG Ownership**

Explicitly permitting utility ownership of DG within microgrids serving critical infrastructure might encourage utility microgrid development by reducing obstacles to the full utility microgrid model. In the past, the PSC has granted utility ownership of DG in cases where the project was a cost competitive and superior solution to reliability issues that would have otherwise been addressed with traditional T&D investments. A similar exception could be made for DG within microgrids serving critical infrastructure due to the societal benefits (i.e. safety and security benefits) resulting from the microgrid.

The key concern of eliminating this barrier, however, is the risk of stifling nonutility microgrid development, which might reduce overall microgrid development and innovation within the state. To address this issue, the permitting of utility ownership of DG within microgrids could be considered under the same guidelines set forth in the VMPP (i.e. showing "substantial ratepayer benefits together with [market power] mitigation measures"). In other words, utility ownership of DG within microgrids could be contingent on providing substantial ratepayer benefits via the provision of safety and security benefits through serving critical infrastructure in scenarios where nonutility investment is unlikely. The likelihood of nonutility investment will be dependent on the overall economics of

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<sup>107</sup> As of 2014, Con Edison's Targeted Demand Side Management program was no longer accepting new participants.

potential microgrid configurations of the proposed project site and the existence of other barriers that limit nonutility microgrid ownership models. If potential microgrid configurations will not produce large enough returns to attract private investment or if barriers inhibit private investment, it may be prudent to allow the utility to own generation to develop microgrids for critical infrastructure.

### **7.8.2 Structure RFPs for Generation, Storage, and/or DR Capacity to Allow Bids Incorporating DERs for Microgrids**

State power authorities (i.e., NYPA and LIPA) periodically issue RFPs for generation capacity within their service territories when future deficiencies in generation capacity are projected. Traditionally, these RFPs have been structured in ways that preclude small-scale DG from bidding. For example, there may be a floor on generation size allowed to bid, or the proposal fees may deter smaller DG submissions that will likely have relatively smaller revenue streams than larger capacity bids and thus will be impacted more by additional costs.

To the extent feasible, these RFPs could be structured to allow and/or prioritize DERs that could be utilized in a microgrid configuration to bid into the process. For example, proposals could be allowed to group together multiple DER installations into a single proposal thereby making it easier to meet any minimum capacity requirements and reducing the fee amount per DER installation. To incentivize proposals that can enable microgrid configurations that provide safety and security benefits, RFPs could be further structured to favor proposals located near critical infrastructure or on areas of the distribution network that could be easily islanded with minimal upgrades. Structuring RFPs in this manner would significantly incentivize the hybrid utility microgrids that also provide significant benefits to the wider grid through the additional generation, storage, and/or DR capacity.

### **7.8.3 Investigate Reducing the Transaction Costs of Compensation Mechanisms for Grid Benefits**

Properly configured microgrids may be able to provide valuable services to the wider grid including ancillary services and T&D investment deferral. However, as previously discussed, the cost associated with participating in current compensation mechanisms for ancillary services (i.e. NYISO ancillary services markets) and the lack of viable compensation mechanisms for distribution level ancillary services and T&D investment deferral reduces or eliminates the potential of microgrids to capture these revenue streams. Establishing and/or reducing the transaction costs of compensation mechanisms for these benefits could create additional revenue streams for nonutility microgrids and potentially enable more financially viable opportunities for these ownership models. Further research and investigation into viable compensation mechanisms that address the various barriers currently inhibiting such measures could provide valuable guidance for unlocking these value streams for nonutility microgrid ownership models.

## 8 Microgrid Benefit-Cost Analysis

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### **Findings**

**Finding 8.1:** Microgrids that are designed with distributed generation that runs only when the local utility is interrupted are difficult to justify economically. This is particularly true if there are existing backup systems that are appropriately designed and maintained. While the integration of standby generators into a microgrid can enhance the reliability of backup service, this benefit alone may not outweigh the incremental cost of designing and installing the control, communication, and electrical infrastructure that a microgrid requires.

**Finding 8.2:** The economics of a microgrid are enhanced if the system can provide service to the macrogrid, such as energy capacity, ancillary services, and demand response. This is a priority of the REV initiative. The value of these services is higher in New York City and on Long Island than elsewhere in New York; thus, microgrids in these areas are best positioned to take advantage of these potential benefits.

### **Recommendation**

**Recommendation 8.1:** The State should continue to develop case studies on the costs and benefits of developing microgrids, with the goal of formulating screening criteria describing the circumstances under which microgrids are likely to prove economically viable.

The Legislation required that the Project Team research “a cost benefit analysis for the development and implementation of microgrids.”

An exhaustive research of the professional literature revealed that no model currently exists for this analysis. So the project team developed a comprehensive cost benefit analysis model and then applied it to the five feasibility case studies in New York City and Broome, Nassau, Rockland, and Suffolk Counties (see Appendices C through G). The goal of these case studies was to illuminate the feasibility of microgrids to support critical health and safety services and to provide insights on factors that have an impact on their overall cost-effectiveness.

The discussion that follows presents a description of the approach to the assessment; the methodology that it employs; the principal elements of the analysis; and the results of each case study. The analysis supports the following conclusions:

- Assessing the benefits of a microgrid for the maintenance of critical services requires careful consideration of numerous factors, including the nature of the facilities that the microgrid would support. These facilities may include fire or police stations; hospitals or emergency medical providers; nursing homes, assisted living residences, or other adult care providers; telecommunication centers; public housing; correctional institutions; public water supply systems; wastewater treatment plants; or other service providers. In each case, the assessment of a microgrid's benefits will entail characterizing the consequences of a sustained power outage, including the impact of an outage on a facility's ability to provide services to the affected community, as well as the cost of any emergency measures that may be necessary to maintain operations or protect health and safety while the power is out.
- Microgrids that are designed to function strictly to support critical infrastructure facilities in the event of an emergency may prove difficult to justify economically, particularly if existing backup systems are appropriately designed and maintained. While the integration of standby generators into a microgrid can enhance the reliability of backup service, this benefit alone may not outweigh the incremental cost of designing and installing the control, communication, and electrical infrastructure a microgrid requires.
- A potential benefit of developing a microgrid is deferring the need to invest in expansion of the conventional grid's energy generation capacity. In theory, this could be accomplished through participation of the facilities served by a microgrid in a demand response program. The New York Independent System Operator (NYISO) does not currently offer a mechanism that would allow all microgrid projects to participate in such programs but is investigating this issue in the context of a broader study on distributed energy resources.
- For illustrative purposes, each case study examines the potential impact of participation in a demand response program on the project's benefits. The results indicate that participation in such programs could significantly enhance the economic rationale for developing microgrids, particularly in areas where the value of generation capacity is high (e.g., New York City, Long Island).

## 8.1 Analytic Process

As an initial step in its economic analysis, the Project Team commissioned a review of the literature and development of a report on best practices in evaluating the costs and benefits of microgrids. The review included outreach to selected experts and an assessment of potentially applicable models, providing a firm foundation for design of a detailed methodology.<sup>108</sup> Based on this methodology, the Project Team developed a benefit-cost assessment (BCA) model designed to assess microgrid projects. The model employs information on the proposed design and operation of a microgrid, coupled with information on the facilities it would support, to estimate the system's potential costs and benefits.

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<sup>108</sup> NYSERDA. 2013. *Methodology for Estimating the Benefits and Costs of Microgrid Projects in New York State*, Final Report, prepared by Industrial Economics, Incorporated.

## 8.1.1 Methodology

### 8.1.1.1 Basic Concepts for Benefit-Cost Analysis

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

- *Benefits* are impacts that have value to a firm, a household, or society in general.
- *Costs* represent the value of resources consumed (or benefits forgone) in the production of a good or service.
- *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.

While the perspective of individual stakeholders with respect to costs and benefits may differ, the BCA model and the case studies presented in Appendices C through G of this report focus on the net benefits of a microgrid to society as a whole. The evaluation of a project's net benefits from this perspective is conducted independent of the distribution of costs and benefits among stakeholders. With respect to public expenditures, its 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. When facing a choice among investments in multiple projects, it guides the decision toward the investment that produces the greatest net benefit. These decision criteria are designed to guarantee that the net benefits of any project undertaken will be positive, and that those who benefit from the project could, at least in theory, compensate those who lose, with everyone thus made better off (Stokey and Zeckhauser 1978).

### 8.1.1.2 Model Overview

The BCA model is a spreadsheet tool comprising 35 linked worksheets developed in Microsoft Excel. 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 that the project is designed to support. The model analyzes discrete operating scenarios specified by the user; it does not identify an optimal project design or operating strategy. A more detailed explanation of the model is included in Appendix J.

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 the annual discount rate the user specifies. It also calculates an annualized estimate of costs and benefits, based on the anticipated engineering life 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 costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the present value of the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2013 dollars.<sup>109</sup>

The BCA model considers the following aspects of a microgrid's costs:

- *Initial design and planning costs*, including the cost of designing the microgrid, obtaining building and development permits, securing financing, and establishing contracts with the local utility and/or bulk energy suppliers.<sup>110</sup>
- *Capital costs*, including those associated with the purchase and installation of energy generation and storage equipment, as well as those associated with the project's electrical infrastructure and control and communications systems. These costs include outlays not only for the microgrid itself, but also "interconnection costs"; i.e., upgrades to the macrogrid necessary to accommodate connection of the microgrid.
- *Operation and maintenance (O&M) costs*, including the cost of labor to operate and monitor the microgrid; the cost of fuel consumed by the microgrid's power generating equipment; the cost of other materials consumed in operating the microgrid (e.g., materials such as oil, fuel filters, coolant fluid, and emissions control catalysts); and the cost of labor and materials for scheduled and unscheduled maintenance. Many of these costs are likely to vary with utilization of the microgrid (i.e., the amount of electricity it produces); the model identifies these as "variable" O&M costs. Other O&M costs, such as the costs associated with software licenses, are unlikely to vary with utilization of the system; the model designates these as "fixed" O&M costs.
- *Environmental costs*, including the cost of acquiring, installing, operating, and maintaining pollution control equipment; the cost of acquiring emission allowances for pollutants that are subject to such requirements; and the estimated value of environmental damages for emissions that are not subject to allowance standards.

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<sup>109</sup> Values are adjusted for inflation using the Gross Domestic Product Implicit Price Deflator, as reported by the U.S. Department of Commerce, Bureau of Economic Analysis on January 30, 2014.

<sup>110</sup> Interest expenses associated with a project's financing are not included in evaluating project costs from a social welfare standpoint; the equivalent value of such expenses is already captured in the BCA through the application of the discount rate. The transaction costs (e.g., management time) incurred in *securing* financing, however, represent a real resource cost. The model treats these costs as an element of project design and planning.

Similarly, the model quantifies the following potential benefits of developing and operating a microgrid:

- *Energy benefits*, including energy cost savings and reductions in the cost of expanding or maintaining energy generation or distribution capacity.
- *Reliability benefits*, which stem from reductions in exposure to power outages that are considered to be within the control of the local utility.
- *Power quality benefits*, including reductions in the frequency of voltage sags and swells or reductions in the frequency of momentary power interruptions.
- *Environmental benefits*, such as reductions in the emissions of air pollutants.
- *Public health and safety benefits*, which include reductions in fatalities, injuries, property losses, or other damages and costs that may be incurred during prolonged power outages. Such outages are generally attributable to major storms or other events beyond the control of the local utility.<sup>111</sup>

The model incorporates standardized calculations for the analysis of all costs and for the analysis of energy benefits, reliability benefits, power quality benefits, and environmental benefits. Additional detail on these calculations, as well as analysis of public health and safety benefits, is provided through the case studies undertaken for this report, which are included in Appendices C through G.

### **8.1.1.3 Major Analytic Assumptions and Considerations**

#### **Discount Rate**

The case studies in appendixes employ a real annual discount rate of 7 percent to calculate the present value of costs and benefits. This rate reflects prevailing estimates of the opportunity cost of capital for private investments (OMB 2003). The use of alternative discount rates would alter the estimated present value of both costs and benefits, and could affect the assessment of a project's cost-effectiveness. The discussion of each case study notes the extent to which its findings are likely to be sensitive to the use of alternative discount rates.

#### **Emergency Fuel Supplies**

Maintenance of adequate fuel supplies is an important consideration in operating a microgrid, particularly in the event of a widespread emergency. Due to the critical nature of the services provided by many of the facilities the case studies consider, deliveries of fuel to the sites analyzed would be a priority for the duration of any power outage; thus, the benefit-cost assessment assumes that fuel supplies would be maintained indefinitely in such circumstances, both in evaluating the baseline scenario and in assessing the impacts of a microgrid.

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<sup>111</sup> As a means of monitoring service reliability, DPS requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions of more than five minutes in length (DPS, 2013). These reports provide a variety of information on each outage, including its duration and cause. 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). A major storm is defined as any storm which causes service interruptions of at least 10 percent of customers in an operating area, and/or interruptions with duration of 24 hours or more.

## **Potential Replacement of Existing Generators**

It is often appropriate, as it was in the case studies for this report, to incorporate the distributed energy resources already available (e.g., emergency backup generators) into the design of a microgrid. It is possible that one or more generators would need to be replaced within the 20-year period analyzed. The analysis assumes that the replacement cycle and the cost of replacing a generator would be the same in both the “with” and “without” microgrid scenarios; thus, the need to replace a generator would have no net impact on the microgrid’s costs.

## **Frequency and Duration of Major Power Outages**

The expected value of public health and safety benefits is dependent upon the anticipated frequency and duration of outages caused by major storms or other events that are difficult to predict. For this reason, the model has the ability to explore the sensitivity of results to alternative assumptions concerning the frequency and duration of major power outages.

## **Peak Load Support Scenarios**

A potential benefit of developing a microgrid is expanding the capacity available to meet peak system demand. This could be accomplished through participation of the facilities served by a microgrid in a demand response program. The New York Independent System Operator (NYISO) currently allows own-use microgrids with a single meter to participate in its demand response programs. It does not have rules developed to accommodate other microgrids. NYISO is investigating this issue in the context of a broader study on distributed energy resources.

For illustrative purposes, this report examines the potential impact of participation in a demand response program on the project’s benefits. The analysis is based on the lower of two figures: the aggregate capacity of the distributed energy resources to be incorporated into the microgrid, adjusted by each generator’s peak load availability factor; or the aggregate peak load of the facilities served by the microgrid.<sup>112</sup> It also assumes that all generators would meet eligibility requirements for participation in the program and that the facilities served by each microgrid would be willing to participate in such an arrangement.<sup>113</sup> These assumptions are important to the outcome of the analysis and would need to be validated before taking further action on development of a microgrid at any site.

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<sup>112</sup> The peak load availability factor is the percentage of a generator’s nameplate capacity that is assumed to be available for energy production during periods of peak demand.

<sup>113</sup> Some of the facilities considered in the case studies may already be eligible to participate in a demand response program; however, none currently do. This may be due to technological hurdles, economic considerations (e.g., costs associated with participating in the program), or other factors. The analysis of the peak load support scenario assumes that development of a microgrid would reduce such barriers and make it technologically feasible, legally possible, and economically viable for the facilities served by the project to participate in a demand response program.

## Appendix A **Enabling Legislation, 2013 NY A.B. 3008, Part T**

Section 1. The New York state energy research and development authority, in consultation with the department of public service and the division of homeland security and emergency services, shall develop recommendations regarding the establishment of microgrids in the state of New York. For purposes of this act, the term "microgrid" shall mean a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode. Specifically, the authority shall develop recommendations which include, but are not limited to, the following:

- (a) Whether hospitals, first responder headquarters, such as police and fire stations, emergency shelters, schools, water filtration plants, sewage treatment plants, municipalities, commercial entities, and other locations in the state of New York may desire to collaborate on successful microgrids;
- (b) The geographic areas in the state of New York where the establishment of such microgrids should be a priority, based upon severe storm damage during the two years prior to the effective date of this act;
- (c) the regulatory structure under which microgrid systems would operate;
- (d) how the operation of microgrids would conform with the current requirements of utilities to provide safe and adequate service to ratepayers;
- (e) the type of microgrid projects that may be implemented, including, but not limited to, distributed generation, combined heat and power; or utilizing renewable technologies such as fuel cells, wind, solar, energy storage, or other energy systems;
- (f) the technical and regulatory aspect of how a microgrid will be interconnected to the power grid;
- (g) the adequacy of a microgrid system to operate in emergency situations and that proper protections are in place to ensure operation in the event of an emergency situation; and
- (h) funding mechanisms that should be considered in order to pay for the establishment, operation and maintenance of such microgrids, including a cost benefit analysis for the development and implementation of microgrids.

Section 2. The authority shall submit a final report of recommendations to the governor, the temporary president of the senate and the speaker of the assembly within one year after the effective date of this act.

Section 3. This act shall take effect immediately.

## Appendix B Microgrid Configurations and Reference Architecture

This Appendix will describe the types of technical configurations and reference architecture that the Project team considered in crafting the feasibility studies employed at the five project sites described over the succeeding Appendices. A microgrid approach can complement a traditional grid by helping to overcome power delivery situations with high grid exposure and limited access. Microgrids can also improve reliability and power quality for critical loads. Advancements in distributed generation technology and storage enable more practical systems. Application of energy management—including heat recovery, efficient appliances, and demand control—can help to overcome the challenges of operating a small power system. This Appendix will consider microgrid applications, particularly for resiliency, and explore various microgrid arrangements and interconnection issues.

### B.1 Microgrid Configurations

Microgrids can be categorized across several classes which represent their size and configuration. As the scale of the different microgrid classes grow they increase in power capacity and include increasingly more grid connection functions and require more sophisticated control and management platforms. The different microgrid classes are categorized using criteria from three important feature sets:

1. Capacity: inherent load demand, generation types and scale, self-sustainability timelines.
2. Grid Connection Criteria: Whether the microgrid is grid connected and what grid connection features are required (e.g. stand-alone microgrid, grid-connected with island/black-start features, connected with utility control interoperability, connected with dispatch ability and support for ancillary services or market interfaces, new or existing infrastructure requirements, security requirements).
3. Management, Control, and System Attributes: native grid control functions and modes, native sensors and building management systems, fuel delivery requirements, load classification, load prioritization and load shedding modes, reliability requirements, public health and safety requirements, maintenance, testing, hardening, and redundancy.

### B.2 Microgrid Reference Architecture

Grid modernization projects have become increasingly more sophisticated, incorporating multiple technologies from both the electrical and information technology domains. Grid management systems can include numerous interacting components representing core generation and distribution functions. They can also address a variety of dynamic load types and grid conditions all connected and monitored with advanced sensing, control, and communications technologies. Developing this type of intricate and integrated grid management system requires the application of system architecture based methods and design processes to ensure a robust assessment of complex operational objectives and a methodical decomposition of a system's requirements into a suite of integrated components.

The Microgrid design team considered all operational objectives including core technical requirements such as power generation, critical load, and electrical distribution infrastructure for each of the five feasibility case studies. The five locations represented different supply and demand scales and a variety of

critical load profiles. Each site was unique including specific geographic issues, different physical infrastructure constraints and individual characteristics that would result in isolation from the macro-grid.

The consultant for this study (General Electric (GE)) applied its Microgrid Reference Architecture to ensure an optimized assessment and configuration for each of the five microgrid designs. Using the Microgrid Reference Architecture, and supporting systems engineering processes, the approach provided a reasonably optimized design at the component level (e.g. Generation/Load/Storage/Electrical/IT) and also made certain all advantages from economies of scale were exploited, while re-using common operational processes at individual sites. The resulting microgrids, if implemented, should also offer efficiencies gained from appropriate correlation to the broader grid. GE's unique approach incorporated a multi-faceted and systems-level perspective

when designing the microgrid configuration and included methods for selecting the individual components and cross-ranking and weighting their functional and performance attributes. The Reference Architecture provides constructs and analysis process-flows for guiding design activities including optimally selecting scale and technology type of generation components, managing cost efficiency by balancing the application of redundancy and hardening, as well as defining a weighted set of metrics used to classify and rank the criticality of loads.

Within the microgrid system design process, the site requirements and operational objectives were first assessed at the enterprise-level. Requirements and system functions were correlated and understood at the enterprise scale as well as the site-level to ensure an optimized site configuration. Taking this perspective allowed the design to consider the grid-level macro operational objectives and inherent grid infrastructure constraints and effects, as well as optimally address a site's critical performance, sustainability, infrastructure and cost constituents. Next, the site level functional and performance requirements and unique physical infrastructure constraints were organized as a single, system-level microgrid platform. In this step the functional and performance requirements were allocated to the component level constructs defined in the Microgrid Reference Architecture. Through this decomposition process the functional and performance requirements were assigned across an optimized set of Generation/ Load / Storage / Electrical / IT components and specifically sized and configured for an individual site. Finally, within the context of each site and specific microgrid system architecture decomposition, the individual microgrid components and their specific function/ performance/ benefit/ cost aspects were identified. This systems-level and top-down methodology to the microgrid architecture and component design was layered across all the feasibility assessment activities.

Figure B-1 below graphically represents the microgrid reference architecture.

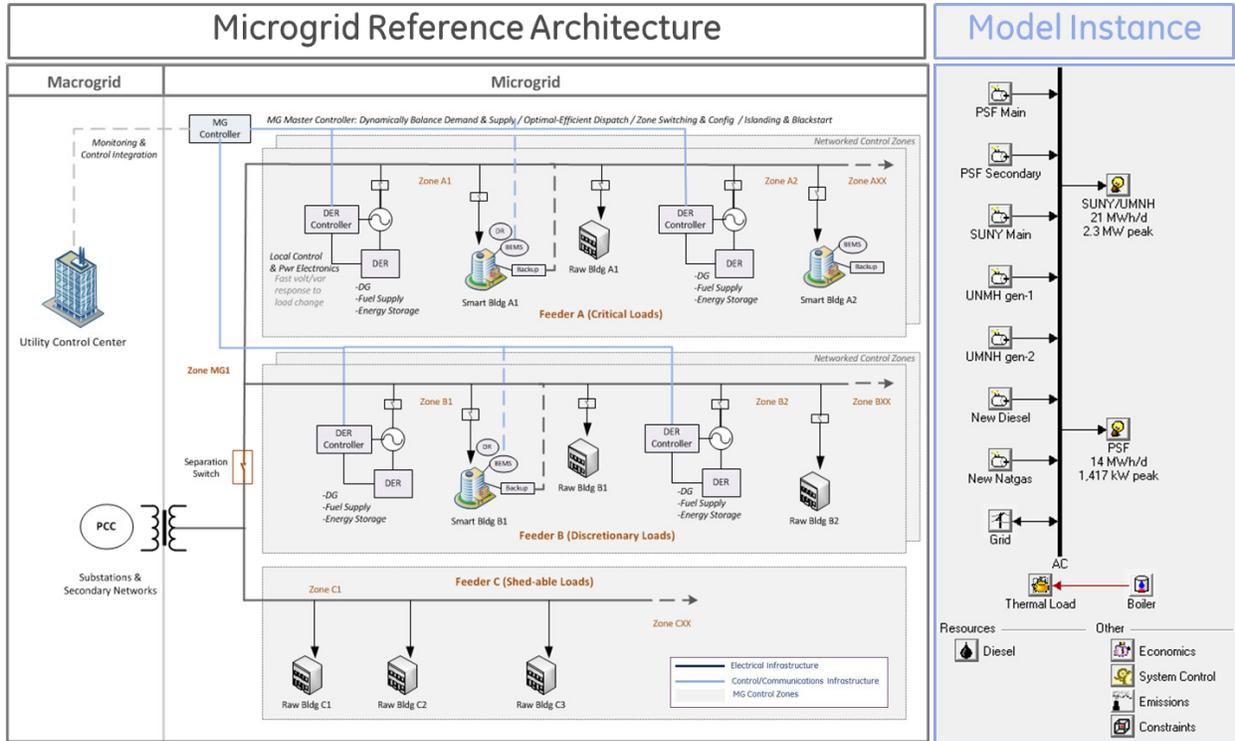


Figure B-1: Microgrid Reference Architecture

## Appendix C Microgrid Case Study: Broome County

### C.1 Overview

The feasibility study for the Broome County site examines the development of a microgrid designed to support:

- **Broome County's public safety facilities**, including the county's emergency operations center/public safety answering point (EOC/PSAP) and the county jail.
- **Buildings on the SUNY Broome campus that provide shelter for first response personnel** during emergencies, including the Ice Center, Student Center, and a dormitory on which construction is scheduled to begin in 2014.
- **A United Methodist Nursing Homes (UMNH) complex**, including Elizabeth Church Manor, a skilled nursing and short-term rehabilitation facility; and St. Louise Manor, an independent living, adult care, and assisted living facility.

As noted in detail in the site feasibility study, the facilities the microgrid would serve are currently equipped with a variety of emergency generators and other backup systems. The system supporting the County's public safety facilities is relatively robust. It includes a 1,500 kW diesel emergency generator; a 123 kW generator that provides secondary backup; and a 3.5 kVA UPS that serves the county's 911 system and maintains security at the correctional facility. Similarly, both manor houses at UMNH are equipped with 375 kW backup generators. In contrast, backup capabilities at SUNY Broome are limited to a 100 kW diesel generator that is designed to power the lights at the Ice Center and a UPS that serves the college's main information technology center. Plans for the construction of the new dormitory incorporate only enough backup service to power the building's emergency lights and fire alarm system.

The microgrid design for the Broome County site incorporates the five diesel generators noted above, providing sufficient generating capacity to meet estimated peak demand during a major power outage. The results of the engineering analysis, however, indicate that it would not be cost-effective to operate the distributed energy resources (DER) at the Broome County site on a continuous basis. Instead, the benefit-cost assessment focuses on two operating scenarios:

- Operation of the DER solely in the event of a power outage, in islanded mode.
- Provision of peak load support via participation in a demand response program.

#### C.1.1 Feasibility Study

##### C.1.1.1 *Site Characteristics*

The goal of site characterization is to understand the particular operating and emergency response missions of facilities composing the proposed microgrid site and to gather data describing the facilities' requirements for power and the specific physical characteristics and constraints of the buildings and their power systems infrastructure. On-site interviews and phone calls were held with various facility, utility, state officials, and business stakeholders involved with this site. The following sections of this report provide a summary of the site visits and present an overview of the various data collected.

The principal site entities are:

- **PSF:** Broome County Public Safety Facilities / Office of Emergency Services
- **SUNY Broome:** State University of New York – Broome
- **UMNH:** United Methodist Nursing Homes

A high level view of the Broome County site is provided in Figure C-1.



**Figure C-1: Broome County Site**

### C.1.2 Site Visit Summary

The Broome County Site (Binghamton, NY) was visited on Tuesday December 10, 2013.

The meeting was attended by representatives from the following entities:

- Broome County Public Safety Facilities/Office of Emergency Services
- SUNY Broome
- Iberdrola USA (NYSEG)
- NYS Public Service Commission
- NYS Division of Homeland Security and Emergency Services

- NYSERDA
- GE Energy Consulting

The meeting started with an introduction to the microgrid project and its objectives provided by the NYS DHSES and NYSERDA. This was followed up by a discussion between attendees from the Public Safety Facilities and SUNY Broome, touching on current operations and operations under emergency conditions, such as those experienced during Hurricanes Lee and Irene.

The key findings from the site visit are:

- Both the Broome County Public Safety Facilities and SUNY Broome are connected to the same NYSEG transformer.
- The Broome County Public Safety Facilities acted as a regional multi-county emergency operations center, and as such, is a critical regional facility.
- The Public Safety Facilities has back-up diesel/natural gas based generation, which can run for 34 hours at full load (but typically runs at 32% of full load, so it would run longer).
- There is ample county-owned land behind the Broome County Public Safety Facilities that would be appropriate for siting of additional on-site generation.
- Both the Public Safety Facilities and SUNY Broome have natural gas access.
- The Broome County site is above the flood level and was not flooded during the Hurricanes Lee and Irene.

#### *C.1.2.1 Data Collection for Site Characterization*

GE team worked with site facility managers, Iberdrola USA (NYSEG), NYSERDA, NYS DHSES, and NYS DPS, to collect detailed data for the Broome site. Their assistance and collaboration were essential in collection of the necessary data and in helping form the needed characterization of the Broome site for the microgrid design. The data collected included:

- Detailed hourly load data for the PSF and SUNY Broome facilities (from NYSEG online system)
- Monthly load data from UMNH, and example of hourly load profiles for UMNH facilities provided by NYSEG
- Detailed one-line diagrams and campus map of SUNY Broome, including square footage of buildings
- Information on on-site generation
- Utility substation, transformers and feeder connections to PSF, SUNY Broome, and UMNH provided by NYSEG.

Additional information needed to construct the energy balance model, fuel data, generation, operational, and cost parameters was collected by the GE team, some from public data, and others from internal GE sources. Some of the values used in the analysis are based on unofficial, non-public, and subjective assessments, but provide a best estimate tempered by the availability of data.

#### *C.1.2.2 Broome Site Constituents, Generation, and Infrastructure*

Table C-1 provides a summary of the Broome site principal entities.

**Table C-1: Broome Site Principal Entities**

Facility	Mission/Role
PSF	<ul style="list-style-type: none"> <li>Broome County Public Safety Facilities/Office of Emergency Services                             <ul style="list-style-type: none"> <li>Administrative Building</li> <li>Jail Building</li> </ul> </li> <li>Used as command center and hub during emergency events</li> </ul>
	<ul style="list-style-type: none"> <li>University Campus                             <ul style="list-style-type: none"> <li>Ice Center</li> <li>Student Center</li> <li>New Dormitory</li> </ul> </li> <li>Used as First Responder shelter during emergency events</li> </ul>
SUNY Broome	
UMNH	<ul style="list-style-type: none"> <li>Nursing Homes: Assisted Living &amp; Senior Living                             <ul style="list-style-type: none"> <li>St. Louise Manor</li> <li>Elizabeth Church Manor</li> </ul> </li> <li>24-Hour Care Facilities</li> </ul>

Table C-2 summarizes the existing generation resources at the Broome site.

**Table C-2: Broome Site Existing Generation Resources**

Facility	Generator Types/Rating
PSF	Backup Generator Main Backup Generator: Diesel/1500 kW, 2000 Amp Secondary Backup Generator: Diesel/123.5 kW, 150 Amp 9000 gal storage tank/auto-transfer 8 sec start Jail/security/911 equipment has 3.5 kVa UPS Boilers: 5 @ 150,000 Btu / used for heat
	Backup Generator 100 kW Serving Ice center lights and new DORM only UPS For main IT center only Solar gen onsite – rating not provided
SUNY	
UMNH	Backup Generator ECM: Caterpillar Diesel - 375 kW SLM: Caterpillar Diesel - 375 kW Site Fuel Storage: Diesel – 700 Gallons Boilers (6 Total) ECM: 2 for Domestic Hot Water + 2 for Heat SLM: 2 for Heat

Table C-3 summarizes the existing electrical and control infrastructure the Broome site.

**Table C-3: Broome Site Infrastructure Characterization**

Facility	Power Distribution & Control Systems
PSF	<p><b>Electrical</b></p> <ul style="list-style-type: none"> <li>• Dedicated Transformer</li> <li>• NYSEG transformer located on BCC campus and feeds county owned transformer</li> <li>• Primary : 34.5 K V</li> <li>• Primary: 480/277 ,4 wire ,3 phase</li> </ul> <p><b>Control</b></p> <ul style="list-style-type: none"> <li>• Building Energy Management System - BEMS (Insight V3.12)</li> <li>• Building has VPN addressable components</li> <li>• Lighting and thermostats on time based schedule</li> <li>• Utility monitors building via network connection</li> </ul>
SUNY	<p><b>Electrical</b></p> <ul style="list-style-type: none"> <li>• No dedicated sub or transformer</li> <li>• Primary : 34.5 KV, 3 wire ,3 phase</li> </ul> <p><b>Control</b></p> <ul style="list-style-type: none"> <li>• BEMS (Honeywell Tridium)</li> <li>• Network addressable components</li> <li>• Lighting and thermostats on time based schedule and motion sensors</li> <li>• No network connection to utility</li> </ul>
UMNH	<p><b>Electrical</b></p> <ul style="list-style-type: none"> <li>• No dedicated sub or transformer</li> </ul> <p><b>Control</b></p> <ul style="list-style-type: none"> <li>• No BEMS</li> <li>• No Internal Advanced Metering</li> <li>• Only Local Thermostat</li> <li>• Remote Communication Capability for Heat Pump Loop via “ACC?” Controller</li> <li>• There are network sensors or data acquisition services used to monitor the electrical infrastructure.</li> </ul>

### C.1.3 Site Modeling and Analysis

#### C.1.3.1 *Modeling of Generation Supply and Demand*

To develop a Microgrid Functional Design, GE performed a detailed supply and demand study of each site using the HOMER<sup>1</sup> model.

The HOMER model inputs include:

- The microgrid projected load data, up to two sets of hourly or 12 x 24 load profiles representing the microgrid facilities (i.e., the microgrid total load, separated or aggregated into one or two load profiles),
- Existing and proposed distributed generation sets of different kinds and sizes,
- Generation cost characteristics, including capital costs, fixed operations and maintenance (FOM) costs, and variable operations and maintenance (VOM),
- Fuel costs
- Criteria Pollutants and Greenhouse Gas emissions, and
- HOMER variability and operating reserve margins and other modeling parameters.

HOMER finds the least cost of generation mix to meet the hourly load for every hour of the year. One can assign different capacity sizes, operating reserve levels, and other parameters as “sensitivities” within the model and Homer determines best generation mix for each sensitivity assumption.

The model outputs information on the selected generation mixes, energy produced, fuel consumption, and emissions. Some of the model outputs are shown in the tables and charts of the following sections.

#### C.1.3.2 *Model Load Data*

##### C.1.3.2.1 Base Load

The Broome site load data consists of load for PSF, SUNY Broome, and UMNH. The hourly PSF and SUNY Broome load data were downloaded from the Iberdrola USA (NYSEG) Energy Profile Online system. Each of these facilities have only one utility meter, and hence there is only one set of load data for PSF and one set for SUNY Broome.

It was earlier decided by NYSERDA, NYS DHSES, and NYS PSC, that only a subsection of the SUNY Broome would be covered by the microgrid, namely:

- Ice Center
- Student Center
- New Dormitory (to be built in the future).

The occupied square footage area estimates for these facilities were used to calculate the portion of the SUNY Broome load that would be under the microgrid, and the approximate portion of SUNY Broome’s load to be served by microgrid was determined to be 35%.

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<sup>1</sup> Hybrid Optimization of Multiple Energy Resources (HOMER), a microgrid optimization model licensed by HOMER Energy LLC, available at <http://www.homerenergy.com/>.

There was no online hourly load data available for UMNH. The monthly utility statement data was used in conjunction with a typical nursing home hourly load shape provided by Iberdrola USA to construct the 12 x 24 load profile for the UMNH.

Since HOMER could only accept two separate load profiles for analysis, it was decided to aggregate SUNY Broome and UMNH together since it was assumed that the electricity usage pattern of these two during a one week to a one-month emergency period would be similar.

Using the historical hourly load for a whole year, the maximum load of each hour during the month was used to construct the 12 x 24 load profiles. For instance, the model load at hour 15 of April was determined by comparing the load at hour 15 for every day of April (30 numbers to compare) and picking the highest value. This method provides a “conservative” estimate of load, since it picks the maximum load for a given hour across all days of the month. The following figures provide the 12 x 24 load profiles for each of the facilities. It should be noted that the UMNH data are constructed using single daily profile applied to monthly data.

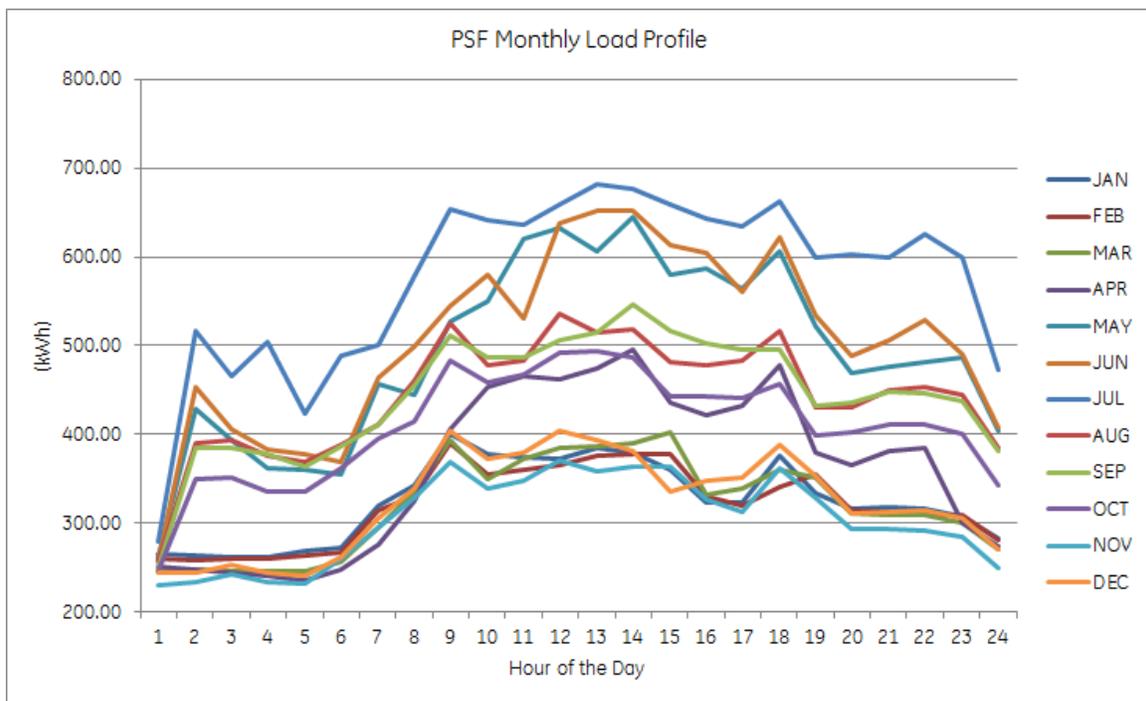
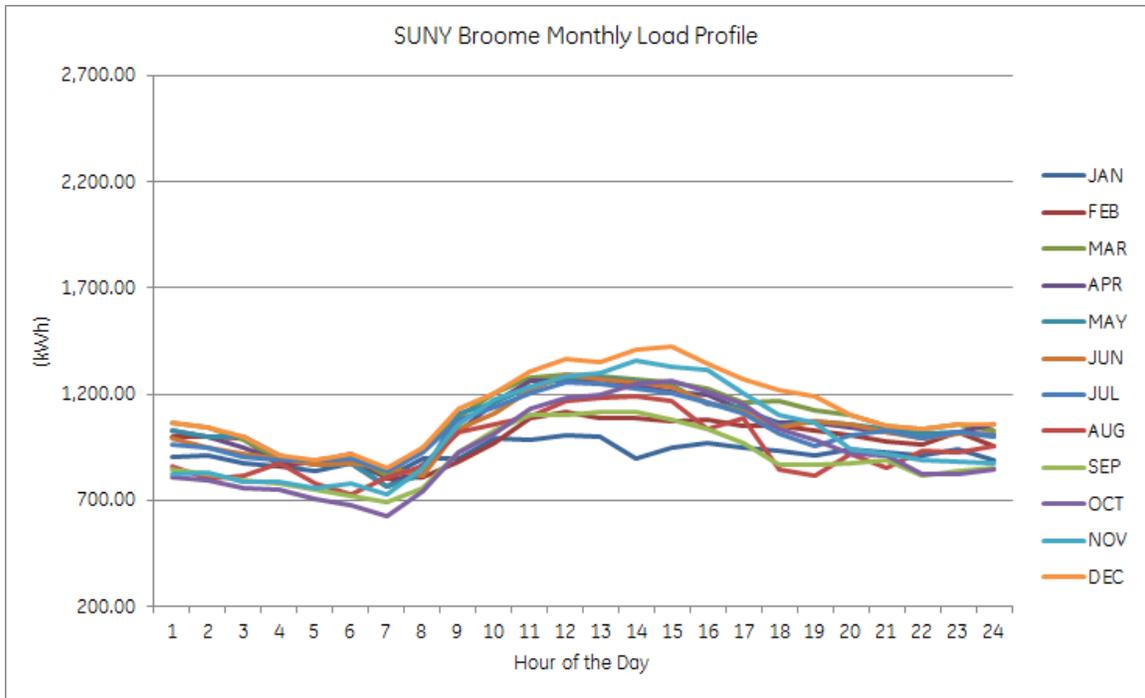
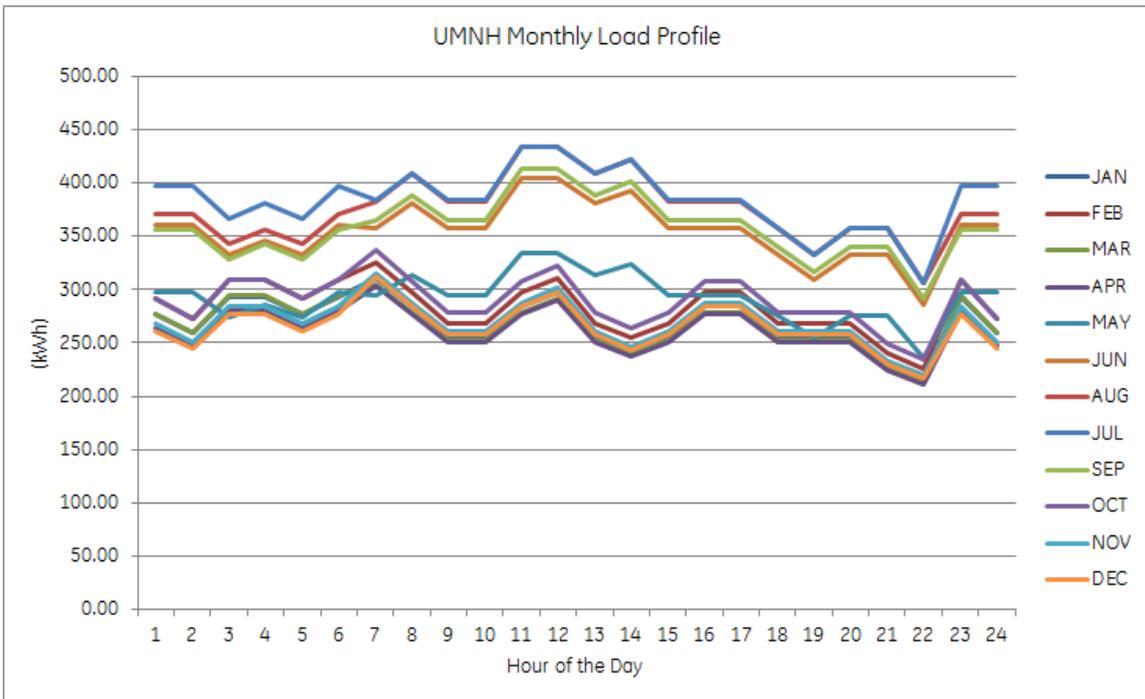


Figure C-2: PSF Monthly Load Profile



**Figure C-3: SUNY Broome Load Profile (Total Campus)**



**Figure C-4: UMNH Load Profile**

The resulting two Load Profile tables are provided below. Only 35% of the SUNY Broome load is included in the final load profiles used by HOMER.

**Table C-4: Monthly Load Profile of 100% of PSF**

Season	W	W	W	W	S	S	S	S	S	W	W	W
Month	1	2	3	4	5	6	7	8	9	10	11	12
Hours	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	300.97	293.83	278.14	284.20	295.79	292.29	315.71	290.98	283.31	278.43	261.43	275.58
2	298.53	291.69	280.93	280.46	486.35	512.75	584.63	442.35	435.22	395.92	264.28	276.35
3	296.51	294.43	278.91	276.71	446.16	460.43	527.50	445.92	436.35	397.11	274.99	286.76
4	296.39	293.77	279.09	272.84	410.66	433.38	571.14	426.24	428.14	379.15	264.88	276.00
5	303.52	298.17	279.38	267.02	408.76	426.96	478.80	417.26	411.56	379.27	262.02	273.38
6	308.64	301.38	289.97	279.98	401.63	417.20	552.94	439.74	437.60	410.01	295.02	295.79
7	361.97	355.67	334.20	313.27	518.22	525.71	568.10	466.14	465.96	447.11	334.14	346.81
8	388.31	374.87	379.15	368.45	503.18	565.01	655.15	522.09	515.25	469.88	372.55	384.03
9	453.59	441.64	444.91	460.61	597.95	616.86	740.23	595.22	578.98	548.07	417.09	458.29
10	427.97	402.76	396.87	514.06	622.69	656.10	725.96	542.18	551.34	518.58	384.03	422.02
11	422.85	408.40	422.14	527.56	702.54	601.22	720.43	547.83	551.46	529.04	393.78	430.58
12	421.07	413.64	435.81	523.51	715.67	723.17	746.83	607.35	572.86	556.33	419.23	458.23
13	435.93	426.24	438.37	537.13	686.66	739.40	772.34	584.04	582.20	558.29	405.55	444.97
14	429.39	428.74	440.99	560.55	730.78	739.16	766.45	586.42	618.58	551.52	411.73	431.18
15	408.40	427.67	455.61	493.72	656.22	693.74	746.47	545.93	584.51	501.81	411.14	379.27
16	366.01	374.16	376.36	477.91	664.30	684.58	728.58	541.35	569.06	501.51	370.53	393.48
17	366.25	362.68	383.67	489.27	639.81	634.52	717.58	547.47	560.55	500.32	354.18	397.29
18	425.29	385.22	408.76	541.82	686.72	704.73	749.62	585.17	561.39	516.50	409.18	439.56
19	377.19	401.39	397.76	430.40	591.65	605.68	678.16	487.84	489.50	452.70	372.08	399.66
20	358.22	355.79	353.05	414.71	530.77	553.83	683.45	486.77	492.89	456.45	332.36	352.69
21	359.77	354.00	350.32	431.59	539.21	572.80	679.29	508.65	507.16	466.14	332.06	353.29
22	357.81	350.85	349.25	436.29	544.62	598.84	709.25	513.58	505.08	464.95	330.99	356.38
23	349.01	349.36	340.45	340.51	551.75	554.37	678.28	503.53	495.51	453.00	321.42	345.74
24	321.06	318.09	307.27	309.41	458.47	462.45	534.81	434.92	431.24	387.60	283.07	307.33

**Table C-5: Monthly Load Profile of 35% of SUNY Broome + 100% of UMNH**

Season	W	W	W	W	S	S	S	S	S	W	W	W
Month	1	2	3	4	5	6	7	8	9	10	11	12
Hours	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	627.96	663.63	624.48	560.89	624.59	640.10	801.91	803.03	817.87	688.07	628.67	624.83
2	610.12	639.35	592.54	534.68	601.65	641.06	790.52	797.08	803.17	661.73	596.13	598.56
3	639.73	659.70	615.56	559.02	569.41	603.41	753.66	755.02	745.84	684.14	624.93	617.01
4	605.55	628.97	608.02	554.94	579.37	625.40	768.93	773.51	751.63	678.26	617.21	609.36
5	587.75	599.21	587.58	531.45	552.43	610.03	752.52	752.74	733.86	663.52	609.85	588.05
6	615.80	628.20	607.40	534.25	600.77	644.07	765.71	766.69	761.54	665.91	625.15	597.68
7	594.49	610.30	602.89	545.81	586.62	638.35	741.38	771.04	790.37	748.22	692.57	629.08
8	601.14	628.74	602.65	541.88	645.14	710.12	813.80	812.33	823.25	713.96	674.58	636.97
9	631.87	656.98	631.25	575.47	689.70	754.00	855.97	843.81	867.87	755.30	695.34	656.70
10	666.45	690.02	649.77	609.32	717.34	779.25	891.91	894.93	977.17	801.34	719.56	692.42
11	720.43	743.25	705.99	662.34	791.01	840.07	962.59	977.45	1,094.19	855.01	754.92	734.21
12	748.82	763.51	743.49	675.81	812.36	861.49	992.65	1,001.12	1,115.99	897.99	787.30	763.42
13	705.78	716.96	697.37	642.17	787.73	838.78	980.28	993.03	1,109.20	847.39	737.09	725.13
14	689.22	698.17	679.71	626.83	817.79	859.95	985.86	1,011.17	1,138.67	825.91	710.36	695.11
15	696.00	703.06	684.83	660.47	793.30	810.82	947.07	976.07	1,099.47	853.97	717.53	697.97
16	713.86	722.15	684.82	676.57	764.45	785.53	928.25	973.61	1,088.04	868.75	728.72	713.30
17	691.55	696.24	668.80	631.03	738.29	751.36	886.50	946.60	1,010.98	817.60	700.79	698.64
18	666.56	650.37	616.26	579.18	702.55	700.90	827.13	883.67	920.22	771.87	678.87	670.88
19	651.02	648.86	626.59	575.65	672.08	685.84	787.34	832.69	865.10	740.52	666.93	654.46
20	643.85	645.37	622.84	557.72	661.21	696.23	801.29	829.50	863.80	737.03	663.00	663.13
21	584.03	609.19	585.33	534.24	642.17	682.42	788.80	826.23	810.48	687.78	620.21	610.46
22	577.62	588.09	559.56	497.21	590.78	617.23	735.87	768.33	754.75	660.26	581.95	572.43
23	651.52	679.21	652.64	573.75	652.18	669.06	833.11	830.71	808.36	728.71	646.46	641.41
24	611.67	643.65	614.77	547.21	647.81	658.63	817.46	823.72	806.33	679.29	625.24	623.18

C.1.3.2.2 Emergency Premium

To account for additional load over the base load in times of emergency, GE assumed a 20% emergency premium. This is the assumed additional load that may materialize during emergency periods resulting from the additional activity, personnel, and accommodation for emergency operations. The 20% emergency premium was applied to all hour loads, and hence the generation requirements are sized to this emergency load (i.e., Base Load + 20%).

HOMER performs additional scaling and massaging of load to create the hourly load shapes, and the resulting load characteristics with the 20% emergency premium are:

**Table C-6: Broome Site Load**

Load Name	Scaled Average (kWh/Day)	Hourly Peak (kW)
PSF	11,584	927
SUNY Broome + UMNH	20,623	1366
<b>Total</b>	<b>32,207</b>	<b>2,293</b>

*C.1.3.3 Model Generation and Fuel Data*

The existing generation set at Broome Site includes the following:

**Table C-7: Existing Generation Resources at Broome Site**

Plant	Capacity
PSF Main	1,500 kW
PSF Secondary	123 kW
SUNY Main	100 kW
UMNH gen-1	375 kW
UMNH gen-2	375 kW
<b>Total</b>	<b>2,473 kW</b>

From the above two tables it is apparent that without additional probabilistic variability in the expected load, or additional load requirements such as inclusion of other buildings in SUNY Broome in the microgrid system, the collective existing generation can cover the total microgrid load at Broome site.

However, it should be noted that without additional microgrid interconnection, PSF Main will only be able to service the PSF load, and additional microgrid infrastructure is needed to connect the loads and generators together.

*C.1.3.4 Generation Selection Considerations*

The Broome Site is special, since it appears to have no need for any new generation resources. However, even if there is no need for new generation under current load assumptions, there may be a need under some future conditions. A few of these scenarios are explored below.

- Q) Why not replace the existing generation with new ones?
  - A) The PSF Main was installed in 1996 and appears to be in good working order.
- Q) Why not consider installation of Combined Heat and Power (CHP) in this location?
  - A) The boilers on site are in good shape and not in need of replacement.

- Q) Assuming that the microgrid will be expanded in the future to include additional facilities, or assuming it is determined that during emergency periods there will be significantly more critical load that needs to be met in addition to the currently assumed load, what will be the most likely need for new generation resources?
  - A) Under the expanded microgrid scenario, the most appropriate generation resource would still be diesel based generation.
    - A natural gas engine would be considered if natural gas prices compared to diesel prices become so low as to compensate for the higher capital cost of natural gas, assuming that the current gas connection to the site (used for heating) can accommodate increased demand for gas. GE has considered natural gas options in other sites.
    - This site has plans to install additional solar photovoltaic (PV) to provide approximately 2.5 – 4 mW of power. Solar generation is intermittent and highly variable but may be able to provide continuous and reliable power if coupled with battery energy storage.
  - Hence, on purely economic considerations, a reasonable choice of new incremental generation would still be diesel generation. Renewable and clean energy would be considered if other factors, such as additional environmental constraints and costs, come into play or regulatory mandates to meet a certain portion of the generation by renewable / clean energy necessitate consideration of such resources.

#### C.1.4 Microgrid Infrastructure Configuration

##### *C.1.4.1 Model Generation Options*

As noted, the existing generation at the Broome site is sufficient and capable of meeting all the designated load of the Broome microgrid, assuming that the communications and control and electrical infrastructure exist within the microgrid to connect all the generators and the load (otherwise, the Main PSF can only serve the PSF load, and SUNY Broome load will not be covered).

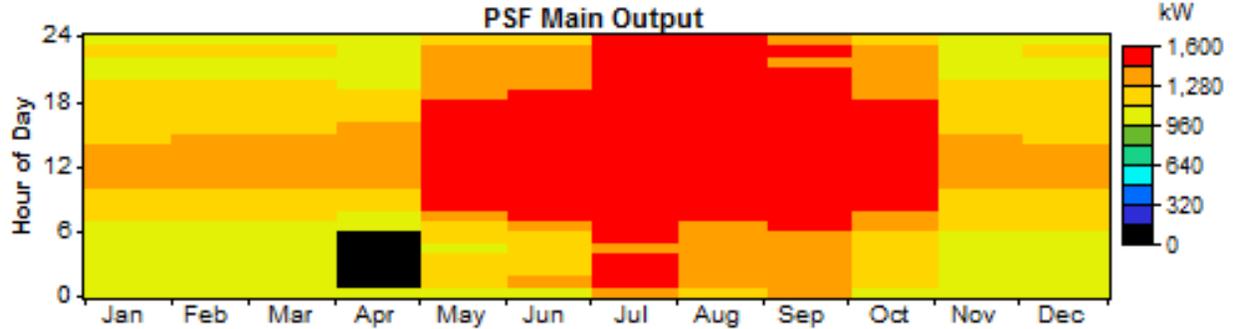
HOMER produced results for generator energy production, their O&M and Fuel costs, fuel consumption, and emissions. It is assumed that the Microgrid will be functional for a minimum duration of one month – although there is no reason to assume that the microgrid cannot run for longer periods of time if the generators are regularly supplied with fuel. Hence, the following results are for a one-month operation of the microgrid.

**Table C-8: Broome Site Generation Performance**

Generation	Capacity (kW)	Production (kWh/Month)	Capacity Factor	Fuel Consumption (Gallons/Month)	O&M Costs (\$/Month)	Fuel Costs (\$/Month)	Total Variable Costs (\$/Month)
PSF Main	1,500	929,687	84.9%	67,048	18,296	202,970	221,266
PSF Secondary	123	9,677	10.8%	698	165	2,113	2,278
SUNY Main	100	8,628	11.8%	622	256	1,884	2,139
UNMH gen-1	375	27,332	10.0%	1,971	551	5,967	6,519
UNMH gen-2	375	4,305	1.6%	310	80	940	1,020
<b>Total</b>	<b>2,473</b>	<b>979,627</b>	<b>54.3%</b>	<b>70,650</b>	<b>19,348</b>	<b>213,873</b>	<b>233,221</b>

It should be noted that since all generation resources are diesel-fueled, and have similar assumed characteristics, they are actually interchangeable. Similar electricity generation, fuel consumption, and O&M and fuel costs can be achieved if total generation is redistributed differently among different plants.

Figure C-5 provides a Pictogram of the PSF Main generation by month and day of the month.



**Figure C-5: Pictogram of PSF Main Generation by Month and Hour of the Day**

Table C-9 presents the monthly emissions by the Broome site generation set.

**Table C-9: Monthly Emissions**

Pollutant	kg/MWh
Carbon dioxide	718.64
Carbon monoxide	1.77
Unburned hydrocarbons	0.20
Particulate matter	0.13
Sulfur dioxide	1.44
Nitrogen oxides	1.21

*C.1.4.2 Electrical Infrastructure*

The following approach was taken for the electrical infrastructure design:

- Assessment of existing electrical infrastructure in and around the proposed site. The assessment included both site (customer) owned and utility owned infrastructures.
- Analysis of one-lines to determine the PCC (point of common coupling) with the utility and to define the electrical boundary of the Microgrid.
- Assessment of voltage levels, existing distribution system routes and distance between various buildings/facilities to determine interconnection options. The initial options included different voltage levels and different routes, both with and without the usage of existing utility or facility assets. The utility and the site each supplied one-lines and maps, which were used to determine the voltage levels and existing routes. Aerial and satellite maps were used to calculate approximate distance between various buildings and facilities of the Microgrid. A similar approach was used to select routes for new distribution lines.
- Assessment and evaluation of different interconnection options (voltage level and route) for optimal system operation. Selection of optimal voltage level is based on engineering judgment and industry practice to maintain the power quality and minimize line loss. Routes are selected so as to minimize the total length of new distribution line. The right of way is assumed to be available.
- Cable, switches, circuit breakers, transformers and other electrical equipment were selected based on the proposed power flow, selected voltage level, layout and connection scheme. The existing backup generators were considered to be equipped with circuit breaker(s) or transfer switch/switches and other equipment necessary to perform break-before-make switching operation.
- The effect on protection systems was also considered during the selection of electrical equipment. Site specific system modeling and in-depth analysis is required to determine any modification or upgrade of the system and is not in the scope of current project.
- The proposed electrical infrastructure design does not consider the operation of the Microgrid in grid-connected mode.

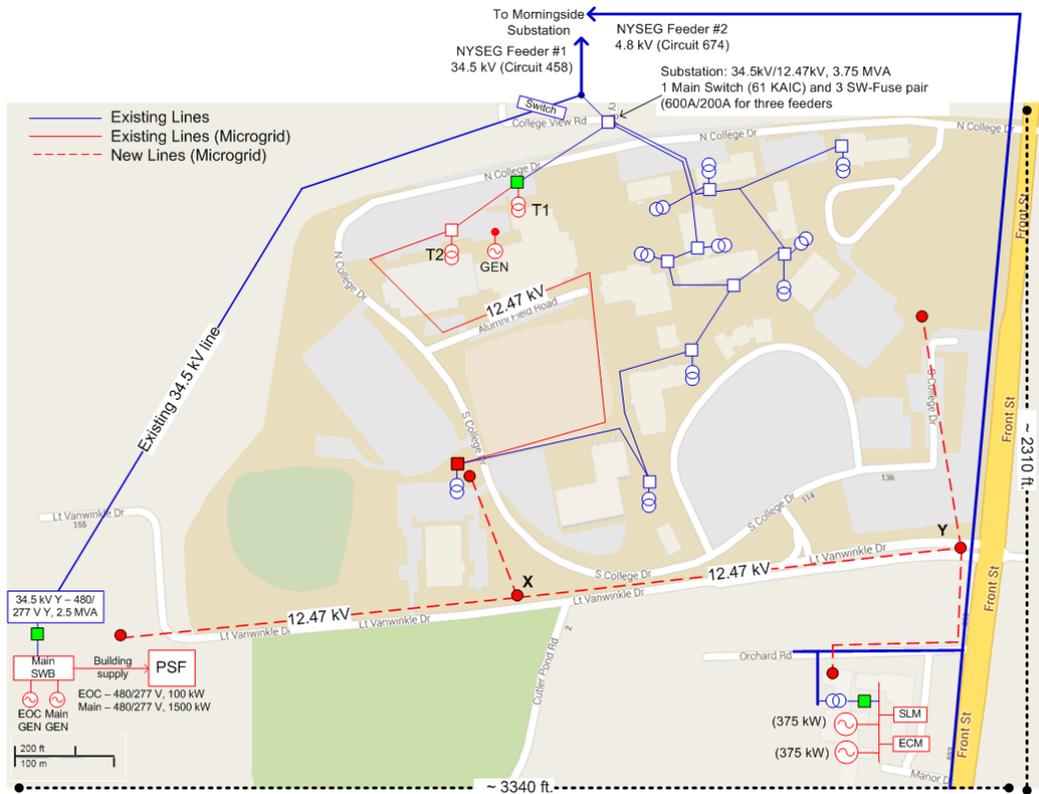


Figure C-6: Layout of Electrical Infrastructure (Broome Site)

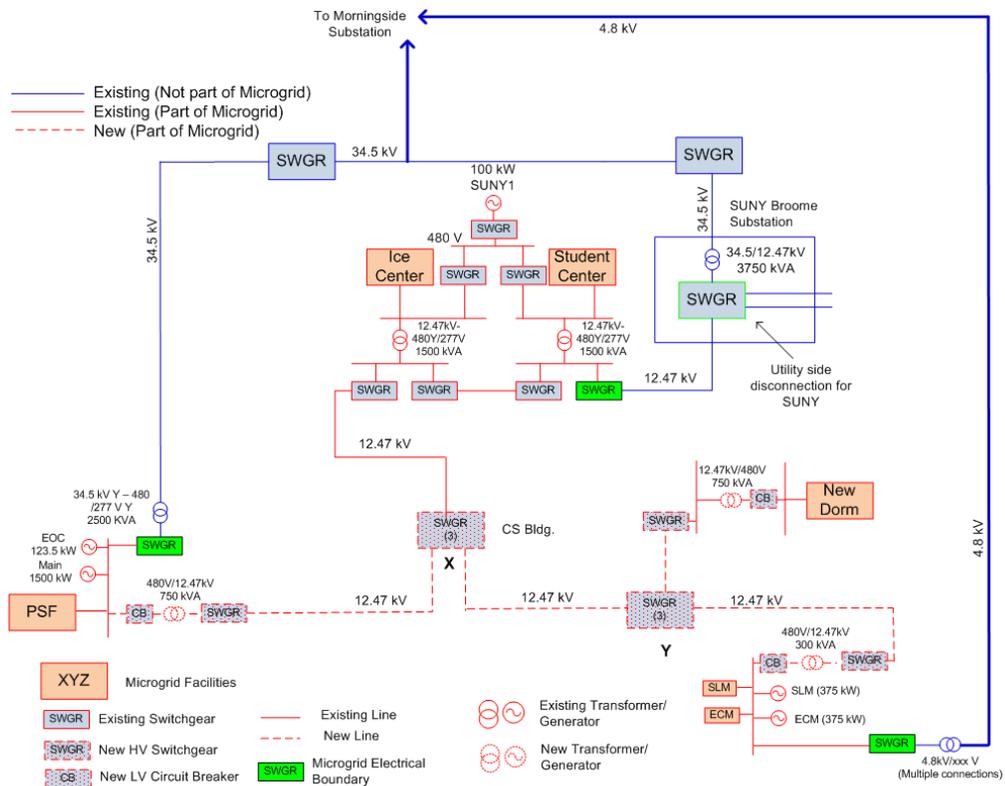


Figure C-7: Electrical One-line of Interconnection (Broome Site)

Figure C-6 provides an overview of the layout of the Broome site's electrical infrastructure, taking into account the points of contacts with the greater grid. Figure C-7 presents the Broome site's electrical one-line of interconnections, although the details of existing connections are not shown.

In developing the electrical infrastructure design, the following considerations, specific to the Broome site were made:

- The two backup generators in UNHM are considered interconnected.
- The two backup generators in PSF building are considered interconnected.

#### *C.1.4.3 Control and Communications Infrastructure*

Site perspective:

There was no input from the utility on existing communications platforms and no input from the site detailing controllable loads. The site, however, does have a Building Energy Management System (BEMS).

Based on the lack of driving technical or interoperability requirements, GE approached the architecture definition as a new system design with the goal to keep costs minimal and select control and communications devices which supported multiple protocols to enable interoperability across the largest array of devices and platforms.

Given the information above, for this prototypical example and high level estimate, GE selected wireless field networks as the communications backbone. This is a common solution for utility neighborhood area networks (NAN) and field area networks (FAN). This solution also allows ease of integration with modern AMI solutions that may be in the area. Another approach would be underground cabling or fiber optic networks. The fiber approach is the highest performing when it comes to bandwidth and reliability, however it is a very large cost commitment for the utility. Underground copper cable is also high performing and very expensive. The lack of physical details concerning area-specific trenching requirements and length of cable runs and lack of input from the utility regarding network requirements ruled out estimating cost for both underground and fiber networks.

Control design was based on the GE Microgrid Reference Architecture (See Appendix B). The Microgrid Reference Architecture divides the Microgrid into 3 control zones (shed-able load, discretionary load, critical load) and 5 formal control types (Utility Control Interface, Master MG controller, Smart Building, Raw Building, and sub or feeder IED's and switches).

To support the 5 control abstractions in the Microgrid Reference Architecture GE crafted a solution that included the notion of:

- Microgrid Energy Management Systems (MG EMS): MG EMS serve as the master control application and orchestrate all control actions as well as provide the utility interface. The MG EMS would be developed per the software design bid listed in the C&C BOM table. This could include integration of some existing control platforms and a lot of new system level control orchestration services.

- Microgrid Master Control Station (1 per site): this Station would host MG EMS, orchestrate all control nodes and DG optimizer/dispatch controller.
- Microgrid Campus Control Node (1 per facility): this Node would coordinate control across multiple buildings composing a specific facility.
- Microgrid Edge Control Node (1 per building): this Node would provide direct interface to any controllable device in a building.
- All hardware level control was architected using programmable, multi-protocol, IED's to enable broadest support of industry standard protocols and interfaces (e.g. IEC61850, DNP3, Modbus TCP/IP, Modbus Serial, or Ethernet as interface to control ports on microgrid deployed devices such as IED's, PLC, switchgear, relay, sensors, meters, digital governors, etc.).

New developed MG EMS monitoring/control services will use 61850 communications to a Protocol gateway which maps 61850 logical nodes to the specific control interfaces on the MG components/devices.

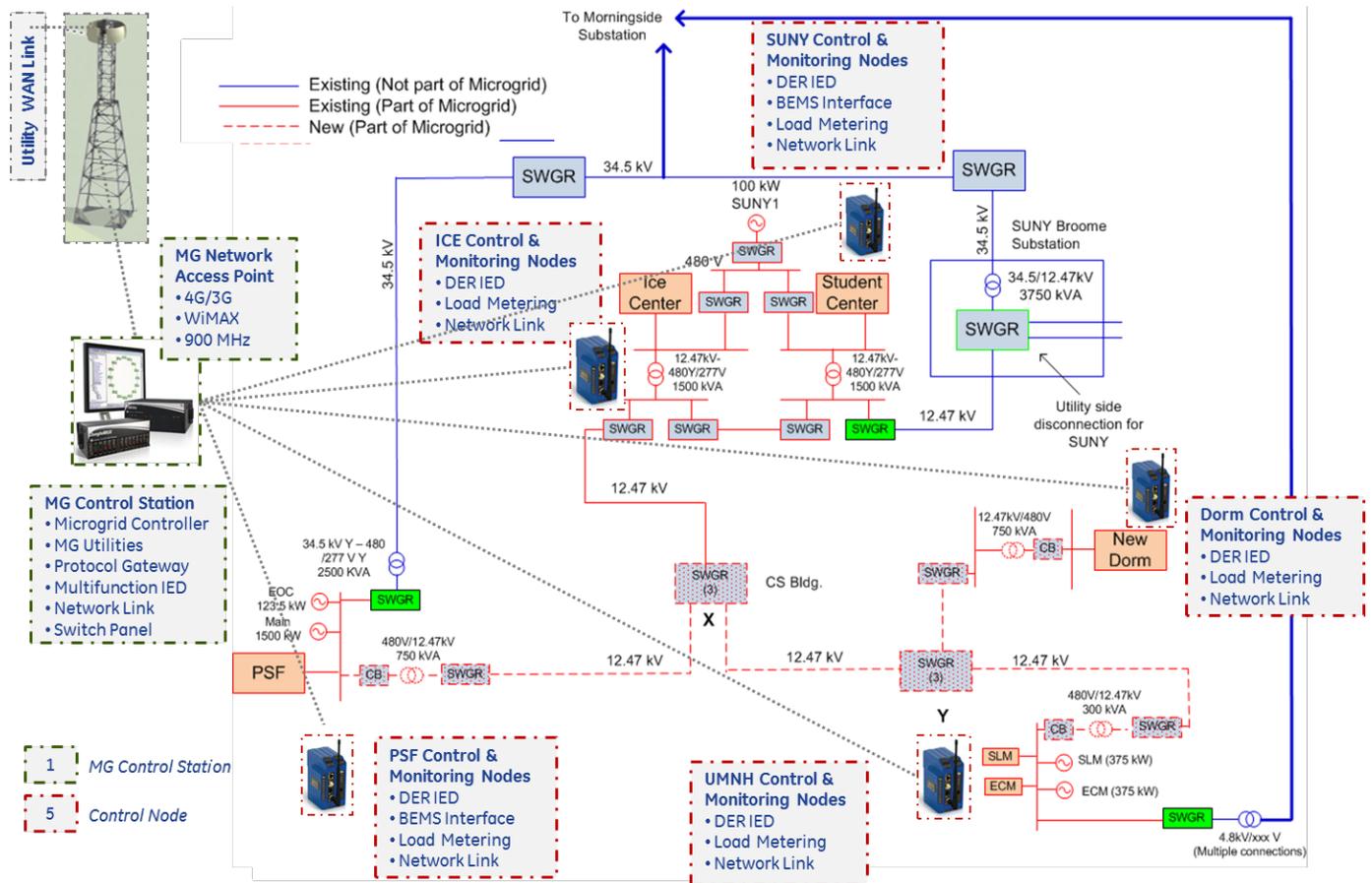


Figure C-8: Microgrid Electrical One-Line Diagram with Control and Communications Overlay

C.1.5 Microgrid Cost Summary

C.1.5.1 *Microgrid Cost Estimate Development*

Based the analysis performed and details of the functional design, the GE team developed its “best estimates” of the cost of microgrid development, using public and non-public sources, with an expected accuracy of +/- 30%.

As noted earlier, additional information needed to construct the energy balance model, fuel data, and generation operational and cost parameters was collected by the GE team. Some data was collected from public data, and other information from internal GE sources. Some of the values used in the analysis are based on unofficial, non-public, and subjective assessments, thereby providing a best estimate tempered by the availability of data.

The microgrid development cost components included (but not limited to) the following:

- Microgrid DG Costs (Capital, Fixed, Operations and Maintenance, Fuel, Etc.)
- Microgrid Control and Communications Infrastructure (components and installation)
- Microgrid Electrical Infrastructure Costs (components and Installations)
- Annual Microgrid Operations and Maintenance Costs

C.1.5.2 *Electric Generation Cost*

Since the existing on-site generation is sized large enough to cover the designated critical microgrid load, the generation costs do not include any capital costs. The only generation cost components are the O&M and Fuel costs, as shown in the following table.

**Table C-10: Broome Site Generation Costs**

Generation	Capacity (kW)	O&M Costs (\$/Month)	Fuel Costs (\$/Month)	Total Variable Costs (\$/Month)
PSF Main	1,500	18,296	202,970	221,266
PSF Secondary	123	165	2,113	2,278
SUNY Main	100	256	1,884	2,139
UNMH gen-1	375	551	5,967	6,519
UMNH gen-2	375	80	940	1,020
<b>Total</b>	<b>2,473</b>	<b>19,348</b>	<b>213,873</b>	<b>233,221</b>

### C.1.5.3 Electrical Infrastructure Cost

The following table summarizes the Broome microgrid electrical infrastructure average cost estimates.

The cost for all electrical infrastructure components are the best estimates obtained from GE internal sources and verified from utility engineers (not related to Microgrid site).

Based on the methodology used for the electrical infrastructure cost estimation, the values presented should be assumed to be the “average” cost estimates. A 10% low and high adjustment was used to calculate the Low and High bookends of electrical infrastructure costs.

**Table C-11: Broome Microgrid Electrical Infrastructure Average Cost Estimates**

SN	Item	Description	Quantity	Unit	Unit Price (\$) (Installed) <sup>#</sup>	Cost (\$)
1	12.47 kV 3-Ph Cable	Cable to connect PSF, SUNY and UNMH (PVC Conduit)	7000	Ft.	30	210,000
2	12.47 kV Switch	High Voltage Switches (Load Break)	9	Nos.	20,000	180,000
3	480V Circuit Breakers	Low Voltage Circuit Breakers at PSF and UNMH	3	Nos.	10,000	30,000
4	480V/12.47kV, 750 kVA Transformer	Transformer at PSF and New Dorm to step up the voltage	2	Nos.	16,000	32,000
5	480V/12.47kV, 300 kVA Transformer	Transformer at UNMH to step up the voltage	1	Nos.	10,000	10,000
6	Transition Compartment	One each at PSF, UNMH and CS Bldg. (SUNY)	3	Nos.	10,000	30,000
7	Protection System	Model the existing system with new infrastructure and evaluate the protection system	1	Unit	20,000	20,000
Total						512,000

### C.1.5.4 Control & Communications Cost

Similar to the approach used to estimate electrical infrastructure cost, GE referred to internal sources to get component costing. The team utilized GE information (documents, website, internal communication), and used the online purchase menus to configure the devices per the store menus and ascertain a price for all communications and control hardware and supporting software applications. GE used list price in all cases to stay at a relatively conservative level.

To estimate system and project costs, GE first created the control/communication costing spread sheets to establish a list of required engineering, design, integration, and site activities. Details of each are

described in the notes column. Based on the engineering activities, GE estimated number of labor/months per tasks and used EC commercial rates to get a number.

To validate costs, GE compared its derived numbers to some industry sources. Two sources in particular were noted: 1) Minnesota Microgrid Project, and 2) DOE Microgrid workshops. GE's cost numbers were somewhat higher, but that was clearly due to the fact that the team had originally used GE commercial consulting rates for engineering design labor. GE has finalized its numbers using a Low, Average, and High estimates in order to provide a range.

Table C-12 summarizes the Broome Microgrid Control & Communications Infrastructure "High" cost estimates.

Based on the methodology used for the electrical infrastructure cost estimation, the values presented should be assumed to be the "high" cost estimates. The "average" cost estimate is 10% lower than the high cost estimate. Similarly, the "low" cost estimate is 10% lower than the average cost estimate.

**Table C-12: Broome Microgrid Control & Communications High Cost Estimates (Rounded to the Nearest \$100)**

Item - P/N	Description	Unit Price (\$)	QTY	Cost (\$)	Notes
<b>MG Master Control Station</b>					
MG Control Station Computer	MG Station Computer: Hosts MG EMS application. Hardened computer with processor/comm/interface expansion ports. Rack system.	15,000	1	15,000	Dell Poweredge R270 Rackmount Server. Racks, Displays, Peripherals. SQL Server DBMS. Priced to approximate a hardened computer to host MG substation applications and support NERC compliance and multiple I/F options
GE EnerVista Engineer	MG Configuration Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Maintenance	MG Maintenance Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Monitoring	MG Monitoring Utility	2,000	1	2,000	MG controller HMI and configuration app
GE EnerVista Integrator	MG Device Integration	1,500	1	1,500	MG controller HMI and configuration app
GE Cimplicity	Cimplicity Globalview and Cimplicity Development	100,000	1	100,000	HMI/SCADA framework providing event/alarm monitoring, logging, and SCADA configuration tools.
GE Multilin U90+	MG Generation Controller/Optimizer	25,000	1	25,000	MG Generation Controller via Multilin UR family. Forecasting and optimal dispatch functions
GE D400	Advanced Protocol Gateway	9,000	1	9,000	Multifunction intelligent gateway. Provides control interface and data collection from protection, control, monitoring, RTU, IED's. Configured using Logiclinx software.
System Integration & I/F Modules	Integration & Control Software: Application functions, control functions, component adapters, and automation scripts	425,000	1	425,000	Engineering labor estimate for code development/integration of site-specific control and automation of buildings, systems, devices, and generators. (TBD scope: depending on requirement for monitoring and automated control of buildings and electrical infrastructure)
<b>MG Campus Ctl Station (BEMS Integration)</b>					
Control Station Computer	Application Host Computer	5,000	2	10,000	Dell Poweredge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	2	1,000	Smart meter monitors main facility load. BEMS I/F provide detailed monitoring.
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	2	18,000	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
BEMS Integration	Configuration/Integration	50,000	2	100,000	BEMS configuration and integration with campus controller. Requires technical discussions with BEMS vendor and facility energy manager.

MG Campus Ctl Station (w/o BEMS)					
Control Station Computer	Application Host Computer	10,000	4	40,000	Dell Poweredge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	6	3,000	interval load monitoring
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	6	54,000	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
Control Node Integration	Integration/Configuration	20,000	4	80,000	Integration/Configuration/Unit-Testing Multifunction controller at campus stations
MG Communications					
GE MDS orbit - MCR-4G access point	MG Control Station network access point: (900Mhz,3G/4G,WiFi, 10-100Ethernet, VoIP, Serial RS232/485)	2,200	1	2,200	Wireless access point for MG control station. Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900Mhz Mesh or 3G/4G as needed for linking to utility field network. Use 900Mhz mesh to MG control nodes at buildings.
GE MDS orbit - remote mxnx-u91-s1n	MG remote control point : MG Sub/FacilityDevice/DG link: (900Mhz,WiFi, 10-100Ethernet)	1,500	6	9,000	Wireless remote node (1 per building)... Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900 Mhz Mesh network back to MG control station. Use WiFi or Ethernet for points inside or near buildings.
GE MLS2400 Ethernet Switch	Network switch panel for MG substation. VoIP/SCADA/Relay data connected via Ethernet	3,000	7	21,000	Ethernet switch, rack, power (1 per building). Wireless access point goes into switch then Wireless or Ethernet to any controllable elements in building.
Total				918,700	

#### C.1.5.5 Total Microgrid Cost Estimates

In addition to the generation costs and the costs of the physical elements used in the control and communications infrastructure, as well as the electrical infrastructure, there are additional costs associated with initial microgrid controller development, engineering specification and design, and actual installation and project management. Table C-13 provides a detailed listing of all the elements of the installed microgrid system costs.

**Table C-13: Broome Summary of Total Costs of Broome Site Microgrid Development (Rounded to the Nearest \$1000)**

Project Activity	Description	Low (\$)	AVG (\$)	High (\$)	Type
Amortized Development of the MG Energy Management System	<p>Integrate U90 master controller and the D400 control nodes with the PCMS EMS. Develop any extra system orchestration functions not native to the off the shelf commercial EMS that are required to perform NYSERDA MG operations.</p> <ul style="list-style-type: none"> <li>-MG System Orchestration</li> <li>-Control Loads</li> <li>-Control Generators</li> <li>-Planning/Forecasting/Scheduling</li> <li>-Monitoring/Diagnostics</li> <li>-Utility Data Exchange</li> <li>-Grid PCC Mgmt.</li> <li>-Utility Baseline Integration</li> </ul>	396,000	554,000	710,000	General Development
MG Communications Fabric Planning/Installation/Configuration	<p>All wireless communications platforms</p> <ul style="list-style-type: none"> <li>-Communications from the MG control room to MG control nodes.</li> <li>-Communication from MG control room to utility</li> </ul>	0	0	0	Site Specific Planning & Development
MG Test Plan Development	<p>Design evaluation and stress tests to validate every function and every protection and safety scheme in the system.</p> <ul style="list-style-type: none"> <li>-develop formal test plan</li> <li>-design test and validation control and workflows</li> <li>- write corresponding code/scripts</li> </ul>	374,000	512,000	648,000	Site Specific Planning & Development
MG System Integration & Site Certification	<p>Run tests to validate every function, system and device in the entire system. All facilities, buildings, BEMS, Generators, MG control fabric, MG electrical fabric, and MG communications fabric.</p> <ul style="list-style-type: none"> <li>- Execute tests and document results</li> <li>- Orchestrate formal acceptance process</li> <li>- Obtain formal site sign off</li> </ul>	95,000	133,000	170,000	Site Specific Planning & Development
Project Management	<p>Program Management, Administration, and Technical interchange meetings</p> <ul style="list-style-type: none"> <li>-Technical interchange with utility/vendors/NYSERDA/DHS/Gov/etc.</li> <li>-Requirements collection and scope definition for complete system</li> <li>- Developing and Reviewing SOWS/RFP/Proposals to subs and vendors</li> <li>-Manage multiple subs and vendor</li> <li>-Manage technical development</li> <li>-Manage internal GE teams</li> <li>-Program interface with sponsors</li> <li>-Reporting and accounting</li> </ul>	504,000	696,000	888,000	Site Specific Planning & Development
Site Design Engineering and Construction	<p>Microgrid Detailed Systems Design</p> <ul style="list-style-type: none"> <li>-Develop formal technical specification</li> <li>-Power Systems Analysis</li> <li>-Power Systems Simulation</li> <li>-Site Planning &amp; Licensing</li> <li>-Site Construction</li> </ul>	518,000	716,000	912,000	Site Specific Planning & Development

Distributed Generation BOM	New Distributed Generation	0	0	0	CAPEX
Control & Communications BOM	CAPEX for the control and communications subsystem	744,000	827,000	919,000	CAPEX
MG Electrical Infrastructure	All required electrical distribution components - /xformers/feeders/switching/protection/ss integration/etc.	461,000	512,000	563,000	CAPEX
Microgrid Maintenance and Support	All software licenses and tech support - maintain MG system - provide 24/7 tech line support - perform routine software maintenance and upgrade	41,000	45,000	50,000	Annual O&M
Total MG One-Time Cost		3,092,000	3,950,000	4,810,000	
Annual MG O&M Cost		41,000	45,000	50,000	

### C.1.6 One-Time Cost Considerations

Some costs are one-time costs, because off-the-shelf and commercially turn-key microgrid controllers are still at development state, and functioning microgrids for the multi-entity sites considered in this study are still being developed.

This study assumes that such a functioning microgrid controller will be developed from scratch for these 5 sites. This will be a one-time development cost consisting of the software and code design to enable currently existing and commercially available hardware to be linked in an optimal manner with enabled communication throughout the network, as well as to provide optimal control and dispatch functions. It is expected that the developed software and codes can then be more easily modified and applied at future sites at a fraction of the initial development costs.

### C.1.7 Assessment of Adequacy of Fuel Supply and Delivery

The Broome site already has a sizable fuel storage tank. In addition, the GE team was informed by the NYS DHSES representative that during emergency conditions diesel fuel will be regularly trucked to the site. As a result, the project team did not have a reason to do further analysis of the fuel supply adequacy and delivery options.

## C.2 **Benefit-Cost Assessment**

### C.2.1 Fixed Cost Factors

The best estimate of initial design and planning costs for development of a microgrid at the Broome County site is approximately \$2.7 million. This figure includes approximately \$2.1 million in site-specific planning and administrative costs as well as \$554,000 in engineering design costs. The project's capital costs are estimated at approximately \$1.3 million, including \$512,000 for electrical infrastructure and \$827,000 for control and communications systems. Since the design does not incorporate energy storage or additional generating capacity, the analysis assumes the microgrid would require no outlay for either purpose. Fixed O&M costs are estimated at \$45,000 per year.

### C.2.2 Variable Cost Factors

The analysis relies on information provided by the Project Team's design consultants and projections of fuel costs from the State Energy Plan (SEP) to estimate the variable costs of operating the microgrid.

Variable O&M costs, excluding fuel, are estimated at \$19.75 per MWh; fuel costs for the microgrid’s first year of operation are estimated at approximately \$286 per MWh.

The analysis of variable costs also considers the environmental damages associated with emissions from distributed energy resources, based on the understanding that the diesel generators at the Broome County site would not be subject to emissions allowance requirements. The estimate of environmental damages relies on pollutant emissions factors provided by the project’s design consultants, as specified in Table C-14.

**Table C-14: Pollutant Emissions Factors for the Broome County Microgrid**

<b>Pollutant</b>	<b>Emissions (Tons/MWh)</b>
CO <sub>2</sub>	0.79
SO <sub>2</sub>	0.0016
NO <sub>x</sub>	0.0174
PM	0.0001

### C.2.3 Analysis of Reliability Benefits

The analysis estimates that development of a microgrid at the Broome County site would yield reliability benefits of approximately \$37,000 annually. This estimate is based on the following indicators of the likelihood and average duration of outages in the Broome County area:

- System Average Interruption Frequency Index (SAIFI) – 0.98 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 120 minutes.<sup>2</sup>

The estimate of reliability benefits takes into account the capabilities of the backup power systems already available at the Broome County site. It also takes into account the variable costs of operating all generators, both in the baseline scenario and as integrated components of a microgrid. The estimated improvement in reliability stems from the assumption that establishment of a microgrid would promote regular testing and maintenance of all generators, reducing the risk that these units may fail when called into service. In the baseline scenario, the analysis assumes a 15 percent failure rate, based on an estimate provided by the Electric Power Research Institute (EPRI).<sup>3</sup> It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

### C.2.4 Analysis of Benefits in the Event of a Major Power Outage

The estimate of the reliability benefits a microgrid would provide does not include the benefits of maintaining service during outages caused by major storm events, as well as other outages generally

<sup>2</sup> SAIFI is the average number of times that a customer is interrupted during a year. CAIDI is the average interruption duration time for those customers that experience an interruption during the year. The SAIFI and CAIDI values employed in the Broome County analysis are the values for New York State Electric and Gas Corporation (NYSEG) in 2012, as reported in State of New York Department of Public Service, *2012 Electric Reliability Performance Report*, June 2013.

<sup>3</sup> <http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1>.

considered beyond the control of the local utility. To estimate the benefits of a microgrid in the event of such outages, the analysis assesses the impact of a total loss of power – including the failure of backup generators – on the operation of the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.

#### *C.2.4.1 Broome County Jail*

A prolonged power outage would have a significant effect on the operation of the Broome County Jail only during the heating season, when a loss of power and subsequent loss of heat would necessitate transferring prisoners to another facility. The Broome County Sheriff's Office reports that the jail's average occupancy in 2013 was 506 prisoners. It estimates the cost of transferring these individuals at approximately \$61,000; this includes both transportation costs and incremental costs for medical and correctional personnel during the transfer. Following the transfer, the county would incur incremental labor costs of approximately \$5,500 per day to secure and maintain the vacant facility.

In addition to the cost of the emergency measures described above, closure of the Broome County Jail would reduce prison capacity in New York State. To calculate the value of the lost capacity, the analysis employs a figure of \$96 per prisoner-day; this figure is based on an analysis of fees charged by county jails in New York State to house prisoners from other jurisdictions. For 506 prisoners, this translates to a cost of approximately \$49,000 per day.

#### *C.2.4.2 PSAP/EOC*

Due to the critical nature of the services provided by the PSAP/EOC, its operations would continue even if faced with a total loss of power; the primary impact would be additional demands on personnel and a resulting increase in labor costs. The Broome County Office of Emergency Services estimates these costs at approximately \$15,500 per day.

#### *C.2.4.3 SUNY Broome*

A major power outage coupled with loss of the backup generator at SUNY Broome would necessitate a call for a 400 kW replacement generator to support the first response personnel who are based at the campus during an emergency. The analysis estimates the fully installed cost of this generator at approximately \$372,000, with operating costs (including O&M, fuel, and emissions damages) of approximately \$800 per day.

In addition to installing a replacement generator, SUNY Broome would require the students housed in its new dormitory to evacuate and seek housing elsewhere. Approximately 325 students would be displaced. Based on a review of listings for off-campus housing at SUNY Binghamton, the analysis estimates the value of student housing in the area at approximately \$12 per student-day. Thus, the economic loss attributable to closure of the dormitory is estimated at approximately \$4,000 per day.

#### *C.2.4.4 UMNH*

A prolonged power outage coupled with the loss of backup generators at the UMNH complex would trigger evacuation of the affected residents/patients. When possible, those affected would be transferred to other facilities within the UMNH network. UMNH would work with the County Office of Emergency Services to transfer any remaining residents/patients to other facilities. UMNH did not estimate the cost of

transferring residents/patients; thus, the analysis focuses solely on the value of the services lost, as measured by the reduction in nursing home and assisted living capacity.

The analysis estimates the economic loss attributable to closure of Elizabeth Church Manor at approximately \$34,000 per day. This figure is based on the facility's capacity (120 beds) and New York Department of Health data on average rates for nursing home care in the state's Central Region (\$284 per person-day)<sup>4</sup>. Similarly, the analysis estimates the economic loss attributable to closure of St. Louise Manor at approximately \$6,000 per day. This figure is based on the facility's capacity (52 beds) and the estimated value of assisted living services in the Syracuse area (\$120 per person-day).<sup>5</sup>

#### C.2.5 Analysis of Peak Load Support Scenario

The benefits of developing a microgrid at the Broome County site would be enhanced if the system could provide peak load support to the macrogrid via participation in a demand response program. Participating in this program would reduce demand to expand the macrogrid's generating capacity, thus providing capacity cost savings. Providing peak load support would increase the microgrid's annual operating costs (including variable O&M costs, fuel costs, and environmental costs). These costs, however, would be offset (at least in part) by a reduction in demand for electricity from the macrogrid, which would lead to energy cost savings and environmental benefits associated with the operation of bulk energy facilities.

The analysis estimates the benefits of the Broome County project's participation in a demand response program based on a peak load for participating facilities of approximately 1,685 kW. Given this figure, the project would generate capacity cost savings of approximately \$153,000 per year. If the system were called upon to provide support for 20 hours a year, its operating costs would increase by approximately \$13,000 annually. These costs would be offset by a reduction of approximately \$3,000 per year in the macrogrid's operating costs. Under this set of assumptions, the system's participation in a demand response program would yield benefits of approximately \$143,000 annually.

#### C.2.6 Summary of Results

The analysis of the Broome County site indicates that the benefits of a microgrid would exceed its costs only if the probability of a major power outage is assumed to be extremely high. As Table C-15 shows, this is particularly true for scenarios that do not include participation in a peak load support program. In those cases, the expected number of days without power must be 17 or more *each year* in order for the project to be cost-effective. Participating in a demand response program would improve the economic case for the project's development. Even in this case, however, the expected number of days without power would need to be from eight to 18 each year for the project to be cost-effective. These results do not change significantly when lower discount rates are employed. Based on these findings, development of a microgrid at the cost projected is unlikely to be economically justified.

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<sup>4</sup> [https://www.health.ny.gov/facilities/nursing/estimated\\_average\\_rates.htm](https://www.health.ny.gov/facilities/nursing/estimated_average_rates.htm).

<sup>5</sup> MetLife Mature Market Institute, *Market Survey of Long-Term Care Costs*, November 2012.

**Table C-15: BCA Results for the Broome County Site: Breakeven Conditions (7% Discount Rate)**

<b>Scenario</b>	<b>Annual Probability of Specified Outage</b>	<b>Duration of Specified Outage</b>	<b>B/C Ratio</b>
Low Cost/No Peak Load Support	100%	17 days	1.02
Average Cost/No Peak Load Support	100%	22 days	1.01
High Cost/No Peak Load Support	100%	27 days	1.00
Low Cost/Peak Load Support	100%	8 days	1.03
Average Cost/Peak Load Support	100%	13 days	1.02
High Cost/Peak Load Support	100%	18 days	1.01

## Appendix D Microgrid Case Study: New York City

### D.1 Feasibility Study

#### D.1.1 Site Characteristics

The New York City site area consists of multiple facilities in a high density urban setting on Manhattan's Upper East Side, between 1st Ave and Park Ave, along the East River, in an area that was heavily affected by Superstorm Sandy. The principal facilities are the Metropolitan Hospital Center campus, the New York City Housing Authority (NYCHA) Lexington and Washington public housing complexes, and the Verizon Central Office at 151 E97 St.

- **MHC:** Metro Hospital Center
- **NYCHA:** New York City Housing Authority's Lexington and Washington complexes
- **VZ:** Verizon Central Office

A high level view of the New York City site is provided in Figure D-1.

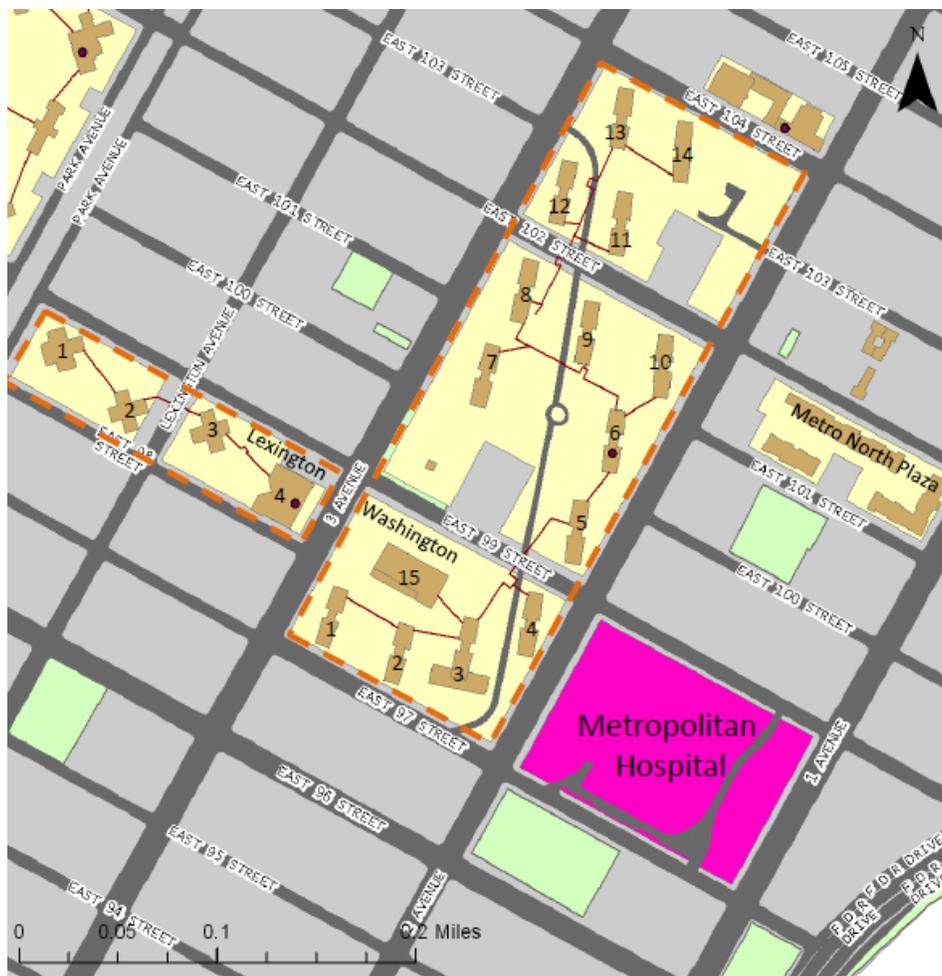


Figure D-1: NYC Site

#### *D.1.1.1 Site Visit Summary*

A meeting was held on December 2, 2013 at the MHC conference room with key stakeholders from NYSERDA, DPS, DHSES, GE, City government, MHC, NYCHA, and Consolidated Edison. Following the meeting, attendees were provided a tour of the hospital facilities, including the boiler room, backup generators, and electrical room.

##### D.1.1.1.1 The Metropolitan Hospital Center (MHC)

The Metropolitan Hospital Center (MHC) on Manhattan's Upper East Side is a 360 bed city hospital that provides both in-patient care (the main hospital is a level 2 trauma center), as well as a variety of outpatient and mental health services. It is located in a flood plain (Zone 2) along the East River and parts of the hospital campus were submerged and damaged during Sandy. Notably, the Draper building on the 1st Ave side that had served as a nursing dormitory was permanently damaged and is now unoccupied and condemned.

The OPD (Out Patient Department) provides ambulatory care during business hours only and is shut down and locked at night. During emergency operations, this area is not considered critical load. The main hospital with 240 beds and mental health building (MHB) with 120 beds both have a mix of both in-patient 24 hour services and clinical/outpatient space that is inactive nights and weekends. In addition to patient care, there are nursing and support services (laundry, food services, etc.) that operate during off-hours. Both the main hospital and OPD can segregate critical loads for priority backup, while the MHB is not easily segregated.

There is an Emergency Operations Plan that allows them to feed staff from hospital supplies. During Sandy, they received an influx of patients and staff from Bellevue and Rockaway, which were both without power.

MHC receives gas and electric delivery service from Consolidated Edison but purchases retail supply from NYPA. They produce their own steam through an aging boiler plant (125 psi and 35,000 lbs./hr.) – the four existing boilers are slated for replacement next year with three new energy efficient ones (n+1 redundancy, so two plus a spare). The original 1950's boilers run on #6 fuel oil; the new boilers will burn natural gas with #2 diesel as a back-up. They looked at CHP but the cost of steam was greater than the cost of power from NYPA.

Consolidated Edison service is provided through underground networked 3 phase/4 wire service at 208V (plus a separate 480V feed for the chiller).

There are three backup generators, two of which are also old and approaching end of life (with no current plans for replacement). There are two 1100 ton chillers with no backup.

Security is composed of locks with controlled keys for all power and mechanical systems.

Total load for the hospital varies between 2.4 and 5 MW. 60% can be interrupted for short duration; the rest is on emergency backup. There is a fuel storage facility with 4 days critical load capacity at "normal order" level (7-8 days at a full tank). The critical loads all switch to emergency backup when a grid voltage sag is detected; other loads will run at under-voltage. Switchover occurs in less than 10 seconds. During Sandy, two of the three generator sets ran for 46 hours straight.

There is one UPS in the computer room.

#### D.1.1.1.2 New York City Housing Authority (NYCHA)

NYCHA operates a cluster of high-rise public housing complexes in the area adjacent to MHC, between 2nd Ave and Park Ave, North of 97th St. (shown in yellow on the map). Only the Lexington and Washington complexes are included in this study. Between the two complexes, NYCHA houses a combined 4,400 residents in approximately 2,000 apartment units.

The Lexington Houses (straddling Lexington Ave) consists of four 14-story buildings with 448 apartments housing some 917 residents at the 3.48-acre complex. The George Washington Houses (between 2nd and 3rd Ave) consists of another 15 buildings – one low rise service building and 14 apartment buildings, 12 and 14-stories tall with 1,510 total apartments housing some 3,517 residents. Completed July 31, 1957, the 20.82-acre complex is between East 97th and East 104th Streets, Second and Third Avenues in Manhattan.

The NYCHA units are all gas fed with steam heat from the boilers. Consolidated Edison provides power through underground network service. Some buildings are master-metered by Consolidated Edison while others have separate meters for each unit. Cooling is only available through individual window A/C.

Elevators and pumps (for water/wastewater circulation) are the most critical loads but are not on a separate circuit. Since buildings have been wired differently at different times, NYCHA is not able to provide circuit drawings or detail at a building level so no estimate has been made here of the cost to upgrade the in-building electrical systems to segregate critical from non-critical loads.

#### D.1.1.1.3 Verizon

The Verizon central office is a 6 story building with 145,000 square feet of conditioned space located on E97th St. between 3rd Ave and Lexington Ave. Electrical service is provided by Consolidated Edison from the street. Electrical usage varies between 350,000 and 500,000 kWh/month, with the higher demand falling in summer months, driven by air conditioning to cool the IT equipment. The site has a 750 kW backup turbine generator, which runs off diesel and a 10,000 gallon underground storage facility. It is tested monthly. There is no on-site boiler.

#### *D.1.1.2 Data Collection for Site Characterization*

The GE team worked with site facility managers, NYCHA, Consolidated Edison (ConEd) staff, NYSERDA, NYS DHSES, and NYS DPS, to collect detailed data for the New York City site. Their assistance and collaboration were essential in collection of the necessary data and in helping form the needed characterization of the site for the microgrid design. The data collected included:

- Detailed hourly load data for the MHC and Verizon facilities
- Monthly load data from NYCHA for the Washington and Lexington buildings
- Detailed one-line diagrams of the complex underground ConEd network serving the facilities
- Information on on-site generation

Additional information needed to construct the energy balance model, fuel data, and generation operational and cost parameters were collected by the GE team, some from public data, and others from

internal GE sources. Some of the values used in the analysis are based on unofficial, non-public, and subjective assessments, but provide a best estimate tempered by the availability of data.

In addition, GE was able to leverage partner companies to evaluate two alternative scenarios. Sungevity, a GE partner and solar project developer based in Oakland, California, provided a view of the solar rooftop PV potential at the MHC site, based on available satellite imagery and proprietary site engineering estimation software. Penn Energy, a GE distributor in the Northeast, provided an independent assessment of CHP potential at MHC. These two scenario analyses are discussed in further detail in D.4.5.1.

*D.1.1.3 NYC Site Constituents, Generation, and Infrastructure*

Table D-1 provides a summary of the NYC site principal entities.

**Table D-1: NYC Site Principal Entities**

Facility	Mission/Role
MHC	<ul style="list-style-type: none"> <li>• Large public hospital complex, includes both:               <ul style="list-style-type: none"> <li>○ In-patient (24/7) care</li> <li>○ Out-patient clinics</li> </ul> </li> <li>• Operated continuously during Sandy and sheltered emergency refugees from other area hospitals</li> </ul>
NYCHA	<ul style="list-style-type: none"> <li>• Washington and Lexington public housing complexes               <ul style="list-style-type: none"> <li>○ 19 high-rise (12-14 story) apartment buildings</li> <li>○ 4,400 residents</li> </ul> </li> </ul>
Verizon	<ul style="list-style-type: none"> <li>• Central Office facility with 24/7 IT and cooling load</li> <li>• Back-up generation for 100% of load</li> </ul>

Table D-2 summarizes the existing generation resources at the NYC site.

**Table D-2: NYC Site Existing Generation Resources**

Facility	Generator Types/Rating
MHC	Backup Generators <ul style="list-style-type: none"> <li>• 3 backup generators / auto transfer / 10 sec start up                             <ul style="list-style-type: none"> <li>○ 600KW / Diesel / 7,500 gallon tank</li> <li>○ 675KW / Diesel / 5,000 gallon tank</li> <li>○ 750KW / Diesel / 6,000 gallon tank</li> </ul> </li> </ul>
	Boilers <ul style="list-style-type: none"> <li>• 4 (old and slated for replacement)</li> </ul>
NYCHA	Backup Generators <ul style="list-style-type: none"> <li>• None</li> </ul>
	Boilers <ul style="list-style-type: none"> <li>• In each building</li> </ul>
Verizon	Backup Generators <ul style="list-style-type: none"> <li>• 750 Kw turbine generator</li> <li>• 10,000 gallon diesel storage</li> </ul>
	Boilers <ul style="list-style-type: none"> <li>• None</li> </ul>

Table D-3 summarizes the existing electrical and control infrastructure within the NYC site.

**Table D-3: NYC Site Infrastructure Characterization**

Facility	Power Distribution & Control Systems
MHC	<b>Electrical</b> <ul style="list-style-type: none"> <li>• Serviced via ConEd underground electrical network</li> <li>• No dedicated substation</li> <li>• 3-Phase 4-wire 208V secondary to main campus</li> <li>• 3 wire 480V to chiller plant with separate power supply on site</li> </ul> <b>Control</b> <ul style="list-style-type: none"> <li>• Legacy BEMS serving partial building control</li> <li>• Major BEMS modernization and control/automation project just started</li> </ul>
	<b>Electrical</b> <ul style="list-style-type: none"> <li>• Serviced via ConEd underground electrical network</li> </ul> <b>Control</b> <ul style="list-style-type: none"> <li>• No BEMS on site</li> <li>• No Integration with utility DR or utility hosted building control systems.</li> </ul>
Verizon	<b>Electrical</b> <ul style="list-style-type: none"> <li>• Serviced via ConEd underground electrical network</li> </ul> <b>Control</b> <ul style="list-style-type: none"> <li>• N/A</li> </ul>

Significantly for purposes of the study, the Consolidated Edison (ConEd) network serving the NYC site is an underground mesh network. Network transformers provide multiple feed paths for each secondary circuit. Under normal operations, network distribution systems, which are commonly found in densely populated urban cores and financial centers, are generally considered more reliable than radial distribution, because service can be redirected around a fault without interruption to end customers.

In planning for emergency conditions, however, network distribution service presents a unique challenge to microgrid design, as there is no unique point upstream of any given connection point on the network where a particular set of customers can readily be electrically isolated and islanded from the surrounding network. In order to allow islanded operation of the microgrid for individual customers within the ConEd mesh network, GE assumed a secondary overbuild of dedicated distribution connections between the facilities in the study.

### D.1.2 Site Modeling and Analysis

#### *D.1.2.1 Modeling of Generation Supply and Demand*

To develop a Microgrid Functional Design, GE performed a detailed supply and demand study of each site using the HOMER<sup>6</sup> model.

The HOMER model inputs include:

- The microgrid projected load data, up to two sets of hourly or 12 x 24 load profiles representing the microgrid facilities (i.e., the microgrid total load, separated or aggregated into one or two load profiles),
- Existing and proposed distributed generation sets of different kinds and sizes,
- Generation cost characteristics, including capital costs, fixed operations and maintenance (FOM) costs, and variable operations and maintenance (VOM),
- Fuel costs,
- Criteria Pollutants and Greenhouse Gas emissions, and
- HOMER variability and operating reserve margins and other modeling parameters.

HOMER finds the least cost of generation mix to meet the hourly load for every hour of the year. One can assign different capacity sizes, operating reserve levels, and other parameters as “sensitivities” and Homer determines best generation mix for each sensitivity assumption.

The model outputs information on the selected generation mixes, energy produced, fuel consumption, and emissions. Some of the model outputs are shown in the tables and charts of the following sections.

#### *D.1.2.2 Model Load Data*

##### D.1.2.2.1 Base Load

The NYC site load data consists of load for MHC, NYCHA, and Verizon.

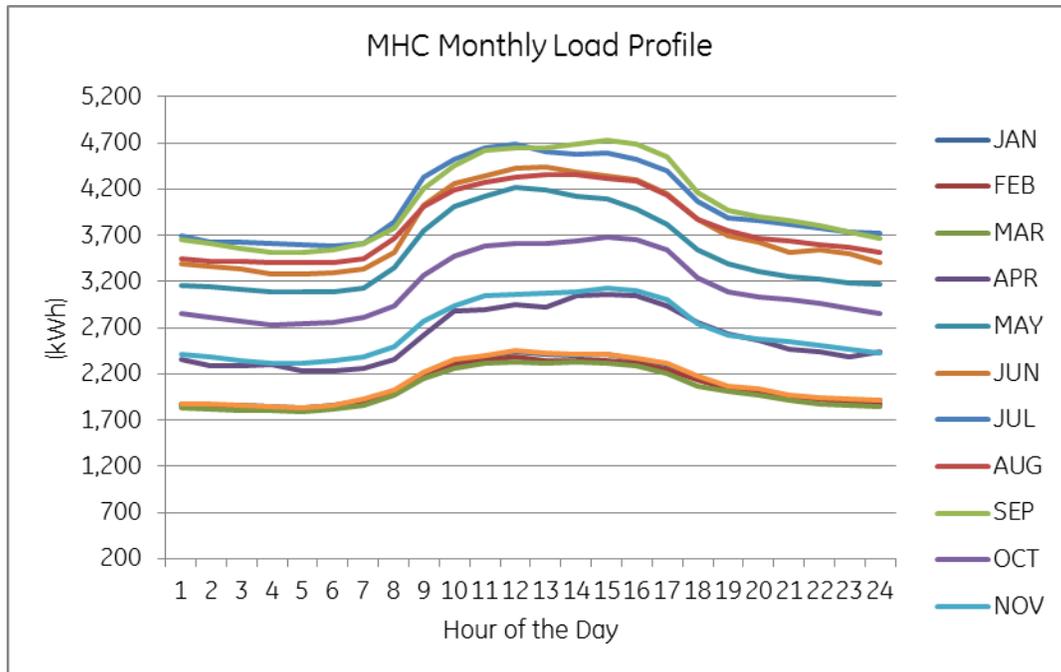
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<sup>6</sup> Hybrid Optimization of Multiple Energy Resources (HOMER), a microgrid optimization model licensed by HOMER Energy LLC: <http://www.homerenergy.com/>

Historic interval load data were obtained from MHC, NYCHA and Verizon. In the case of NYCHA and Verizon, interval data were available for at least a full calendar year. In the case of MHC, interval data were not yet available for the months of November and December. Since HOMER requires only a single peak load value for each hour-of-day in each month, scaling factors were used to extrapolate values from the same hours in adjacent months to fill the gaps, matching the highest peak hour to the known monthly peak loads from utility billing data that was also provided.

Since HOMER could only accept two separate load profiles for analysis, it was decided to aggregate the Verizon and NYCHA loads together. This decision was made because MHC was determined to have the most distinctive characteristics, including both load variability and a diversity of existing on-site generation. Verizon, by contrast, has fairly flat load during different hours of the day, with some seasonal variation due to cooling energy requirements (building loads are driven by IT equipment, which generates heat all year round, however, it is more energy intensive to shed this heat when the outside air temperature is high). The addition of Verizon loads to NYCHA has the effect of preserving the NYCHA shape while shifting it up by a fairly constant amount.

Using the historical hourly load for a whole year, the maximum load of each hour during the month was used to construct the 12 x 24 load profiles. For instance, the model load at hour 15 of April was determined by comparing the load at hour 15 for every day of April (30 numbers to compare) and picking the highest value. This method provides a “conservative” estimate of load, since it picks the maximum load for a given hour across all days of the month. The following figures provide the 12 x 24 load profiles for each of the facilities.



**Figure D-2: MHC Monthly Load Profile**

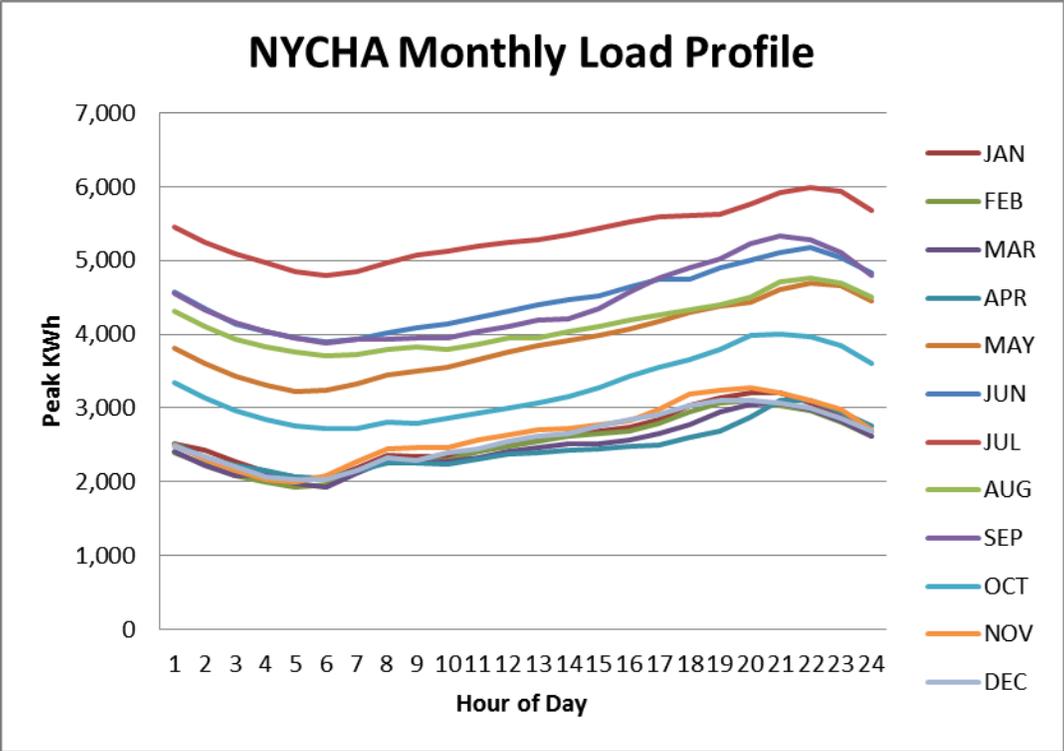


Figure D-3: NYCHA Monthly Load Profile

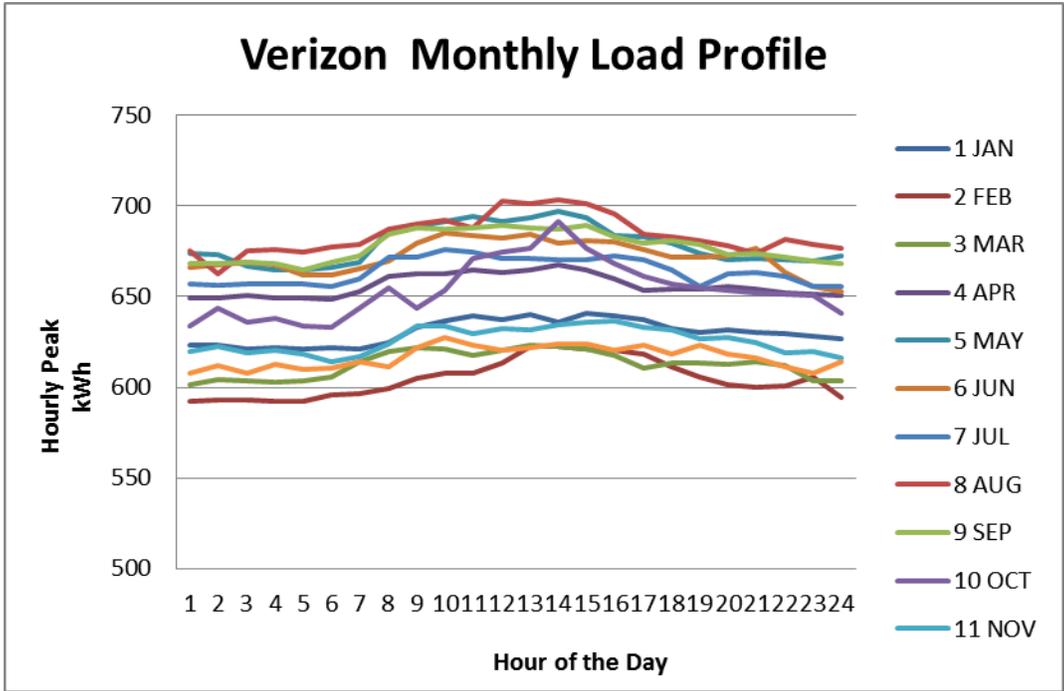


Figure D-4: Verizon Monthly Load Profile

The resulting two Load Profile tables are provided below.

**Table D-4: Monthly Load Profile of MHC**

Season	W	W	W	W	S	S	S	S	S	W	W	W
Month	1	2	3	4	5	6	7	8	9	10	11	12
Hours	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	1,870	1,861	1,835	2,352	3,164	3,396	3,695	3,450	3,660	2,847	2,416	1,878
2	1,863	1,851	1,821	2,290	3,150	3,369	3,623	3,423	3,613	2,810	2,385	1,871
3	1,858	1,843	1,812	2,282	3,114	3,333	3,623	3,414	3,556	2,766	2,347	1,866
4	1,845	1,836	1,808	2,306	3,092	3,286	3,615	3,405	3,516	2,735	2,321	1,853
5	1,828	1,828	1,798	2,232	3,085	3,279	3,600	3,400	3,519	2,737	2,323	1,836
6	1,859	1,841	1,815	2,234	3,082	3,297	3,581	3,407	3,545	2,758	2,340	1,867
7	1,917	1,893	1,863	2,257	3,134	3,341	3,619	3,453	3,614	2,811	2,385	1,926
8	2,014	1,992	1,966	2,351	3,347	3,516	3,849	3,665	3,781	2,941	2,496	2,023
9	2,208	2,183	2,156	2,616	3,755	4,029	4,326	4,006	4,201	3,268	2,773	2,218
10	2,340	2,304	2,267	2,876	4,019	4,255	4,529	4,197	4,458	3,468	2,943	2,351
11	2,385	2,346	2,314	2,897	4,128	4,349	4,653	4,279	4,616	3,591	3,047	2,396
12	2,445	2,387	2,334	2,947	4,225	4,425	4,687	4,329	4,642	3,611	3,064	2,456
13	2,414	2,345	2,316	2,918	4,195	4,437	4,606	4,362	4,649	3,616	3,069	2,425
14	2,405	2,343	2,323	3,041	4,129	4,379	4,577	4,351	4,682	3,642	3,090	2,416
15	2,408	2,350	2,318	3,063	4,092	4,343	4,598	4,322	4,736	3,684	3,126	2,419
16	2,359	2,319	2,289	3,045	3,979	4,306	4,528	4,284	4,692	3,650	3,097	2,370
17	2,308	2,253	2,212	2,943	3,814	4,155	4,403	4,143	4,553	3,542	3,005	2,318
18	2,167	2,132	2,069	2,758	3,549	3,869	4,067	3,874	4,161	3,237	2,746	2,177
19	2,057	2,046	2,012	2,639	3,392	3,698	3,891	3,745	3,967	3,086	2,618	2,066
20	2,028	1,995	1,968	2,560	3,304	3,621	3,861	3,667	3,907	3,039	2,579	2,037
21	1,964	1,953	1,912	2,470	3,256	3,521	3,816	3,634	3,860	3,003	2,548	1,973
22	1,931	1,929	1,876	2,443	3,221	3,545	3,776	3,597	3,808	2,962	2,513	1,940
23	1,915	1,890	1,860	2,389	3,190	3,498	3,743	3,566	3,742	2,911	2,470	1,924
24	1,910	1,871	1,843	2,434	3,174	3,408	3,719	3,513	3,668	2,853	2,421	1,919

**Table D-5: Monthly Load Profile of NYCHA plus Verizon**

Season	W	W	W	W	S	S	S	S	S	W	W	W
Month	1	2	3	4	5	6	7	8	9	10	11	12
Hours	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	3,141	2,991	3,016	3,160	4,488	5,242	6,104	4,982	5,228	3,987	3,115	3,089
2	3,056	2,826	2,825	2,981	4,275	5,020	5,907	4,767	5,006	3,777	2,932	2,952
3	2,902	2,675	2,680	2,868	4,101	4,814	5,750	4,615	4,834	3,601	2,771	2,811
4	2,760	2,582	2,696	2,797	3,976	4,702	5,621	4,512	4,704	3,481	2,660	2,682
5	2,679	2,527	2,590	2,707	3,896	4,612	5,510	4,433	4,623	3,395	2,619	2,642
6	2,661	2,553	2,539	2,694	3,900	4,568	5,450	4,389	4,547	3,356	2,702	2,646
7	2,804	2,735	2,738	2,812	3,997	4,591	5,502	4,398	4,603	3,374	2,884	2,772
8	2,978	2,919	2,911	2,923	4,145	4,686	5,638	4,485	4,620	3,463	3,073	2,930
9	2,973	2,881	2,882	2,918	4,195	4,760	5,739	4,520	4,634	3,433	3,090	2,917
10	2,986	2,891	2,896	2,898	4,249	4,834	5,797	4,490	4,630	3,513	3,100	3,013
11	3,047	3,012	2,950	2,975	4,359	4,918	5,877	4,557	4,727	3,603	3,197	3,067
12	3,148	3,094	3,040	3,045	4,449	4,990	5,911	4,652	4,802	3,675	3,271	3,165
13	3,203	3,172	3,086	3,064	4,548	5,081	5,960	4,660	4,888	3,752	3,331	3,242
14	3,289	3,240	3,138	3,091	4,615	5,144	6,020	4,744	4,900	3,843	3,364	3,277
15	3,330	3,278	3,144	3,112	4,677	5,205	6,107	4,799	5,034	3,950	3,414	3,380
16	3,386	3,310	3,183	3,133	4,757	5,325	6,203	4,893	5,264	4,094	3,466	3,460
17	3,478	3,411	3,256	3,146	4,859	5,418	6,256	4,943	5,437	4,219	3,612	3,544
18	3,664	3,555	3,394	3,262	4,970	5,423	6,272	5,014	5,578	4,320	3,824	3,644
19	3,773	3,672	3,565	3,343	5,049	5,569	6,292	5,080	5,693	4,447	3,873	3,726
20	3,845	3,697	3,657	3,542	5,109	5,670	6,438	5,177	5,899	4,646	3,901	3,718
21	3,842	3,636	3,676	3,757	5,284	5,778	6,588	5,393	6,016	4,652	3,840	3,680
22	3,699	3,567	3,596	3,759	5,368	5,840	6,651	5,445	5,946	4,622	3,726	3,613
23	3,510	3,407	3,433	3,599	5,323	5,698	6,599	5,366	5,773	4,491	3,594	3,468
24	3,310	3,206	3,220	3,411	5,120	5,487	6,341	5,183	5,463	4,253	3,324	3,300

D.1.2.2.2 Critical Load Modifiers

Before introducing the loads into HOMER, assumptions were developed for each facility about the minimum percentage of load that would be critical to serve in an emergency and would therefore justify inclusion in microgrid design. For MHC and Verizon, these assumptions were provided by the existing backup capability of the facilities and confirmed by facility staff. MHC provides backup for 40% of its load – this corresponds to the consumption of in-patient care and critical life services, food preparation and laundry for residential patients, etc. During Superstorm Sandy, Metro Hospital was able to

accommodate additional patient load from evacuees from Bellevue Hospital with its existing generation, therefore GE assumed no further emergency premium would be required.

Verizon backs up 100% of its load and considers it all to be critical. No further modifier is therefore required. Verizon would most likely act as a “donor” site during planned microgrid operation, exporting power to the other facilities. For Verizon, the main benefit of participation in the microgrid would likely be the potential to integrate with neighboring systems to enable greater resilience in the event of a generator failure, maintenance downtime, fuel shortage, or other constraint in operating exclusively on backup power during an extended emergency outage.

In the case of NYCHA, the determination of critical load is more subjective, since there is no existing backup or physical separation of critical from non-critical loads. During Superstorm Sandy, residents were without not only domestic electricity but common building services, such as stairway lighting, elevators and pumped water for sanitation. These services are considered critical, due to the requirements of high rise apartment living. NYCHA’s objective for the microgrid would be to provide these services first in an emergency and supply power for other building loads, secondarily. However, NYCHA does not maintain a centralized record of the internal wiring of the buildings. Each building’s electrical system and circuit panel is configured differently, and without a detailed audit of each building, GE was unable to determine the ability to segregate critical from non-critical loads. Even with further investment in automation, it is likely that in many instances critical loads may be co-mingled on the same circuit with non-critical loads. Therefore, as a conservative design assumption, GE assumed 50% of the normal NYCHA load would need to be met during an emergency, in order to serve the necessary critical loads, as well as any other, non-critical loads co-mingled on the same in-building circuits.

In the event design work were to move forward toward construction of a microgrid at this site, a prudent first step would be to conduct further evaluation and audit of the actual current state of the building electrical systems within the NYCHA buildings, and to consider further investment requirements to upgrade and/or reconfigure circuit panels and building controls, in order to direct power to the most critical loads in each building during microgrid operation.

**Table D-6: NYC Site Critical Load Modifiers**

Facility	Critical Load as a Percentage of Base Load
MHC	<ul style="list-style-type: none"> <li>• 40% (in-patient and critical care)</li> </ul>
NYCHA	<ul style="list-style-type: none"> <li>• 50% (elevators, water pumping, and additional non-critical loads co-mingled on the same circuits)</li> </ul>
Verizon	<ul style="list-style-type: none"> <li>• 100%</li> </ul>

The final input loads for the HOMER model, after adjusting for the critical load modifiers are shown below:

**Table D-7: Monthly Load Profile of MHC**

Season	W	W	W	W	S	S	S	S	S	W	W	W
Month	\$1.00	\$2.00	\$3.00	\$4.00	\$5.00	\$6.00	\$7.00	\$8.00	\$9.00	\$10.00	\$11.00	\$12.00
Hours	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
\$1.00	748	744	734	941	1,266	1,358	1,478	1,380	1,464	1,139	966	751
\$2.00	745	740	728	916	1,260	1,348	1,449	1,369	1,445	1,124	954	749
\$3.00	743	737	725	913	1,246	1,333	1,449	1,366	1,422	1,106	939	747
\$4.00	738	734	723	922	1,237	1,314	1,446	1,362	1,406	1,094	928	741
\$5.00	731	731	719	893	1,234	1,312	1,440	1,360	1,408	1,095	929	734
\$6.00	744	736	726	894	1,233	1,319	1,432	1,363	1,418	1,103	936	747
\$7.00	767	757	745	903	1,254	1,336	1,448	1,381	1,446	1,124	954	770
\$8.00	806	797	786	940	1,339	1,406	1,540	1,466	1,512	1,176	998	809
\$9.00	883	873	862	1,046	1,502	1,612	1,730	1,602	1,680	1,307	1,109	887
\$10.00	936	922	907	1,150	1,608	1,702	1,812	1,679	1,783	1,387	1,177	940
\$11.00	954	938	926	1,159	1,651	1,740	1,861	1,712	1,846	1,436	1,219	958
\$12.00	978	955	934	1,179	1,690	1,770	1,875	1,732	1,857	1,444	1,226	982
\$13.00	966	938	926	1,167	1,678	1,775	1,842	1,745	1,860	1,447	1,227	970
\$14.00	962	937	929	1,216	1,652	1,752	1,831	1,740	1,873	1,457	1,236	966
\$15.00	963	940	927	1,225	1,637	1,737	1,839	1,729	1,894	1,474	1,250	968
\$16.00	944	928	916	1,218	1,592	1,722	1,811	1,714	1,877	1,460	1,239	948
\$17.00	923	901	885	1,177	1,526	1,662	1,761	1,657	1,821	1,417	1,202	927
\$18.00	867	853	828	1,103	1,420	1,548	1,627	1,550	1,664	1,295	1,099	871
\$19.00	823	818	805	1,056	1,357	1,479	1,556	1,498	1,587	1,234	1,047	827
\$20.00	811	798	787	1,024	1,322	1,448	1,544	1,467	1,563	1,216	1,032	815
\$21.00	786	781	765	988	1,302	1,408	1,526	1,454	1,544	1,201	1,019	789
\$22.00	772	772	750	977	1,288	1,418	1,510	1,439	1,523	1,185	1,005	776
\$23.00	766	756	744	956	1,276	1,399	1,497	1,426	1,497	1,164	988	769
\$24.00	764	748	737	974	1,270	1,363	1,488	1,405	1,467	1,141	968	767
	20,119	19,836	19,515	24,937	33,836	36,262	38,794	36,594	38,858	30,227	25,649	20,210

**Table D-8: Monthly Load Profile of NYCHA plus Verizon**

Season	W	W	W	W	S	S	S	S	S	W	W	W
Month	\$1.00	\$2.00	\$3.00	\$4.00	\$5.00	\$6.00	\$7.00	\$8.00	\$9.00	\$10.00	\$11.00	\$12.00
Hours	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
\$1.00	1,882	1,792	1,809	1,905	2,581	2,954	3,381	2,828	2,948	2,311	1,867	1,848
\$2.00	1,840	1,709	1,715	1,815	2,474	2,844	3,281	2,715	2,837	2,210	1,777	1,782
\$3.00	1,762	1,634	1,642	1,759	2,384	2,741	3,203	2,645	2,751	2,118	1,695	1,709
\$4.00	1,691	1,587	1,649	1,723	2,320	2,685	3,139	2,594	2,686	2,059	1,640	1,647
\$5.00	1,650	1,560	1,597	1,678	2,280	2,637	3,083	2,554	2,644	2,015	1,618	1,626
\$6.00	1,641	1,574	1,572	1,671	2,283	2,615	3,053	2,533	2,608	1,995	1,658	1,628
\$7.00	1,713	1,666	1,676	1,732	2,333	2,628	3,081	2,538	2,638	2,009	1,750	1,693
\$8.00	1,802	1,759	1,765	1,792	2,416	2,678	3,155	2,586	2,652	2,059	1,848	1,771
\$9.00	1,803	1,743	1,752	1,790	2,442	2,720	3,205	2,605	2,661	2,038	1,862	1,769
\$10.00	1,811	1,749	1,759	1,780	2,470	2,759	3,236	2,591	2,659	2,084	1,867	1,820
\$11.00	1,843	1,810	1,784	1,820	2,527	2,801	3,276	2,623	2,708	2,137	1,913	1,845
\$12.00	1,893	1,854	1,830	1,854	2,570	2,836	3,291	2,677	2,745	2,175	1,952	1,893
\$13.00	1,922	1,897	1,855	1,864	2,621	2,883	3,316	2,681	2,788	2,214	1,981	1,932
\$14.00	1,962	1,931	1,880	1,879	2,656	2,912	3,345	2,724	2,793	2,268	1,999	1,950
\$15.00	1,985	1,950	1,883	1,889	2,685	2,943	3,389	2,750	2,862	2,313	2,025	2,002
\$16.00	2,013	1,965	1,900	1,896	2,721	3,002	3,438	2,794	2,974	2,381	2,051	2,040
\$17.00	2,058	2,015	1,933	1,900	2,771	3,047	3,463	2,814	3,058	2,440	2,123	2,084
\$18.00	2,148	2,083	2,004	1,958	2,825	3,048	3,468	2,848	3,130	2,488	2,228	2,131
\$19.00	2,202	2,139	2,089	1,999	2,861	3,120	3,474	2,881	3,186	2,551	2,250	2,174
\$20.00	2,238	2,149	2,135	2,099	2,890	3,171	3,550	2,928	3,286	2,650	2,264	2,168
\$21.00	2,236	2,118	2,145	2,205	2,978	3,227	3,626	3,033	3,345	2,652	2,233	2,148
\$22.00	2,164	2,084	2,104	2,206	3,019	3,251	3,656	3,063	3,309	2,637	2,173	2,112
\$23.00	2,069	2,006	2,019	2,125	2,996	3,177	3,628	3,022	3,221	2,571	2,106	2,038
\$24.00	1,968	1,900	1,912	2,031	2,896	3,070	3,498	2,930	3,066	2,447	1,970	1,957
	46,295	44,674	44,407	45,372	62,999	69,750	80,236	65,958	69,555	54,821	46,851	45,770

*D.1.2.3 Model Generation and Fuel Data*

The existing generation set at the NYC Site includes the following:

**Table D-9: Existing Generation Resources at NYC Site**

Plant	Capacity
MHC-1	600 kW
MHC-2	675 kW
MHC-3	750 kW
Verizon	750 kW
<b>Total</b>	<b>2,775 kW</b>

Additional generators were modeled in HOMER to meet the difference between existing backup generation and critical load.

For purposes of setting a lower bound for the least cost microgrid design, all new generation units are assumed to be diesel in this analysis.

The use of diesel generation as the least cost incremental generation resource should not be interpreted as an endorsement or recommendation of diesel as the best solution for any site. Diesel generation may have undesirable characteristics when compared to other generation options, such as high emissions, noise, and space requirements (including space for generators, fuel storage tanks, fueling truck access, etc.).

In a subsequent section, this report provides an assessment of two alternate scenarios of higher cost, but potentially more desirable alternatives, solar photovoltaic (PV) and Combined Heat and Power (CHP), using natural gas.

*D.1.2.4 Generation Selection Considerations*

GE considered two possible scenarios of new generation in HOMER:

- S1 Scenario – In this scenario, critical requirements are met with the existing generation, plus six new diesel generators as follows:

**Table D-10: S1 Scenario Generation**

Verizon	750 kW
Metro-1	600 kW
Metro-2	675 kW
Metro-3	750 kW
New Diesel 1	750 kW
New Diesel 2	750 kW
New Diesel 3	500 kW
New Diesel 4	500 kW
New Diesel 5	500 kW
New Diesel 6	375 kW

- S2 Scenario – For this scenario, GE wanted to explore what would happen if MHC’s three aging diesel generators were replaced with new, larger and more efficient 1000 kW diesel units. In this scenario, only 5 New Diesel units were required to meet the critical loads.

**Table D-11: S2 Scenario Generation**

Verizon	750 kW
New Metro-1	1,000 kW
New Metro-2	1,000 kW
New Metro-3	1,000 kW
New Diesel 1	500 kW
New Diesel 2	500 kW
New Diesel 3	500 kW
New Diesel 4	500 kW
New Diesel 5	375 kW

There is currently no plan or funding in place to replace the MHC generators; therefore, only the S1 scenario was utilized for design of the microgrid. However, as can be seen from the above, the likely need

to eventually replace the aging MHC units could result in significant savings to the microgrid, due to the reduced capital cost of the additional generation required to meet critical loads.

### D.1.3 Microgrid Infrastructure Configuration

#### D.1.3.1 Model Generation Options

HOMER produced results for generator energy production, their O&M and Fuel costs, fuel consumption, and emissions. It is assumed that the Microgrid will be functional for a minimum duration of one month – although there is no reason to assume that the microgrid cannot run for longer periods of time if the generators are regularly supplied with fuel. Hence, the following results are for a one-month operation of the microgrid.

**Table D-12: NYC Site Generation Performance**

Generation	Capacity (kW)	Production (kWh/Month)	Capacity Factor	Fuel Consumption (Gallons/Month)	O&M Costs (\$/Month)	Fuel Costs (\$/Month)	Total Variable Costs (\$/Month)
Verizon	750	547,500	100.0%	39,297	9,308	119,521	128,829
Metro-1	600	299,900	68.5%	21,526	5,098	65,477	70,575
Metro-2	675	296,156	60.1%	21,257	5,035	64,655	69,689
Metro-3	750	515,428	94.1%	36,995	8,764	112,521	121,285
New Diesel 1	750	381,208	69.6%	27,362	6,487	83,225	89,712
New Diesel 2	750	214,057	39.1%	15,364	3,643	46,735	50,378
New Diesel 3	500	323,346	88.6%	23,208	5,517	70,589	76,106
New Diesel 4	500	249,743	68.4%	17,925	4,290	54,521	58,811
New Diesel 5	500	133,483	36.6%	9,581	2,315	29,142	31,456
New Diesel 6	375	144,845	52.9%	10,396	2,750	31,622	34,372
<b>Total</b>	6150	3,105,666	69.2%	222,912	53,205	678,008	731,213

It should be noted that since all generation resources are diesel-fueled, and have similar assumed characteristics, they are actually interchangeable and similar electricity generation, fuel consumption, and O&M and fuel costs can be achieved if total generation is redistributed differently among different plants.

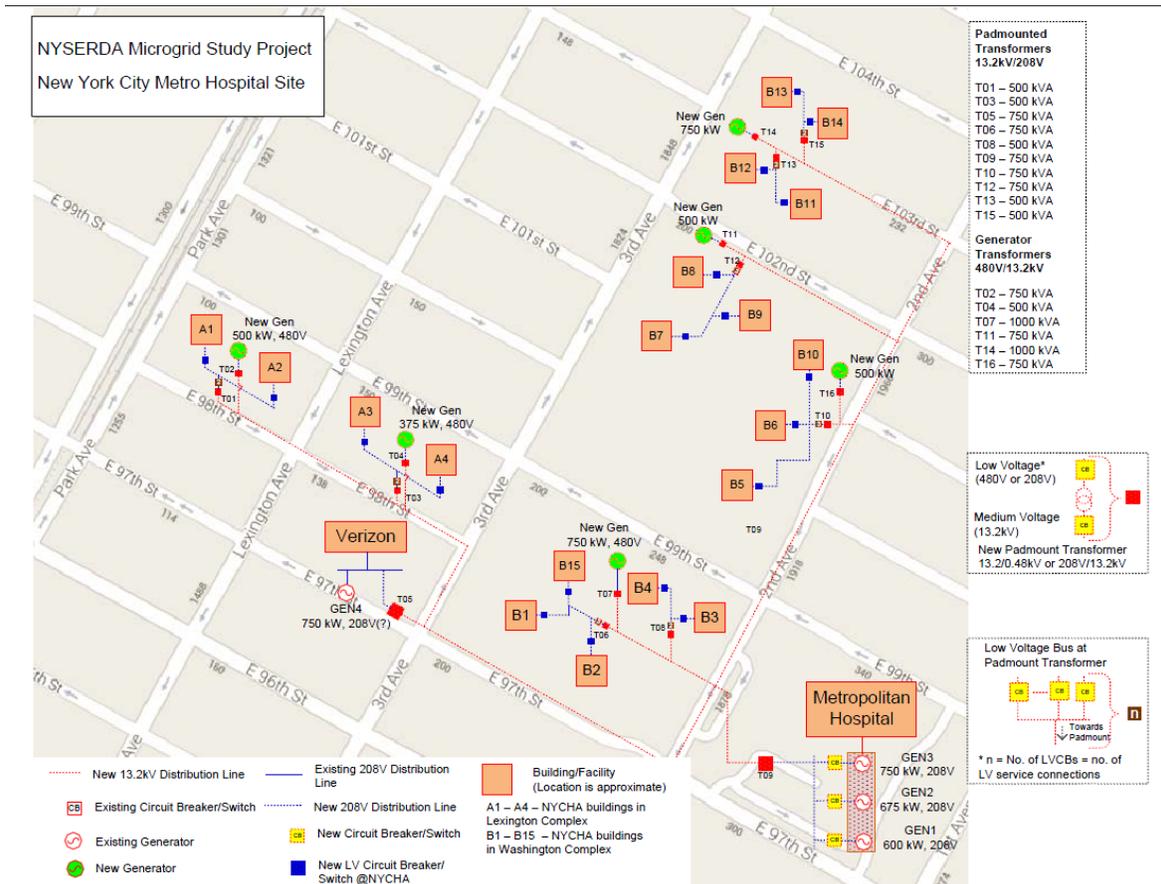
The following table presents the emissions from the NYC site generation:

**Table D-13: Monthly Emissions**

Pollutant	kg/MWh
Carbon dioxide	718.61
Carbon monoxide	1.77
Unburned hydrocarbons	0.20
Particulate matter	0.13
Sulfur dioxide	1.44
Nitrogen oxides	13.11

*D.1.3.2 Electrical Infrastructure*

Figure D-5 provides an overview of the NYC electrical infrastructure, including proposed locations for the new generators (shown in green) required to support the microgrid.



**Figure D-5: Layout of Electrical Infrastructure (NYC Site)**

The following considerations are specific to the NYC site:

- The three existing generators at Metro Hospital are considered to be interconnected or capable of interconnection without additional hardware/software.
- The NYCHA complexes are considered to have enough space within the property (or basement) to house new generators, generator transformers and padmounted transformers.
- The underground trench/vaults are considered to have enough space for installation of new distribution lines.

### D.1.3.3 Control and Communications Infrastructure

The Communications and Control design for the NYC Site is based on the GE Microgrid Reference Architecture described previously. Figure D-6 below shows the Site specific design.

## NYC MG: Control & Communications Architecture

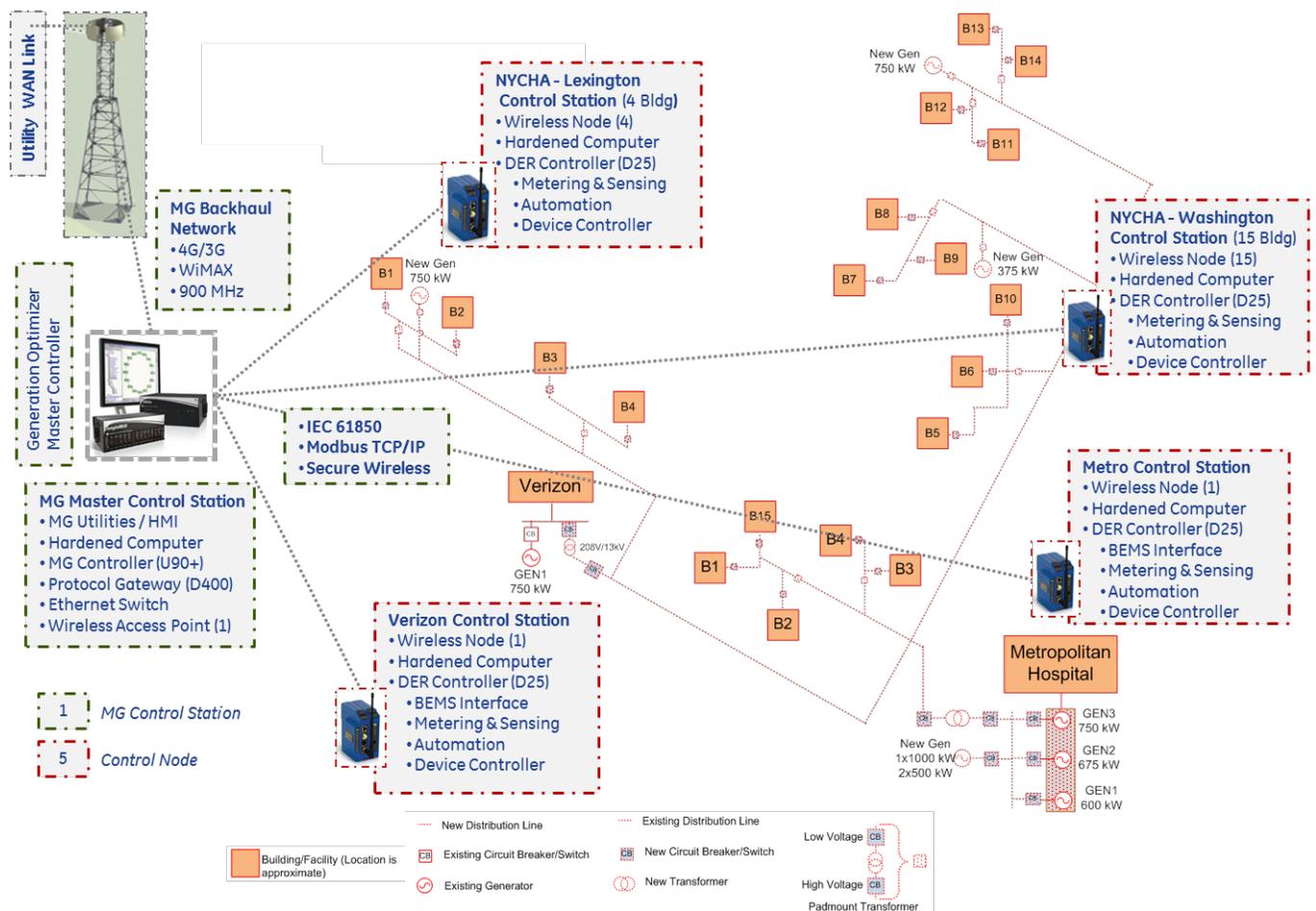


Figure D-6: Microgrid Electrical One-Line Diagram with Control and Communications Overlay (NYC Site)

#### D.1.4 Cost Summary

##### *D.1.4.1 Microgrid Cost Estimate Development*

Based on the analysis performed and details of the functional design, GE team developed its “best estimates” of the cost of microgrid development, using public and non-public sources, with an expected accuracy of +/- 30%.

As noted earlier, additional information needed to construct the energy balance model, fuel data, and generation operational and cost parameters were collected by the GE team, some from public data, and others from internal GE sources. Some of the values used in the analysis are based on unofficial, non-public, and subjective assessments, but provide a best estimate tempered by the availability of data.

The microgrid development cost components included (but not limited to) the following:

- Microgrid DG Costs (Capital, Fixed, Operations and Maintenance, Fuel, Etc.)
- Microgrid Control and Communications Infrastructure (components and installation)
- Microgrid Electrical Infrastructure Costs (components and Installations)
- Annual Microgrid Operations and Maintenance Costs

##### *D.1.4.2 Electric Generation Cost*

Capital costs are shown for new generation units. Existing generating units are not incremental to the microgrid, therefore their capital costs are not included in this study. Variable costs include O&M and fuel consumption during microgrid operation.

**Table D-14: NYC Site Generation Costs**

Generation	Capacity (kW)	Capital Cost (\$)	O&M Costs (\$/Month)	Fuel Costs (\$/Month)	Total Variable Costs (\$/Month)
Verizon	750	N/A	9,308	119,521	128,829
Metro-1	600	N/A	5,098	65,477	70,575
Metro-2	675	N/A	5,035	64,655	69,689
Metro-3	750	N/A	8,764	112,521	121,285
New Diesel 1	750	637,500	6,487	83,225	89,712
New Diesel 2	750	637,500	3,643	46,735	50,378
New Diesel 3	500	425,000	5,517	70,589	76,106
New Diesel 4	500	425,000	4,290	54,521	58,811
New Diesel 5	500	425,000	2,315	29,142	31,456
New Diesel 6	375	318,750	2,750	31,622	34,372
<b>Total</b>	<b>6,150</b>	<b>2,868,750</b>	<b>53,205</b>	<b>678,008</b>	<b>731,213</b>

##### *D.1.4.3 Electrical Infrastructure Cost*

The following table summarizes the NYC microgrid electrical infrastructure average cost estimates.

The cost for all electrical infrastructure components are the best estimates obtained from GE internal sources and verified from utility engineers (not related to Microgrid site).

**Table D-15: NYC Microgrid Electrical Infrastructure Average Cost Estimates**

SN	Item	Description	Quantity	Unit	Unit Price (Installed) (\$)	Cost (\$)
1	15 kV Class 3-Ph Cable	HV Cable to connect Hospital, Verizon and NYCHA buildings (Conduit)	7200	Ft.	60	432,000
2	600 V Class 3-Ph Cable	LV Cable to connect transformers to backup generators and buildings	3000	Ft.	60	180,000
3	High Voltage (15kV class) Switch/Circuit Breakers	HV switches at various locations	16	Nos.	20,000	320,000
4	Low Voltage Circuit Breakers	LV Circuit Breakers at various locations	57	Nos.	10,000	570,000
5	1000 kVA Transformer	Generator transformers at NYCHA locations	2	Nos.	20,000	40,000
6	750 kVA Transformer	Generator and Padmount transformers at NYCHA locations	6	Nos.	16,000	96,000
7	500 kVA Transformer	Generator and Padmount transformers at NYCHA locations	6	Nos.	13,000	78,000
8	750 kVA Transformer	Padmount transformer at Metro Hospital	1	Nos.	16,000	16,000
9	750 kVA Transformer	Padmount transformer at Verizon building	1	Nos.	16,000	16,000
10	Transition Compartment	One each at Verizon and 19 NYCHA buildings, and three at Metro Hospital	23	Nos.	10,000	230,000
11	Protection System Evaluation	Model the existing system with new infrastructure and evaluate the protection system	1	unit	50,000	50,000
<b>Total</b>						<b>2,028,000</b>

Based on the methodology used for the electrical infrastructure cost estimation, the values presented should be assumed to be the “average” cost estimates. A 10% low and high adjustment was used to calculate the Low and High bookends of electrical infrastructure costs.

#### *D.1.4.4 Control & Communications Cost*

Similar to the approach for electrical infrastructure cost estimation, to get component costing, GE referred to its internal sources. GE utilized its information (documents, website, internal communication), and

used the online purchase menus to configure the devices per the store menus and ascertain a price for all communications and control hardware and supporting software applications. GE used list price in all cases to stay at a relatively conservative level.

To estimate system and project costs, GE first created the control/communication costing spread sheets to establish a list of required engineering, design, integration, and site activities. Details of each are described in the notes column. Based on the engineering activities GE estimated number of labor/months per tasks and used EC commercial rates to get a number.

To validate costs GE compared its derived numbers to some industry sources. Two sources in particular were noted: 1) Minnesota Microgrid Project, and 2) DOE Microgrid workshops. GE cost numbers were somewhat higher, but that was clearly due to the fact GE had originally used its commercial consulting rates for engineering design labor. GE has finalized its numbers using a Low, Average, and High estimates in order to provide a range.

The following table summarizes the NYC Microgrid Control & Communications Infrastructure “High” cost estimates. Estimates of integration cost were developed separately for the facilities with existing Building Energy Management Systems (BEMS), Verizon and MHC, versus the facilities with little or no existing BEMS capability (NYCHA). The integration costs are expected to be much higher for buildings that have existing BEMS (which already provide a high level of operational visibility and control), as the Microgrid would need to be integrated within the complex systems and interfaces already present within these facilities. For the case of a highly automated building, the MG would need to be gracefully integrated with the existing BEMS platform and in some cases require more formal integration with control devices and other systems located throughout the building.

Based on the methodology used for the electrical infrastructure cost estimation, the values presented should be assumed to be the “high” cost estimates. The “average” cost estimate is 10% lower than the high cost estimate. Similarly, the “low” cost estimate is 10% lower than the average cost estimate.

**Table D-16: NYC Microgrid Control & Communications High Cost Estimates (Rounded to the Nearest \$100)**

Item - P/N	Description	Unit Price (\$)	QTY	Cost (\$)	Notes
MG Master Control Station					
MG Control Station Computer	MG Station Computer: Hosts MG EMS application. Hardened computer with processor/comm/interface expansion ports. Rack system.	15,000	1	15,000	Dell PowerEdge R270 Rackmount Server. Racks, Displays, Peripherals. SQL Server DBMS. Priced to approximate a hardened computer to host MG substation applications and support NERC compliance and multiple I/F options
GE EnerVista Engineer	MG Configuration Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Maintenance	MG Maintenance Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Monitoring	MG Monitoring Utility	2,000	1	2,000	MG controller HMI and configuration app
GE EnerVista Integrator	MG Device Integration	1,500	1	1,500	MG controller HMI and configuration app
GE Cimplicity	Cimplicity Globalview and Cimplicity Development	100,000	1	100,000	HMI/SCADA framework providing event/alarm monitoring, logging, and SCADA configuration tools.
GE Multilin U90+	MG Generation Controller/Optimizer	25,000	1	25,000	MG Generation Controller via Multilin UR family. Forecasting and optimal dispatch functions
GE D400	Advanced Protocol Gateway	9,000	1	9,000	Multifunction intelligent gateway. Provides control interface and data collection from protection, control, monitoring, RTU, IED's.. Configured using Logixlinx software.
System Integration & I/F Modules	Integration & Control Software: Application functions, control functions, component adapters, and automation scripts	500,000	1	500,000	Engineering labor estimate for code development/integration of site-specific control and automation of buildings, systems, devices, and generators. (TBD scope: depending on requirement for monitoring and automated control of buildings and electrical infrastructure)

MG Campus Ctl Station (Facilities with BEMS)					
Control Station Computer	Application Host Computer	5,000	2	10,000	Dell PowerEdge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	4	2,000	Smart meter monitors main facility load. BEMS I/F provides detailed monitoring.
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	2	18,000	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
BEMS Integration	Configuration/Integration	100,000	2	200,000	BEMS configuration and integration with campus controller. Requires technical discussions with BEMS vendor and facility energy manager.
MG Campus Ctl Station (Facilities w/o BEMS)					
Control Station Computer	Application Host Computer	10,000	2	20,000	Dell PowerEdge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	19	9,500	interval load monitoring
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	2	18,000	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
Control Node Integration	Integration/Configuration	20,000	2	40,000	Integration/Configuration/Unit-Testing Multifunction controller at campus stations
MG Communications					
GE MDS orbit - MCR-4G access point	MG Control Station network access point: (900Mhz,3G/4G,WiFi, 10-100Ethernet, VoIP, Serial RS232/485)	2,200	1	2,200	Wireless access point for MG control station. Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900Mhz Mesh or 3G/4G as needed for linking to utility field network. Use 900Mhz mesh to MG control nodes at

buildings.

GE MDS orbit - remote mxnx-u91-s1n	MG remote control point: MG Sub/FacilityDevice/DG link: (900Mhz,WiFi, 10- 100Ethernet)	1,500	21	31,500	Wireless remote node (1 per building)... Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900 MHz Mesh network back to MG control station. Use Wi-Fi or Ethernet for points inside or near buildings.
GE MLS2400 Ethernet Switch	Network switch panel for MG substation. VoIP/SCADA/Relay data connected via Ethernet	3,000	24	72,000	Ethernet switch, rack, power (1 per building). Wireless access point goes into switch then Wireless or Ethernet to any controllable elements in building.
Total				1,078,700	

#### D.1.4.5 Total Microgrid Cost Estimates

In addition to the generation costs and the costs of the physical elements used in the control & communications infrastructure and the electrical infrastructure, there are additional costs associated with initial microgrid controller development, engineering specification and design, and actual installation and project management. The following table provides a detailed listing of all the elements of the installed microgrid system costs.

**Table D-17: NYC Microgrid Full System Cost Estimates (Rounded to the Nearest \$1000)**

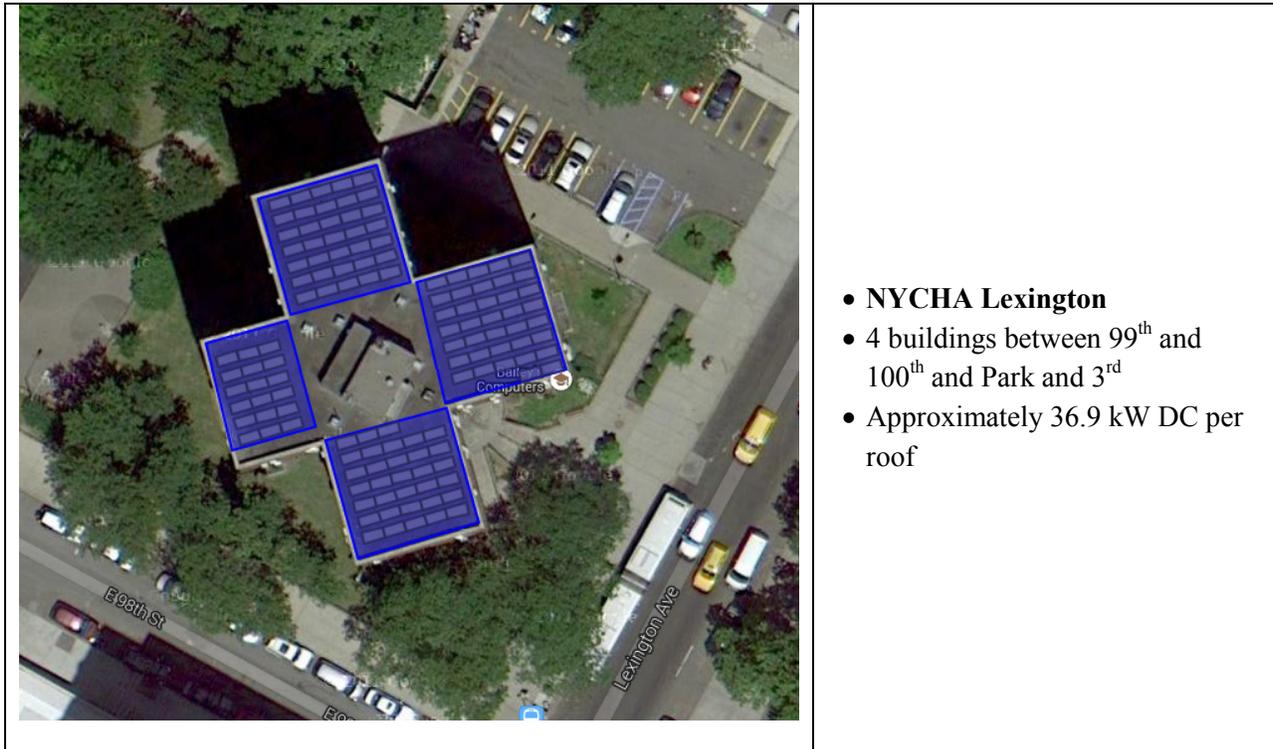
Project Activity	Description	Low (\$)	AVG (\$)	High (\$)	Type
<b>Amortized Development of the MG Energy Management System</b>	<b>Integrate U90 master controller and the D400 control nodes with the PCMS EMS. Develop any extra system orchestration functions not native to the off the shelf commercial EMS that are required to perform NYSERDA MG operations.</b> -MG System Orchestration -Control Loads -Control Generators -Planning/Forecasting/Scheduling -Monitoring/Diagnostics -Utility Data Exchange -Grid PCC Mgmt. -Utility Baseline Integration	396,000	554,000	710,000	General Development
<b>MG Communications Fabric Planning/Installation/Configuration</b>	<b>All wireless communications platforms</b> -Communications from the MG control room to MG control nodes. -Communication from MG control room to utility	77,000	86,000	95,000	Site Specific Planning & Development

<b>MG Test Plan Development</b>	<b>Design evaluation and stress tests to validate every function and every protection and safety scheme in the system.</b> -develop formal test plan -design test and validation control and workflows - write corresponding code/scripts	748,000	1,024,000	1,296,000	Site Specific Planning & Development
<b>MG System Integration &amp; Site Certification</b>	<b>Run tests to validate every function, system and device in the entire system. All facilities, buildings, BEMS, Generators, MG control fabric, MG electrical fabric, and MG communications fabric.</b> - Execute tests and document results - Orchestrate formal acceptance process - Obtain formal site sign off	190,000	266,000	340,000	Site Specific Planning & Development
<b>Project Management</b>	<b>Program Management, Administration, and Technical interchange meetings</b> -Technical interchange with utility/vendors/NYSERDA/DHS/Gov/etc. -Requirements collection and scope definition for complete system - Developing and Reviewing SOWS/RFP/Proposals to subs and vendors -Manage multiple subs and vendor -Manage technical development -Manage internal GE teams -Program interface with sponsors -Reporting and accounting	1,008,000	1,392,000	1,776,000	Site Specific Planning & Development
<b>Site Design Engineering and Construction</b>	<b>Microgrid Detailed Systems Design</b> -Develop formal technical specification -Power Systems Analysis -Power Systems Simulation -Site Planning & Licensing -Site Construction	1,036,000	1,432,000	1,824,000	Site Specific Planning & Development
<b>Distributed Generation BOM</b>	<b>New Distributed Generation</b>	2,582,000	2,869,000	3,156,000	CAPEX
<b>Control &amp; Communications BOM</b>	<b>CAPEX for the control and communications subsystem</b>	874,000	971,000	1,079,000	CAPEX
<b>MG Electrical Infrastructure</b>	<b>All required electrical distribution components</b> -/xformers/feeders/switching/protection/ss integration/etc.	1,825,000	2,028,000	2,231,000	CAPEX
<b>Microgrid Maintenance and Support</b>	<b>All software licenses and tech support</b> - maintain MG system - provide 24/7 tech line support - perform routine software maintenance and upgrade	41,000	45,000	50,000	Annual O&M
<b>Total MG One-Time Cost</b>		<b>8,736,000</b>	<b>10,622,000</b>	<b>12,507,000</b>	
<b>Annual MG O&amp;M Cost</b>		<b>41,000</b>	<b>45,000</b>	<b>50,000</b>	

## D.1.5 Alternative Scenarios: PV and CHP

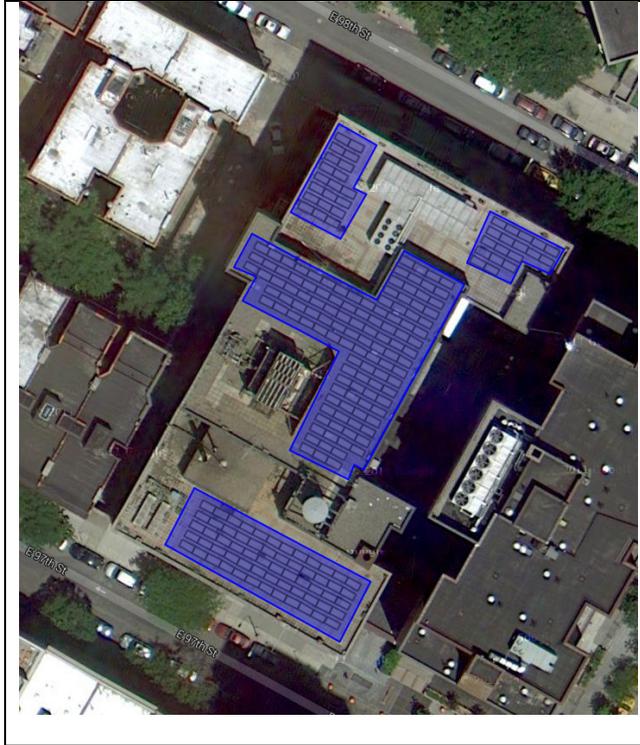
### D.1.5.1 *Solar PV*

As an alternative to the least cost all diesel scenario, GE wanted to explore the technical potential for solar PV within the NYC Site. GE's partner Sungevity is a solar design and construction firm specializing in site engineering of solar PV systems using internet-based satellite imagery. At GE's request<sup>7</sup>, Sungevity applied its proprietary model to available images of the NYC site and determined that approximately 1 MW (DC) of solar PV could be accommodated within the existing roof area. Visible features, such as rooftop HVAC equipment and shading from adjacent structures are taken into account. The following renderings show the Sungevity preliminary designs:



**Figure D-7: Solar PV Rendering of NYCHA Lexington**

<sup>7</sup> Estimates prepared by Steve Birndorf, Director Commercial Development, sbirndorf@sungevity.com.



- **Verizon Building**
- 151 East 97<sup>th</sup>
- Approximately 65.1 kW DC in total

**Figure D-8: Solar PV Rendering of Verizon Building**

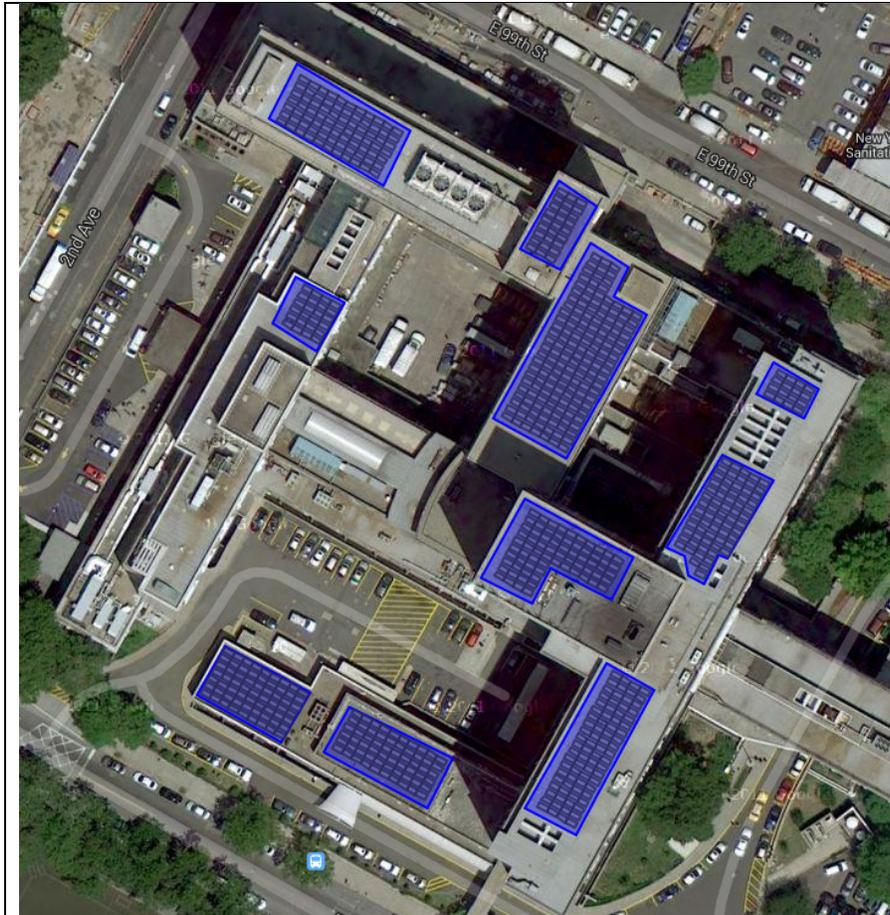


- **NYCHA Washington**
- B1 – B4
- 4 buildings between 97<sup>th</sup> and 99<sup>th</sup> and 3<sup>rd</sup> and 2<sup>nd</sup>
  
- B5 – B10
- 6 buildings between 102<sup>nd</sup> and 99<sup>th</sup> and 2<sup>nd</sup> and 3<sup>rd</sup>
  
- B11 – B14
- 4 buildings between 102<sup>nd</sup> and 104<sup>th</sup> and 2<sup>nd</sup> and 3<sup>rd</sup>
  
- Approximately 39.9 kW DC per roof



- **NYCHA Washington (cont'd)**
- B15
- 1 buildings between 97<sup>th</sup> and 99<sup>th</sup> and 3<sup>rd</sup> and 2<sup>nd</sup>
  
- Approximately 135 kW DC per roof

**Figure D-9: Solar PV Rendering of NYCHA Washington**



- **Metropolitan Hospital**
- Multiple buildings between 97<sup>th</sup> and 99<sup>th</sup> and 1<sup>st</sup> and 2<sup>nd</sup>
- Approximately 190 kW DC total

**Figure D-10: Solar PV Rendering of Metropolitan Hospital**

**Table D-18: NYC Site Solar PV Potential**

Buildings	Total PV Potential (kW DC)
NYCHA Lexington (B1-4)	147.6
NYCHA Washington (B1-15)	693.6
Verizon	65.1
MHC	190
<b>Total PV Potential (kW DC)</b>	<b>1096.3</b>

#### *D.1.5.2 Combined Heat and Power*

The GE team arranged a visit by Fred Ferrand, VP Equipment Sales, with GE partner Northeast Energy Systems (part of the Penn Power Group). Mr. Ferrand visited MHC in May, 2014 to evaluate the potential for Combined Heat and Power (CHP) as part of the planned boiler replacement. Based on Mr. Ferrand's review, Metro Hospital appears to be a challenging candidate for CHP for several reasons.

First, as a public institution, MHC purchases power at low NYPA rates. On-site generation will therefore not be cost competitive on a routine basis and, even with the added thermal capture from CHP (reducing the boiler replacement cost), the payback would likely be quite long (15+ years in Mr. Ferrand's best professional judgment). Natural gas – the preferred solution for economic CHP – is not an alternative to replacing the current diesel units required for backup of the life critical functions at the hospital. Natural gas fired generation is not as flexible in terms of start-up time and load following capability.

Furthermore, in addition to challenging economics, there are several technical constraints that make Metro a less than ideal site for CHP. As a public hospital, facilities budgets and staffing levels are extremely tight and would likely not be sufficient to operate and maintain generating equipment 24 x 7 (the existing generating facilities are run only in rare emergency conditions with staff called in on overtime, if needed). In Mr. Ferrand's experience, private hospitals in NYC that are currently developing CHP, such as Sloan Kettering, have several times the facilities maintenance staff of MHC.

Another site issue is the lack of available space within the hospital buildings to accommodate additional infrastructure. The transportation depot across the street (owned by MHC but currently leased to another City department) represents an option for expansion, but would require significant upgrade from its current use, including further flood protection.

## **D.2 Benefit-Cost Assessment**

### **D.2.1 Overview**

Current backup capabilities at MHC, NYCHA and Verizon vary significantly. The NYCHA complex has no backup generators. In contrast, the Verizon station is backed by a 750 kW diesel generator, which offers sufficient capacity to meet the facility's peak demand; an emergency battery system provides additional resilience and is capable of maintaining the facility's operations for up to eight hours. MHC is equipped with 600 kW, 675 kW, and 750 kW diesel generators, along with a UPS system that serves its information technology center. The capacity of MHC's generators is not sufficient to maintain all of the hospital's operations but is sufficient to meet its critical load, allowing it to maintain inpatient and emergency medical services.

The microgrid design for the New York City site incorporates the four diesel generators noted above and adds six new diesel generators, ranging in size from 375 kW to 750 kW. The addition of the new generators would bring the system's total generating capacity to 6,150 kW. This capacity would be sufficient to support the following loads:

- 40 percent of MHC's peak demand (*i.e.*, the hospital's critical load).
- 50 percent of peak demand from the NYCHA complex.
- 100 percent of the Verizon facility's peak demand.

The results of the engineering analysis indicate that it would not be cost-effective to operate the DER at the New York City site on a continuous basis. Instead, the benefit-cost assessment focuses on two operating scenarios:

- Operation of the DER solely in the event of a power outage, in islanded mode.
- Provision of peak load support via participation in a demand response program.

#### D.2.2 Fixed Cost Factors

The best estimate of initial design and planning costs for development of a microgrid at the New York City site is approximately \$4.7 million. This figure includes approximately \$4.1 million in site-specific planning and administrative costs as well as \$554,000 in engineering design costs. The project’s capital costs are estimated at approximately \$5.9 million, including \$2.9 million for distributed generation equipment, \$2.0 million for electrical infrastructure, and \$1.0 million for control and communications systems. Fixed O&M costs are estimated at \$45,000 per year.

#### D.2.3 Variable Cost Factors

The analysis relies on information provided by the Project Team’s design consultants and projections of fuel costs from the SEP to estimate the variable costs of operating the microgrid. Variable O&M costs, excluding fuel, are estimated at \$17.13 per MWh; fuel costs for the microgrid’s first year of operation are estimated at approximately \$181 per MWh.

The analysis of variable costs also considers the environmental damages associated with emissions from distributed energy resources, based on the understanding that the diesel generators at the New York City site would not be subject to emissions allowance requirements. The estimate of environmental damages relies on pollutant emissions factors provided by the project’s design consultants, as specified in Table D-19.

**Table D-19: Pollutant Emissions Factors for the New York City Microgrid**

<b>Pollutant</b>	<b>Emissions (Tons/MWh)</b>
CO <sub>2</sub>	0.79
SO <sub>2</sub>	0.0016
NO <sub>x</sub>	0.0145
PM	0.0001

#### D.2.4 Analysis of Reliability Benefits

The analysis estimates that development of a microgrid at the New York City site would yield reliability benefits of approximately \$7,000 annually. This estimate is based on the following indicators of the likelihood and average duration of outages in the service area:

- System Average Interruption Frequency Index (SAIFI) – 0.1 events per year.

- Customer Average Interruption Duration Index (CAIDI) – 143.4 minutes.<sup>8</sup>

The estimate of reliability benefits takes into account the capabilities of the backup power systems already available at the New York City site. It also takes into account the variable costs of operating all generators, both in the baseline scenario and as integrated components of a microgrid. As in the Broome County case, the analysis assumes a 15 percent failure rate for backup generators under baseline conditions. It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

#### D.2.5 Analysis of Benefits in the Event of a Major Power Outage

The estimate of reliability benefits presented above does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the analysis assesses the impact of a total loss of power – including the failure of backup generators – on MHC, the NYCHA apartment complex, and the Verizon switching station. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.

##### *D.2.5.1 Metropolitan Hospital Center*

The MHC complex includes the following units:

- The main hospital, a Level II trauma center with 240 beds.
- The mental health building, with 120 beds.
- The outpatient department, which provides ambulatory care during business hours.

As noted above, MHC's existing backup system is sufficient to keep the hospital's inpatient services and emergency medical services operational, but does not support the outpatient unit. In the event of a prolonged power outage and failure of its backup generators, MHC would be forced to close the main hospital and mental health unit and transfer all patients to other facilities, as directed by the New York City Health and Hospitals Corporation and/or the Office of Emergency Management. Transfer of patient records, medicine, and some equipment would also be necessary.

The analysis estimates the cost of relocating the hospital's inpatients at approximately \$196,000, based on the following assumptions:

- The need to transfer approximately 244 patients, a figure that reflects an assumed occupancy rate of 67.9 percent.<sup>9</sup>
- Relocation of all patients to the nearest alternative facility, Bellevue Hospital, which is located three miles south.

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<sup>8</sup> The SAIFI and CAIDI values employed in the New York City analysis are the values for Consolidated Edison in 2012, as reported in State of New York Department of Public Service, *2012 Electric Reliability Performance Report*, June 2013.

<sup>9</sup> American Hospital Association Annual Survey of Hospitals, 2009 average occupancy for hospitals with 300-399 beds.

- An average transport cost of \$800 per patient.<sup>10</sup>

The analysis does not estimate the cost of transferring patient records, medicine, or equipment. It does, however, incorporate a cost of \$5,500 per day to secure and maintain the hospital while it is vacant.

In addition to the cost of the emergency measures described above, closure of MHC would reduce hospital capacity in the New York metropolitan area. To calculate the value of this lost capacity, the analysis employs a figure of \$675 per bed per day; this figure is based on a World Health Organization estimate of average hospital costs for urban areas in the United States. For MHC's 360 beds, this translates to a loss of approximately \$243,000 per day.

To estimate the impact of closing MHC's emergency department, the analysis employs a methodology developed by the Federal Emergency Management Agency (FEMA). The methodology calculates the economic damages attributable to closure of an emergency department based on an estimate of the number of patient visits the closure would affect and associated increases in the distance patients must travel to obtain emergency care; the amount of time spent traveling; the amount of time patients must wait to receive care; and the risk of dying as a result of a heart attack or injury. The analysis treats Bellevue Hospital as the alternative service provider. Based on this approach, it estimates the social cost of closing MHC's emergency department to be approximately \$517,000 per day, primarily due to the increase in mortality risks attributable to delays in providing care to patients who have suffered injuries or heart attacks.

It is important to note that the estimated impact of closing MHC does not account for potential adverse effects on the health of any inpatients that would need to be transferred to another hospital. In addition, it assumes that transfer to a nearby facility is feasible and that emergency departments elsewhere in Manhattan (e.g., Bellevue) remain open and operational. If that were not the case, the economic damages associated with closure of MHC could be much greater.

#### *D.2.5.2 NYCHA*

NYCHA's Lexington and George Washington Houses are home to approximately 4,400 residents. Because the complex has no backup generators, an outage would cause all of these residents to lose power. The loss of power would also disable the elevators and water pumps that serve the complex.

NYCHA did not provide detailed information on its plans for responding to a prolonged power outage. It indicated that it would attempt to lease emergency generators and/or relocate the affected residents to a temporary shelter, but did not estimate the cost of these emergency measures. In lieu of data on NYCHA's emergency response costs, the benefits analysis focuses on the value of the services residents would lose when a power outage occurs, assuming no attempt to move them to alternative housing. It relies on figures from FEMA on willingness to pay for electric and water service, which FEMA estimates at \$82.69 per person-day. Thus, for the affected population of 4,400, the economic damage attributable to the loss of electric and water service is estimated at approximately \$364,000 per day. The plans for the microgrid developed by the Team's design consultants call for a system that would meet approximately

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<sup>10</sup> This figure assumes transport of each patient in an ambulance and is based on the Fire Department of New York's published Ambulance Fee Schedule for basic life support service, with oxygen. The estimate assumes a total travel distance of three miles.

50 percent of the NYCHA complex's peak demand; thus, the benefits analysis assumes that the microgrid would reduce the damages associated with loss of electric and water service by approximately \$182,000 per day.

#### *D.2.5.3 Verizon*

As noted above, the Verizon switching station is equipped with a backup generator that offers sufficient capacity to meet the facility's peak demand; an emergency battery system provides additional resilience and is capable of maintaining the facility's operations for up to eight hours. In the event of a major power outage and failure of its backup generator, Verizon would dispatch a generator truck which, it estimates, would be able to restore operations within 24 hours; thus, the analysis assumes that the maximum duration of any loss of service would be 16 hours (*i.e.*, the maximum interval between failure of the battery and restoration of service by the mobile generator). During this period, the switching station would lose the ability to handle local voice and data traffic. All other traffic ordinarily handled by the station would be rerouted to other facilities.

The benefits analysis assumes, in the baseline scenario, that there is a 15 percent probability that Verizon's backup generator will fail, and that this failure would lead to a loss of local voice and data service for 16 hours. Further, it assumes that establishment of a microgrid would eliminate the risk of failure. To value this impact it relies on the same methods used to value reliability benefits, setting SAIFI and CAIDI values to estimate the economic losses that a medium to large customer in the transportation, communication, and utilities sector would experience as a result of a 16-hour outage. The resulting figure, \$76,000, represents the estimated benefit the microgrid would provide by keeping the Verizon station fully operational.

#### D.2.6 Analysis of Peak Load Support Scenario

The benefits of developing a microgrid at the New York City site would be enhanced if the system could provide peak load support to the macrogrid via participation in a demand response program. Participating in this program would reduce demand to expand the macrogrid's generating capacity, thus providing capacity cost savings. Providing peak load support would increase the microgrid's annual operating costs (including variable O&M costs, fuel costs, and environmental costs). These costs, however, would be offset in part by a reduction in demand for electricity from the macrogrid, which would lead to energy cost savings and environmental benefits associated with the operation of bulk energy facilities.

The Team's design consultants estimate the peak load for the facilities to be served by the microgrid at more than 10.7 MW, well in excess of the generating capacity of the microgrid's DER; therefore, the analysis of demand response benefits is based on the generating capacity of the DER at participating facilities. Given uncertainty over the willingness and ability of a hospital to participate in a demand response program, the analysis considers two cases: the first based on the capacity of all generators the microgrid would incorporate (6.15 MW); and a second that excludes the capacity of MHC's generators (leaving a total capacity of 4.125 MW).

In the first case, the analysis estimates that the New York City project's participation in a demand response program would generate capacity cost savings of approximately \$1.0 million per year. If the system were called upon to provide support for 20 hours a year, its operating costs would increase by approximately \$46,000 annually. These costs would be offset by a reduction of approximately \$14,000

per year in the macrogrid's operating costs. Under this set of assumptions, the system's participation in a demand response program would yield benefits of approximately \$970,000 annually.

In the second case, the capacity cost savings associated with participation in a demand response program would decline to approximately \$672,000 per year. If the system provided support for 20 hours a year, its operating costs would increase by approximately \$31,000 annually. These costs would be offset by a reduction of approximately \$9,000 per year in the macrogrid's operating costs. Under these assumptions, the system's participation in a demand response program would yield benefits of approximately \$651,000 annually.

#### D.2.7 Summary of Results

The analysis of the New York City site indicates that without participation in some type of demand response program, the benefits of a microgrid are unlikely to exceed its costs. Absent involvement in such a program, benefits would exceed costs only if the probability of a major power outage is assumed to be extremely high. As Table D-20 shows, the expected number of days without power would have to be on the order of three to five *each year* in order for the project to be cost-effective.

Participating in a demand response program would improve the economic case for development of a microgrid:

- **With MHC** – The breakeven conditions for the site are the most positive when MHC is included as a participant in the demand response program. The analysis indicates that in this case, in the low cost scenario, benefits would exceed costs even if the probability of a prolonged power outage is assumed to be zero. In contrast, the breakeven conditions for the average and high cost scenarios include a non-zero chance of a prolonged outage. The expected number of days without power, however, would need to be no greater than 0.28 to 0.89 annually for the project to be cost-effective.
- **Without MHC** – The breakeven conditions for the peak load support scenario change when MHC is not included as a participant in the demand response program. The analysis indicates that in this case, the expected number of days without power would need to range from 0.67 to 2.1 annually for the project to be cost-effective.

**Table D-20: BCA Results for the New York City Site: Breakeven Conditions (7% Discount Rate)**

<b>Scenario</b>	<b>Annual Probability of Specified Outage</b>	<b>Duration of Specified Outage</b>	<b>B/C Ratio</b>
Low Cost/No Peak Load Support	100%	3 days	1.01
Average Cost/No Peak Load Support	100%	4 days	1.08
High Cost/No Peak Load Support	100%	5 days	1.14
Low Cost/Peak Load Support with MHC	NA	NA	1.12
Average Cost/Peak Load Support with MHC	28%	1 day	1.00
High Cost/Peak Load Support with MHC	89%	1 day	1.00
Low Cost/Peak Load Support without MHC	67%	1 day	1.00
Average Cost/Peak Load Support without MHC	69%	2 days	1.00
High Cost/Peak Load Support without MHC	70%	3 days	1.01

As previously noted, the analysis of the peak load support scenario assumes that the generators at the New York City site would meet eligibility requirements for participation in a demand response program. Additionally, it assumes that the facilities analyzed in each case would be willing to participate in such an arrangement. These issues are important to the outcome and should be investigated further before any action on development of a microgrid at the New York City site.

## Appendix E Microgrid Case Study: Rockland County (New City)

### E.1 Feasibility Study

#### E.1.1 Site Characteristics

The goal of site characterization activity is to understand the particular operating and emergency response missions of facilities composing the proposed microgrid site and to gather data describing the facilities requirements for power and the specific physical characteristics and constraints of the buildings and their power systems infrastructure. On-site interviews and phone calls were held with various facility, utility, state officials and business stakeholders involved with this site. The following sections of this report provide a summary of the site visits and present an overview of the various data collected.

The principal site entities are:

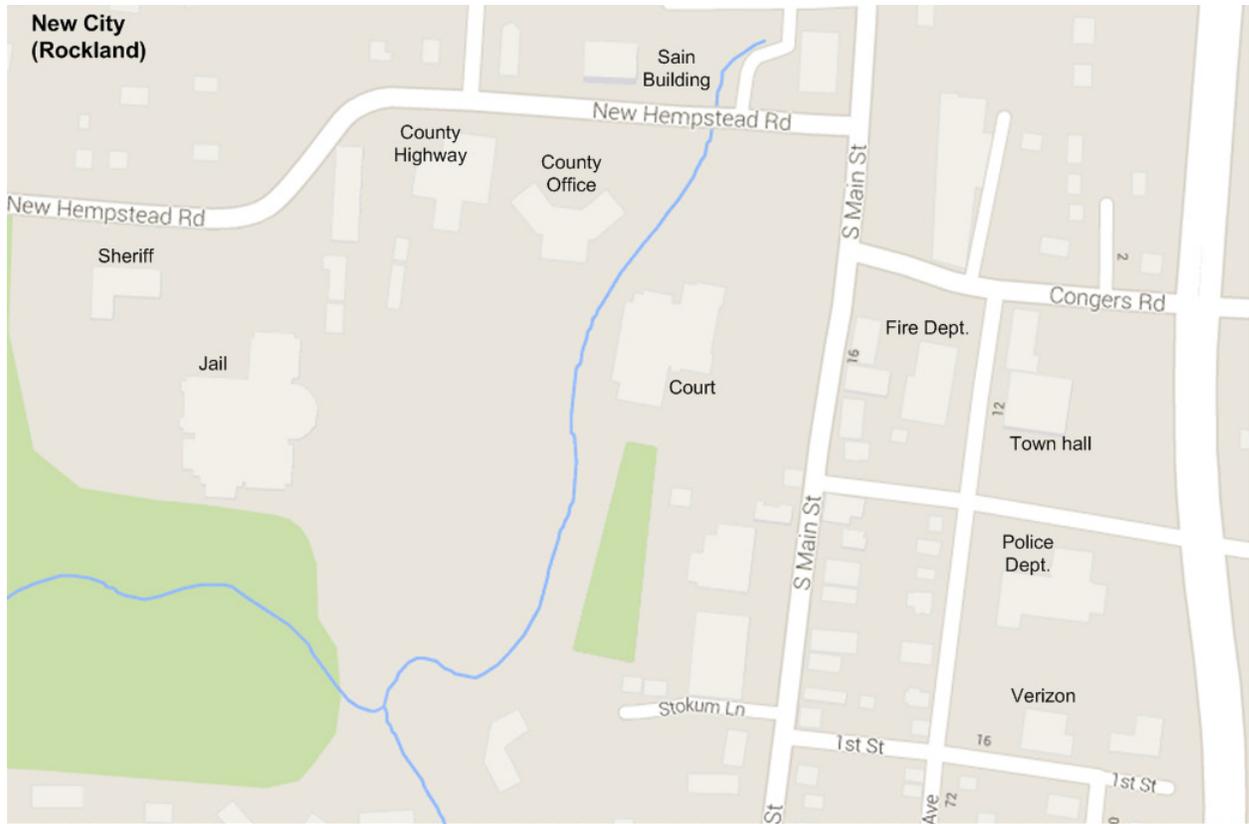
- **Sheriff Office**
- **County Jail**
- **Allison-Parris County Office Building**
- **County Court House**
- **County Highway Garage:**
- **Sain Building**
- **Town of Clarkstown Town Hall**
- **Town of Clarkstown Police Headquarters**
- **New City Fire Department**
- **Verizon Building**

A high level view of the Rockland County site is provided in Figure E-1.

##### *E.1.1.1 Site Visit Summary*

Eight different facilities were initially identified as a part of Suffolk County Microgrid site; Sain building and Verizon building were added later to the site's scope. An onsite interview was conducted on December 6, 2013 at the Rockland County office in New City to understand and characterize the site. The interview was attended by representatives from NY DHSES, NYSERDA, DPS, Rockland County, Clarkstown Police Department, Orange and Rockland Utility (ORU) and GE.

The site is comprised of a cluster of town and county facilities on the east and west sides of S Main St. Critical facilities were identified on both the town and county side of the site.



**Figure E-1: Rockland Site**

The key findings from the site visit are:

- This site is located on a hill and does not have flooding problem.
- County office, Sheriff’s office and County Jail were identified as most critical facilities for county side.
- Police department, Town hall and Fire department were identified as most critical facilities for town side.
- There are four community centers in the area which can provide shelter during emergency. Government buildings are not used to provide shelter.
- Sheriff office, County Jail, County Courthouse, Town Hall, Police department, Fire department and Verizon have generators, and remaining facilities have been approved for installation.

*E.1.1.2 Data Collection for Site Characterization*

GE team worked with site contacts, ORU, NYSEDA, NYS DHSES, and NYS DPS, to collect detailed data for the Rockland site. Their assistance and collaboration were essential in collection of the necessary data and in helping form the needed characterization of the Rockland site for the microgrid design. The data collected included:

- Monthly energy usage (kWh), power demand (kW) and rate class for all facilities from ORU website using each facilities’ account number.

- Load research data with hourly load profile for similar rate class loads from ORU.
- One-line diagram of feeders serving the identified microgrid site facilities including one-line diagram of some facilities.
- Information on on-site generation.

Additional information needed to construct the energy balance model, fuel data, and generation operational and cost parameters were collected by the GE team, some from public data, and others from internal GE sources. Some of the values used in the analysis are based on unofficial, non-public, and subjective assessments, but provide a best estimate tempered by the availability of data.

*E.1.1.3 Rockland Site Constituents, Generation, and Infrastructure*

Following table provides a summary of the Rockland site principal entities.

**Table E-1: Rockland Site Principal Entities**

Facility Name	Mission/Role
Sheriff Office	Law Enforcement, storage site for critical county data; backs up town dispatch and call center; communication tower at site
County Jail	Corrections Facility
County Office Building	Public Works, hosts county offices; critical for continuity of government
County Court House	
County Highway Garage	
Sain Building	Finance
Clarkstown Town Hall	Used for staging and distribution of supplies during emergencies. EOC can be moved from Police HQ to Town hall if needed.
Clarkstown Police Headquarters	Law Enforcement, houses the EOC, call center and fuel dispensing station
New City Fire Department	Fire & Rescue
Verizon Building	Telecommunication

The following table summarizes the existing generation resources at the Rockland site.

**Table E-2: Rockland Site Existing Generation Resources**

Facility	Generator Types/Rating
Sheriff Office	250 KW Emergency Generator - Natural Gas Emergency Generator powers the entire sheriff building
County Jail	1500 KW Emergency Generator - 8000 Gallon Diesel Fuel Tank Emergency Generator powers the entire jail building.
County Office Building	No Backup Gen (Approved for installation – no further info)
Court House	400 KW Emergency Generator - 600 Gallon Diesel Fuel Tank Emergency Generator only powers building life safety equipment.
County Highway Garage	No Backup Gen (Approved for installation – no further info)
Sain Building	No Backup Generator (Approved for installation – no further info)
Clarkstown Town Hall	264 backup Generator.* The building has UPS.
Clarkstown Police Headquarters	4 x 161kW* and 300 kW Emergency Generator – 2000 Gallon Diesel Storage 60 kW UPS powers call center for 12 hrs. Plan to install a 500 kW Emergency Generator (with existing 300 kW as secondary backup).
New City Fire Department	60 kW <sup>11</sup> Natural Gas Generator
Verizon Building	200 kW, Diesel Generator, 4000 Gallon storage

\* Existing generation capacity is based on revised latest information. Original data is used for Homer model, see Table 5-6 for capacity considered in Homer model.

GE was unable to get information of existing electrical and control infrastructure of the Rockland site. Table E-4 shows limited information extracted from the feeder one-line diagram obtained from the utility (ORU).

**Table E-3: Rockland Site Infrastructure Characterization**

Facility	Power Distribution
Sheriff Office	Dedicated transformer, 300 kVA, 13.2kV/208V
County Jail	Dedicated transformer, 1500 kVA, 13.2kV/480V
County Office Building	Dedicated transformer, 750 kVA, 13.2kV/208V
Court House	Dedicated transformer, 300 kVA, 13.2kV/208V
County Highway Garage	Dedicated transformer, 2000 kVA, 13.2kV/480V
Sain Building	Dedicated transformer, 75 kVA, 13.2kV/208V
Clarkstown Town Hall	Dedicated transformer, 300 kVA, 13.2kV/208V
Clarkstown Police Headquarters	Dedicated transformer, 300 kVA, 13.2kV/208V
New City Fire Department	Pole mounted transformer
Verizon Building	Dedicated transformer, 750 kVA, 13.2kV/208V

<sup>11</sup> The study uses 90kW as the capacity for modeling purpose. The capacity of generator was later revised as 60kW. The 30kW generation difference has to be shifted to diesel generator which likely will have some impact on fuel cost but should be minimal.

## E.1.2 Site Modeling and Analysis

### *E.1.2.1 Modeling of Generation Supply and Demand*

To develop a Microgrid Functional Design, GE performed a detailed supply and demand study of each site using the HOMER<sup>12</sup> model.

The HOMER model inputs include:

- The microgrid projected load data, up to two sets of hourly (24 x 365) or 12 x 24 load profiles representing the microgrid facilities (i.e., the microgrid total load, separated or aggregated into one or two load profiles),
- Existing and proposed distributed generation sets of different kinds and sizes,
- Generation cost characteristics, including capital costs, fixed operations and maintenance (FOM) costs, and variable operations and maintenance (VOM),
- Fuel costs
- Criteria Pollutants and Greenhouse Gas emissions, and
- HOMER variability and operating reserve margins and other modeling parameters.

HOMER finds the least cost of generation mix to meet the hourly load for every hour of the year. One can assign different capacity sizes, operating reserve levels, and other parameters as “sensitivities” and Homer determines best generation mix for each sensitivity assumption.

The model outputs information on the selected generation mixes, energy produced, fuel consumption, and emissions. Some of the model outputs are shown in the tables and charts of the following sections.

### *E.1.2.2 Model Load Data*

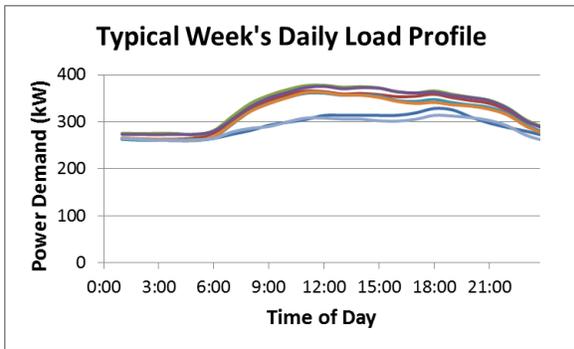
#### E.1.2.2.1 Base Load

The Rockland site load data consists of load for the Sheriff Office, County Jail, County Office Building, Court House, County Highway Garage, Sain Building, Town Hall, Police Headquarters, New City Fire Department, and Verizon Building. The Sheriff office and Jail share the same meter and are represented as a single load for the purpose of load profile model.

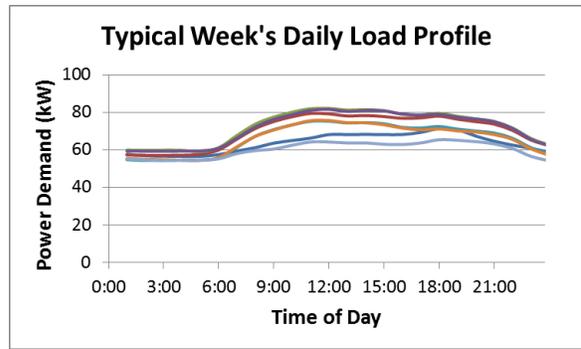
The monthly demands for all facilities were downloaded from the ORU website and load research data for similar facilities was used to create a 365 x 24 hour load profile. Figure E-2 and Figure E-3 show a typical week’s (mid-January) load profiles for all the facilities.

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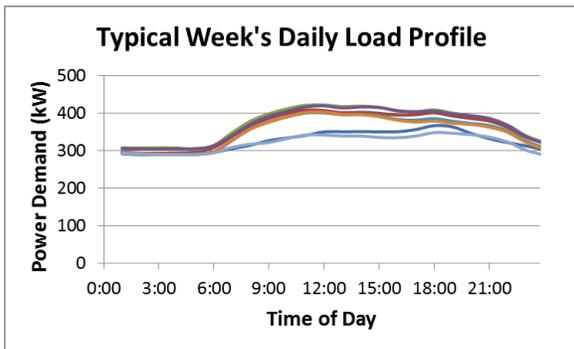
<sup>12</sup> Hybrid Optimization of Multiple Energy Resources (HOMER), a microgrid optimization model licensed by HOMER Energy LLC: <http://www.homerenergy.com/>.



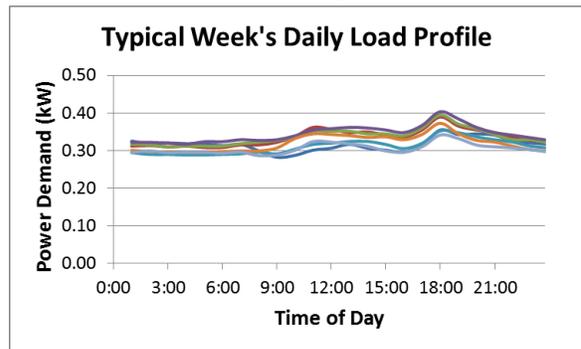
a) Sheriff – Jail



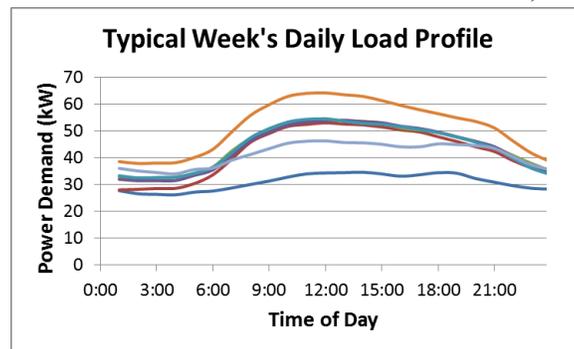
b) County Office



c) Court House

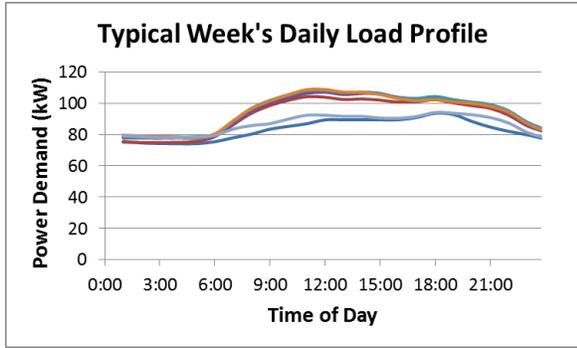


d) Highway Garage

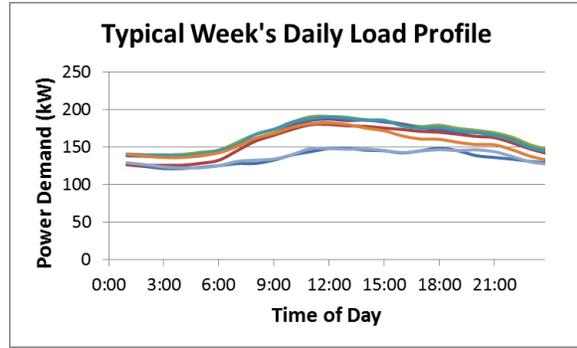


e) Sain Building

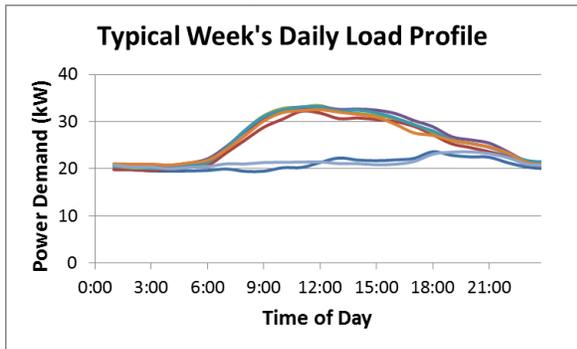
**Figure E-2: Typical Load Profile (a week in January) for County Side Facilities**



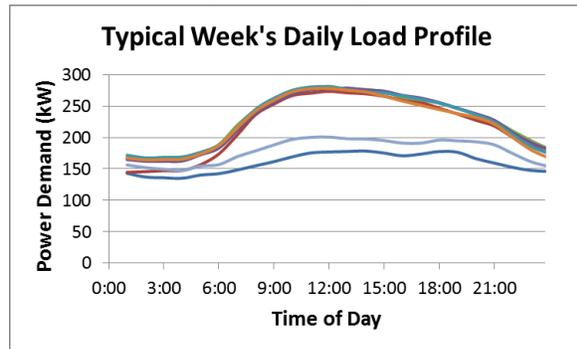
a) Town Hall



b) Police Department



c) Fire Department



d) Verizon

**Figure E-3: Typical Load Profile (a week in January) for Town Side Facilities**

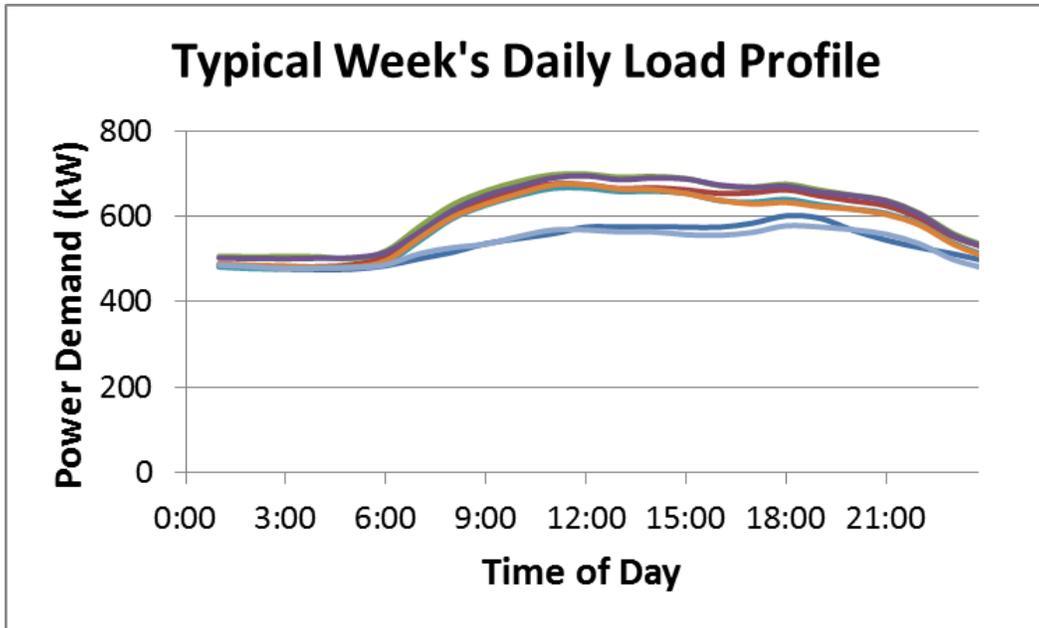
Since HOMER could only accept two separate load profiles for analysis, the aggregate load for county side facilities (Sheriff Office, County Jail, County Office Building, Court House, County Highway Garage, and Sain Building) was placed into one group and town side facilities (Town Hall, Police department, and Fire department) and Verizon were placed into another group. An assumption for critical load percentage was made for each facility and only the critical load share was used for each aggregate load. The following criteria was used for the assumed critical load share:

- If a facility does not have a backup generator then the critical load is 50% of maximum demand,
- If the facility has one or more backup generator but the generation capacity is less than the maximum, then the percentage of annual peak load equal to generation capacity is critical load, and
- If the facility has one or more backup generator and the generation capacity is sufficient to support maximum demand, then 100% of load is critical load.

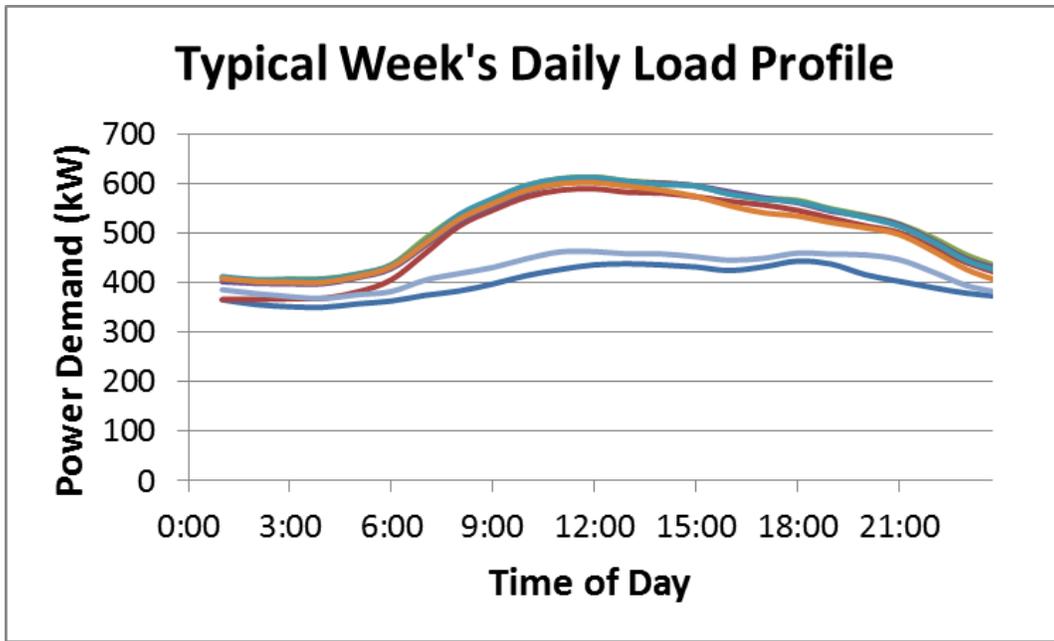
Table E-4 shows the critical load percentage per facility for Rockland site facilities and Figure E-4 and Figure E-5 show the aggregate load profile of two load groups for the typical week.

**Table E-4: Critical load percentage per facility**

Facility	Critical Load Percentage
Sheriff Office & County Jail	100%
County Office Building	50%
Court House	60%
County Highway Garage	50%
Sain Building	50%
Clarkstown Town Hall	100%
Clarkstown Police Headquarters	100%
New City Fire Department	100%
Verizon Building	100%



**Figure E-4: Typical Load Profile (a week in January) for group one (County side)**



**Figure E-5: Typical Load Profile (a week in January) for group two (Town side)**

E.1.2.2.2 Emergency Premium

To account for additional load over the base load in times of emergency, GE assumed a 20% emergency premium. This is the assumed additional load that may materialize during emergency periods resulting from the additional activity, personnel, and accommodation for emergency operations. The 20% emergency premium was applied to all hour loads, and hence the generation requirements are sized to this emergency load (i.e., Base Load + 20%). HOMER performs additional scaling and massaging of load to create the hourly load shapes and the resulting load characteristics, with and without the 20% emergency premium, are in Table E-5.

**Table E-5: Total Demand for Rockland Site**

Load Name	Hourly Peak (kW) without 20% premium	Hourly Peak (kW) with 20% premium
Group One (County Side)	1,055	1,266
Group Two (Town Side)	760	912
<b>Total</b>	<b>1,815</b>	<b>2,178</b>

E.1.2.3 Model Generation and Fuel Data

The existing generation set at Rockland Site includes the following:

**Table E-6: Existing Generation Resources at Rockland Site**

Facility	Capacity (kW)
Sheriff Office & County Jail	1,750
County Office Building	-
Court House	400
County Highway Garage	-
Sain Building	-
Clarkstown Town Hall	510 <sup>13</sup>
Clarkstown Police Headquarters	300 <sup>14</sup>
New City Fire Department	90
Verizon Building	200
<b>Total</b>	<b>3,250</b>

From the above two tables it is apparent that, the collective existing generation can cover the total microgrid load at Rockland site. The critical load in facilities with backup generator are able to sustain an outage even without microgrid interconnection without considering the added emergency premium during such events. However, it should be noted that without the interconnection, the facilities with no backup generation will not have any service in an event of grid outage.

It should be noted here that the total capacities of generators at Town Hall, Police Department and Fire Department were updated at the later stage of study. Homer modeling is done based on the information that GE had at the beginning of the study, which is as shown in Table E-6. Refer to Table E-2 for updated generation capacity.

### E.1.3 Microgrid Infrastructure Configuration

#### *E.1.3.1 Model Generation Options*

HOMER produced results for generator energy production, their O&M and Fuel costs, fuel consumption, and emissions. It is assumed that the Microgrid will be functional for a minimum duration of one month – although there is no reason to assume that the microgrid cannot run for longer periods of time if the generators are regularly supplied with fuel. Hence, the following results are for a one-month operation of the microgrid.

<sup>13</sup> The generation capacity at Town Hall reflects the information GE had at the beginning of the study.

<sup>14</sup> See previous footnote.

**Table E-7: Rockland Site Generation Performance**

Type of Distributed Energy Resource	Fuel	Nameplate Capacity (kW)	Production (kWh/Month)	Capacity Factor (%)	Fuel Consumption (Gallons/Month or cubic ft./month)
Sheriff	Natural Gas	250	182,500	100.0%	1,462
Jail	Diesel	1,500	83,042	7.6%	5,989
Court	Diesel	400	182,910	62.6%	13,191
Town hall	Diesel	510	206,952	55.6%	14,925
Police Dept.	Diesel	300	145,100	66.3%	10,464
Fire Dept.	Natural Gas	90	65,700	100.0%	526
Verizon	Diesel	200	63,776	43.7%	4,599
<b>Total</b>		<b>3,250</b>	<b>929,980</b>	<b>39.2%</b>	<b>49,169 (Diesel) 1,989 (NG)</b>

It should be noted that generation resources with similar fuel have similar assumed characteristics, they are actually interchangeable and similar electricity generation, fuel consumption, and O&M and fuel costs can be achieved if total generation is redistributed differently among different plants that use similar fuel.

Table E-8 presents the monthly emissions by the Rockland site generation set.

**Table E-8: Monthly Emissions**

Pollutant	kg/MWh
Carbon dioxide	672.64
Carbon monoxide	1.79
Unburned hydrocarbons	0.20
Particulate matter	0.14
Sulfur dioxide	1.44
Nitrogen oxides	12.85

*E.1.3.2 Electrical Infrastructure*

The following approach was taken for the electrical infrastructure design

- Assessment of existing electrical infrastructure in and around the proposed site. The assessment included both site (customer) owned and utility owned infrastructures.
- Analysis of one-lines to determine the PCC (point of common coupling) with the utility and to define the electrical boundary of Microgrid.
- Assessment of voltage levels, existing distribution system routes and distance between various buildings/facilities to determine interconnection options. The initial options included different voltage levels and different routes, both with and without the usage of existing utility or facility assets. Utility and site supplied one-lines and maps were used to determine the voltage levels and existing routes. Aerial and satellite maps were used to calculate approximate distance between various buildings and facilities of the Microgrid. A similar approach was used for selection of routes for new distribution lines.
- Assessment and evaluation of different interconnection options (voltage level and route) for optimal system operation. Selection of optimal voltage level is based on engineering judgment and industry practice to maintain the power quality and minimize line loss. Routes are selected so as to minimize the total length of new distribution line. The right of way is assumed to be available.
- Cable, switches, circuit breakers, transformers and other electrical equipment were selected based on the proposed power flow, selected voltage level, layout and connection scheme. The existing backup generators were considered to be equipped with circuit breaker(s) or transfer switch/switches and other equipment necessary to perform break-before-make switching operation.
- The effect on protection system was also considered during the selection of electrical equipment but site specific system modeling and in-depth analysis is required to determine any modification or upgrade of the system.
- The proposed electrical infrastructure design does not consider the operation of the microgrid in grid-connected mode.

Figure E-6 provides an overview of the layout of the Rockland site's electrical infrastructure, taking into account the points of contacts with the greater grid.

**New City  
Rockland**

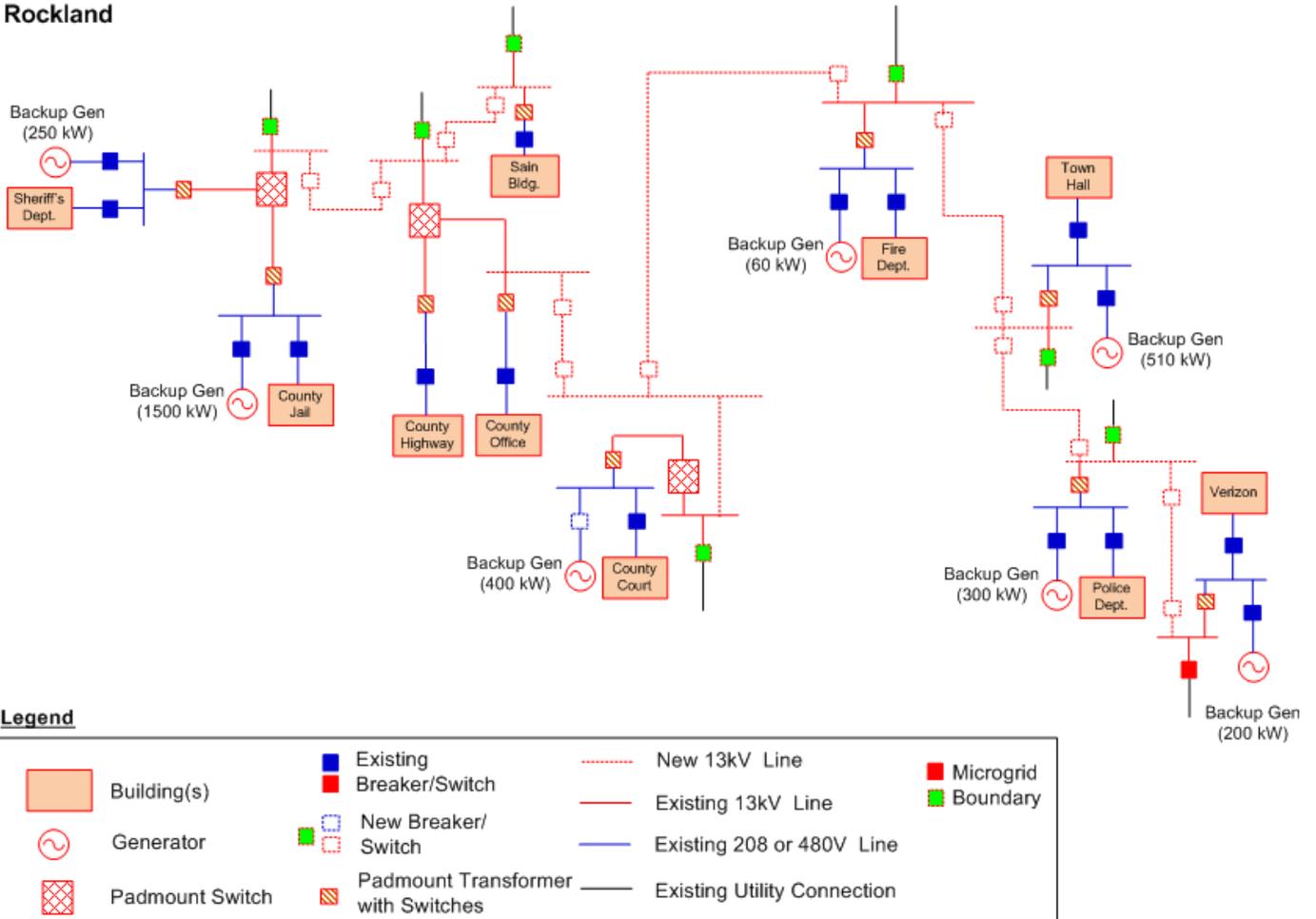


Figure E-7: Electrical One-line of Interconnection (Rockland Site) presents the site's electrical one-line of interconnections, although the details of existing connections are not shown.

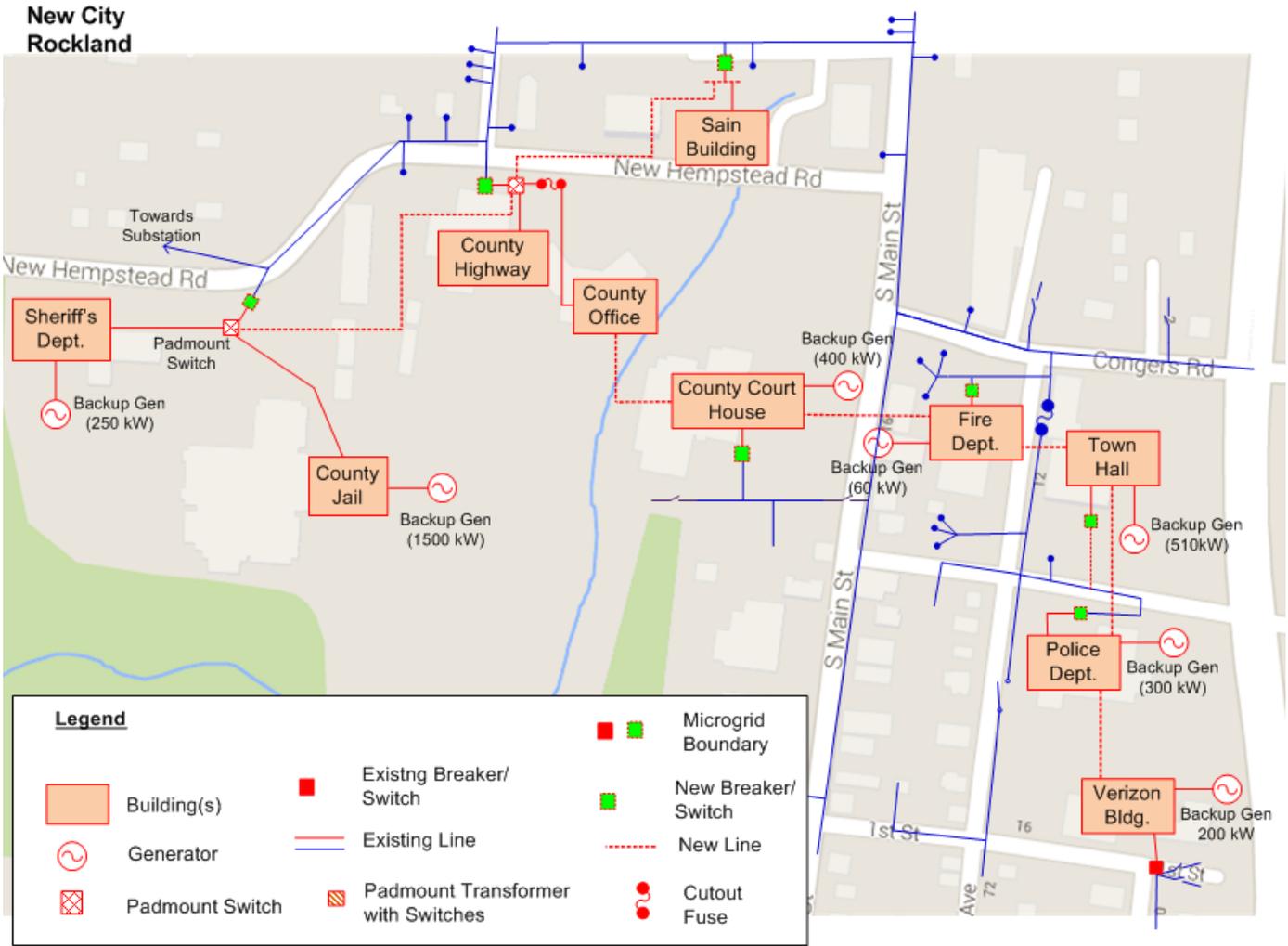
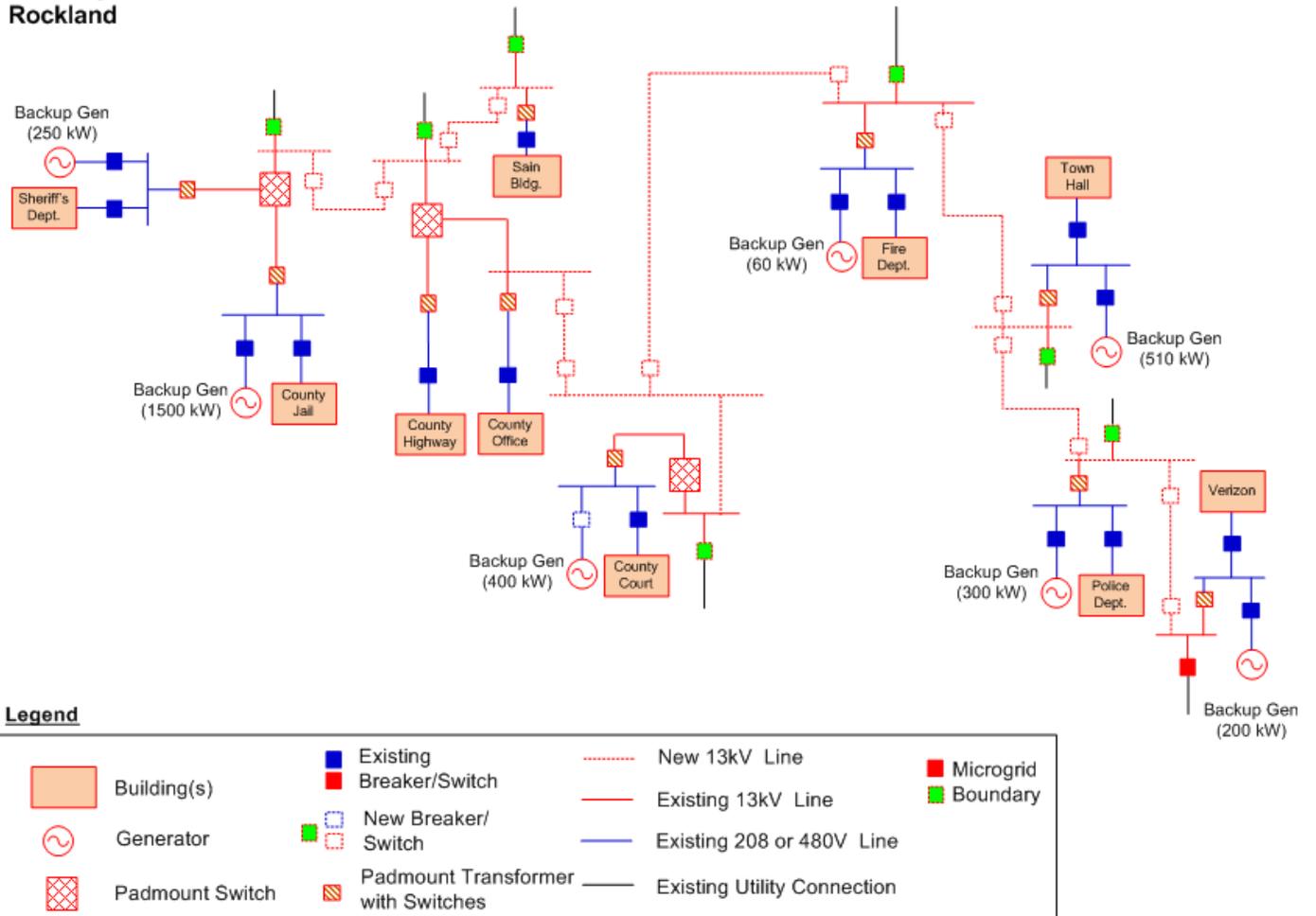


Figure E-6: Layout of Electrical Infrastructure (Rockland Site)

**New City  
Rockland**



**Figure E-7: Electrical One-line of Interconnection (Rockland Site)**

### *E.1.3.3 Control & Communications Infrastructure*

#### Site Perspective:

- There was no input from the utility on existing communications platforms and no input from the site detailing controllable loads. The site, however does have a Building Energy Management System (BEMS)
- Based on the lack of driving technical or interoperability requirements, GE approached the architecture definition as a new system design with a goal to minimize costs and select control and communications devices which supported multiple protocols to enable interoperability across the largest array of devices and platforms.

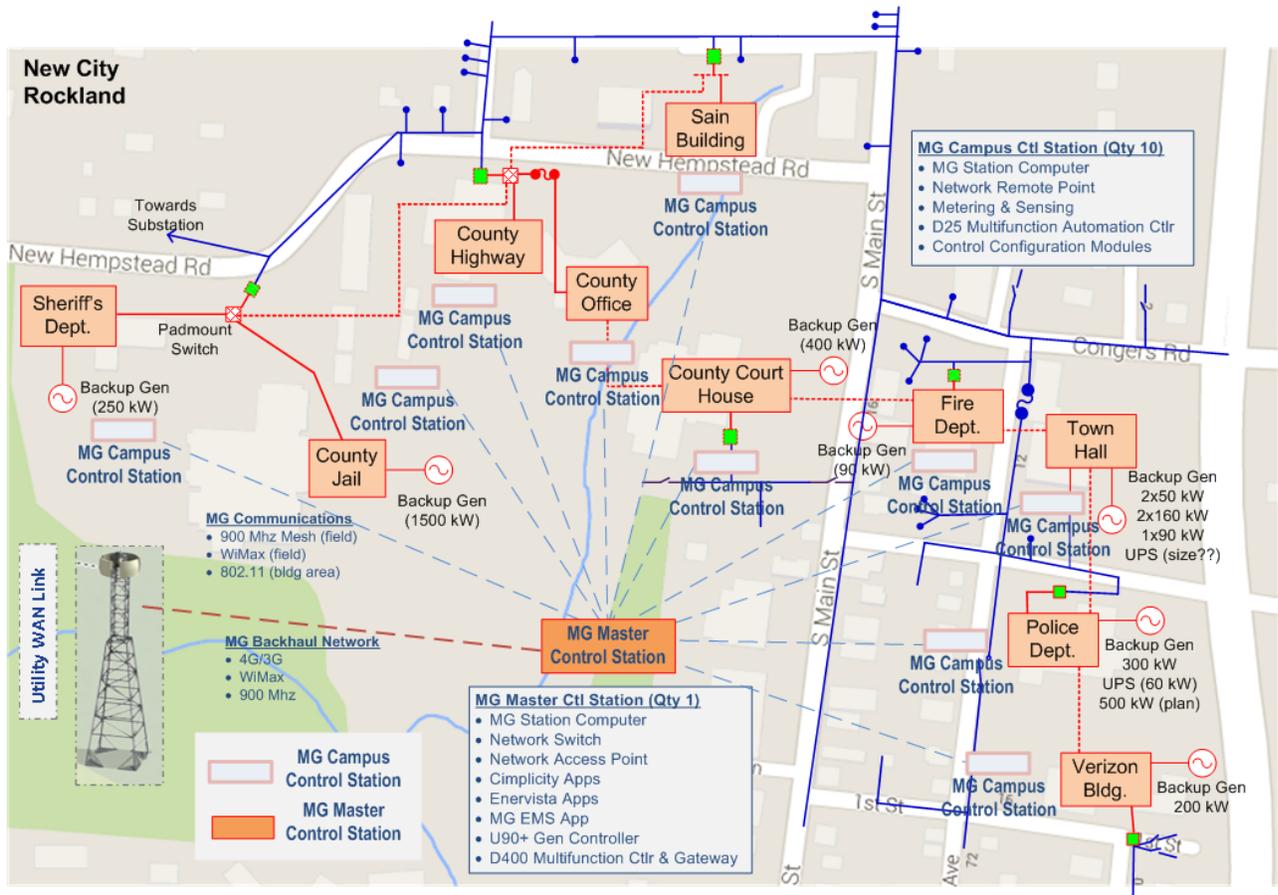
Given the information above, for this prototypical example and high level estimate, GE selected wireless field networks as the communications backbone. This is a common solution for utility neighborhood area networks (NAN) and field area networks (FAN). This solution also allows ease of integration with modern AMI solutions that may be in the area. Another approach would be underground cabling or fiber optic networks. The fiber approach is the highest performing when it comes to bandwidth and reliability however it is a very large cost commitment for the utility. Underground copper cable is also high performing and very expensive. The lack of physical details concerning area-specific trenching requirements and length of cable runs and lack of input from the utility regarding network requirements ruled out estimating cost for both underground and fiber networks.

Control design was based on the GE Microgrid Reference Architecture (See Appendix B). The Microgrid Reference Architecture divides the microgrid into 3 control zones (shed-able load, discretionary load, critical load) and 5 formal control types (Utility Control Interface, Master MG controller, Smart Building, Raw Building, and sub or feeder IED's and switches).

To support the 5 control abstractions in the Microgrid Reference Architecture GE crafted a solution that included the notion of:

- Microgrid Energy Management System (MG EMS) which would serve as the master control application and orchestrate all control actions as well as provide the utility interface. The MG EMS would be developed per the software design bid listed in the C&C BOM table. This could include integration of some existing control platforms and a lot of new system level control orchestration services.
- Microgrid Master Control Station (1 per site): host MG EMS, orchestrate all control nodes and DG optimizer/dispatch controller.
- Microgrid Campus Control Node (1 per facility): coordinate control across multiple buildings composing a specific facility.
- Microgrid Edge Control Node (1 per building): direct interface to any controllable device in a building.
- All hardware level control was architected using programmable, multi-protocol, IED's to enable broadest support of industry standard protocols and interfaces (e.g. IEC61850, DNP3, Modbus TCP/IP, Modbus Serial, or Ethernet as interface to control ports on microgrid deployed devices such as IED's, PLC, switchgear, relay, sensors, meters, digital governors, etc.)

New developed MG EMS monitoring/control services will use 61850 communications to a Protocol gateway which maps 61850 logical nodes to the specific control interfaces on the MG components/devices.



**Figure E-8: Microgrid Electrical One-Line Diagram with Control and Communications Overlay (Rockland Site)**

#### E.1.4 Microgrid Cost Summary

##### E.1.4.1 *Microgrid Cost Estimate Development*

Based on the analysis performed and details of the functional design, GE developed its “best estimates” of the cost of microgrid development, using public and non-public sources, with an expected accuracy of +/- 30%.

As noted earlier, additional information needed to construct the energy balance model, fuel data, and generation operational and cost parameters were collected by the GE team, some from public data, and others from internal GE sources. Some of the values used in the analysis are based on unofficial, non-public, and subjective assessments, but provide a best estimate tempered by the availability of data.

The microgrid development cost components included (but not limited to) the following:

- Microgrid DG Costs (Capital, Fixed, Operations and Maintenance, Fuel, Etc.)

- Microgrid Control and Communications Infrastructure (components and installation)
- Microgrid Electrical Infrastructure Costs (components and Installations)
- Annual Microgrid Operations and Maintenance Costs

*E.1.4.2 Electric Generation Cost*

Since the existing on-site generation is sized large enough to cover the designated critical microgrid load, the generation costs do not include any capital costs. The only generation cost components are the O&M and Fuel costs, as shown in the following table.

**Table E-9: Rockland Site Generation Costs**

Generation	Capacity (kW)	O&M Costs (\$/Month)	Fuel Costs (\$/Month)	Total Variable Costs (\$/Month)
Sheriff	250	3,103	14,576	17,679
Jail	1,500	1,428	18,130	19,558
Court	400	3,110	39,933	43,044
Town hall	510	3,519	45,183	48,702
Police Dept.	300	2,652	31,679	34,331
Fire Dept.	90	1,117	5,246	6,363
Verizon	200	1,581	13,924	15,505
<b>Total</b>	<b>3,250</b>	<b>16,510</b>	<b>168,671</b>	<b>185,181</b>

*E.1.4.3 Electrical Infrastructure Cost*

Table E-10 summarizes the Rockland microgrid electrical infrastructure average cost estimates.

The cost for all electrical infrastructure components are the best estimates obtained from GE internal sources and verified from utility engineers (not related to Microgrid site).

Based on the methodology used for the electrical infrastructure cost estimation, the values presented should be assumed to be the “average” cost estimates. A 10% low and high adjustment was used to calculate the Low and High bookends of electrical infrastructure costs.

**Table E-10: Rockland Microgrid Electrical Infrastructure Average Cost Estimates**

SN	Item	Description	Quantity	Unit	Unit Price (Installed) (\$)	Cost (\$)
1	15 kV Class 3-Ph Cable	Cable to interconnect MG facilities	4900	Ft.	30	147,000
2	600 V Class 3-Ph Cable	LV cable	0	Ft.	30	0
3	Medium Voltage (15kV class) Switch/Circuit Breakers	Switches at various locations	21	Nos.	20,000	420,000
4	Low Voltage Circuit Breakers	LV Circuit Breakers at various locations	1	Nos.	10,000	10,000
5	300 kVA Transformer	Padmount transformer at Fire Department	1	Nos.	10,000	10,000
6	Transition Compartment	One each at 9 interconnection/ utility disconnection locations	9	Nos.	10,000	90,000
7	Protection System Evaluation	Model the existing system with new infrastructure and evaluate the protection system	1	unit	50,000	50,000
<b>Total</b>						<b>727,000</b>

*E.1.4.4 Control & Communications Cost*

Similar to the approach for electrical infrastructure cost estimation, to get component costing, GE referred to GE internal sources. GE utilized its information (documents, website, internal communication), and used the online purchase menus to configure the devices per the store menus and ascertain a price for all communications and control hardware and supporting software applications. GE used list price in all cases to stay at a relatively conservative level.

To estimate system and project costs, GE first created the control/communication costing spread sheets to establish a list of required engineering, design, integration, and site activities. Details of each are described in the notes column. Based on the engineering activities GE estimated number of labor/months per tasks and used GE commercial rates to get a number.

To validate costs GE compared its derived numbers to industry sources. Two sources in particular were noted: 1) Minnesota Microgrid Project, and 2) DOE Microgrid workshops. This study’s cost numbers were somewhat higher, but this was due to the fact that GE had originally used its commercial consulting rates for engineering design labor. GE has finalized its numbers using a Low, Average, and High estimates in order to provide a range.

Table E-11 summarizes the Rockland Microgrid Control & Communications Infrastructure “High” cost estimates.

Based on the methodology used for the electrical infrastructure cost estimation, the values presented should be assumed to be the “high” cost estimates. The “average” cost estimate is 10% lower than the high cost estimate. Similarly, the “low” cost estimate is 10% lower than the average cost estimate.

**Table E-11: Rockland Microgrid Control & Communications High Cost Estimates (Rounded to the Nearest \$100)**

Item - P/N	Description	Unit Price (\$)	QTY	Cost (\$)	Notes
MG Master Control Station					
MG Control Station Computer	MG Station Computer: Hosts MG EMS application. Hardened computer with processor/comm/interface expansion ports. Rack system.	15,000	1	15,000	Dell PowerEdge R270 Rackmount Server. Racks, Displays, Peripherals. SQL Server DBMS. Priced to approximate a hardened computer to host MG substation applications and support NERC compliance and multiple I/F options
GE EnerVista Engineer	MG Configuration Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Maintenance	MG Maintenance Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Monitoring	MG Monitoring Utility	2,000	1	2,000	MG controller HMI and configuration app
GE EnerVista Integrator	MG Device Integration	1,500	1	1,500	MG controller HMI and configuration app
GE Cimplicity	Cimplicity Globalview and Cimplicity Development	100,000	1	100,000	HMI/SCADA framework providing event/alarm monitoring, logging, and SCADA configuration tools.
GE Multilin U90+	MG Generation Controller/Optimizer	25,000	1	25,000	MG Generation Controller via Multilin UR family. Forecasting and optimal dispatch functions
GE D400	Advanced Protocol Gateway	9,000	1	9,000	Multifunction intelligent gateway. Provides control interface and data collection from protection, control, monitoring, RTU, IED's.. Configured using Logiclinx software.

System Integration & I/F Modules	Integration & Control Software: Application functions, control functions, component adapters, and automation scripts	150,000	1	150,000	Engineering labor estimate for code development/integration of site-specific control and automation of buildings, systems, devices, and generators. (TBD scope: depending on requirement for monitoring and automated control of buildings and electrical infrastructure)
MG Campus Ctl Station (BEMS Integration)					
Control Station Computer	Application Host Computer	5,000	0	0	Dell PowerEdge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	0	0	Smart meter monitors main facility load. BEMS I/F provides detailed monitoring.
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	0	0	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
BEMS Integration	Configuration/Integration	50,000	0	0	BEMS configuration and integration with campus controller. Requires technical discussions with BEMS vendor and facility energy manager.
MG Campus Ctl Station (w/o BEMS)					
Control Station Computer	Application Host Computer	10,000	10	100,000	Dell PowerEdge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	10	5,000	interval load monitoring
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	10	90,000	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
Control Node Integration	Integration/Configuration	20,000	10	200,000	Integration/Configuration/Unit-Testing Multifunction controller at campus stations
MG Communications					
GE MDS orbit - MCR-4G access point	MG Control Station network access point: (900Mhz, 3G/4G, WiFi, 10-100Ethernet, VoIP, Serial RS232/485)	2,200	1	2,200	Wireless access point for MG control station. Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900Mhz Mesh or 3G/4G as needed for linking to utility field network. Use

					900Mhz mesh to MG control nodes at buildings.
GE MDS orbit - remote mxnx-u91-s1n	MG remote control point : MG Sub/FacilityDevice/DG link: (900Mhz,WiFi, 10-100Ethernet)	1,500	10	15,000	Wireless remote node (1 per building)... Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900 MHz Mesh network back to MG control station. Use Wi-Fi or Ethernet for points inside or near buildings.
GE MLS2400 Ethernet Switch	Network switch panel for MG substation. VoIP/SCADA/Relay data connected via Ethernet	3,000	11	33,000	Ethernet switch, rack, power (1 per building). Wireless access point goes into switch then Wireless or Ethernet to any controllable elements in building.
<b>Total</b>				<b>750,700</b>	

#### E.1.4.5 Total Microgrid Cost Estimates

In addition to the generation costs and the costs of the physical elements used in the control & communications infrastructure and the electrical infrastructure, there are additional costs associated with initial microgrid controller development, engineering specification and design, and actual installation and project management. The following table provides a detailed listing of all the elements of the installed microgrid system costs.

**Table E-12: Rockland Microgrid Full System Cost Estimates (Rounded to the Nearest \$1000)**

Project Activity	Description	Low (\$)	AVG (\$)	High (\$)	Type
Amortized Development of the MG Energy Management System	Integrate U90 master controller and the D400 control nodes with the PCMS EMS. Develop any extra system orchestration functions not native to the off the shelf commercial EMS that are required to perform NYSEERDA MG operations. -MG System Orchestration -Control Loads -Control Generators -Planning/Forecasting/Scheduling -Monitoring/Diagnostics -Utility Data Exchange -Grid PCC Mgmt. -Utility Baseline Integration	396,000	554,000	710,000	General Development
MG Communications Fabric Planning/Installation/Configuration	All wireless communications platforms -Communications from the MG control room to MG control nodes. -Communication from MG control room to utility	0	0	0	Site Specific Planning & Development
MG Test Plan Development	Design evaluation and stress tests to validate every function and every protection and safety scheme in the system. -develop formal test plan	374,000	512,000	648,000	Site Specific Planning & Development

	-design test and validation control and workflows - write corresponding code/scripts				
MG System Integration & Site Certification	Run tests to validate every function, system and device in the entire system. All facilities, buildings, BEMS, Generators, MG control fabric, MG electrical fabric, and MG communications fabric. - Execute tests and document results - Orchestrate formal acceptance process - Obtain formal site sign off	95,000	133,000	170,000	Site Specific Planning & Development
Project Management	Program Management, Administration, and Technical interchange meetings -Technical interchange with utility/vendors/NYSERDA/DHS/Gov/etc. -Requirements collection and scope definition for complete system - Developing and Reviewing SOWS/RFP/Proposals to subs and vendors -Manage multiple subs and vendor -Manage technical development -Manage internal GE teams -Program interface with sponsors -Reporting and accounting	504,000	696,000	888,000	Site Specific Planning & Development
Site Design Engineering and Construction	Microgrid Detailed Systems Design -Develop formal technical specification -Power Systems Analysis -Power Systems Simulation -Site Planning & Licensing -Site Construction	518,000	716,000	912,000	Site Specific Planning & Development
Distributed Generation BOM	New Distributed Generation	0	0	0	CAPEX
Control & Communications BOM	CAPEX for the control and communications subsystem	608,000	676,000	751,000	CAPEX
MG Electrical Infrastructure	All required electrical distribution components -xformers/feeders/switching/protection/ss integration/etc.	654,000	727,000	800,000	CAPEX
Microgrid Maintenance and Support	All software licenses and tech support - maintain MG system - provide 24/7 tech line support - perform routine software maintenance and upgrade	38,000	43,000	47,000	Annual O&M
<b>Total MG One-Time Cost</b>		<b>3,149,000</b>	<b>4,014,000</b>	<b>4,879,000</b>	
<b>Annual MG O&amp;M Cost</b>		<b>38,000</b>	<b>43,000</b>	<b>47,000</b>	

### E.1.5 One-Time Cost Considerations

Some of the costs are one-time costs, because off-the-shelf and commercially turn-key microgrid controllers are still at development state, and functioning microgrids for the multi-entity sites considered in this study are still being developed.

This study assumed that such a functioning microgrid controller will be developed from scratch for these 5 sites. This will be a one-time development cost consisting of the software and code design to enable currently existing and commercially available hardware to be linked in an optimal manner with enabled

communication throughout the network and to provide optimal control and dispatch functions. It is expected that the developed software and codes can then be more easily modified and applied at future sites at a fraction of the initial development costs.

## **E.2 Benefit-Cost Assessment**

### **E.2.1 Overview**

The feasibility study for the Rockland County site examines the development of a microgrid designed to support a cluster of county and municipal facilities in New City, a hamlet within the Town of Clarkstown that serves as the county seat. The facilities include:

- *The New City Fire Department (NCFD)*, which provides heated bays for three pumper trucks, a tower ladder truck, a heavy duty rescue truck, an all-terrain brush fire truck, a patrol truck, a pickup truck, and a rescue boat.
- *The Town of Clarkstown's Police Headquarters*, which houses the town's emergency operations and communications centers, as well as a fuel dispensing station.
- *Clarkstown's Town Hall*, which serves as a staging point for the distribution of supplies during an emergency and, if necessary, can also serve as an emergency operations center.
- *The Rockland County Sherriff's Office*, which is responsible for civil and criminal law enforcement and serves as a back-up dispatch and call center.
- *The Rockland County Correctional Center*, which houses approximately 300 inmates.
- *The Rockland County Courthouse*.
- *The Allison-Parris County Office Building*, which houses both the Rockland County legislature and the County's Executive offices.
- *The Rockland County Highway Department Garage*.
- *The Sain Building*, which houses a number of county offices.
- *A Verizon telecommunications switching station*.

Many of these facilities are currently equipped with backup generators. The microgrid design for the Rockland site draws exclusively upon these generators, including natural gas units at the Sherriff's Office and NCFD and diesel units at the Police Headquarters, Town Hall, Correctional Center, County Courthouse, and Verizon building. These generators range in size from 60 kW to 1.5 MW, with a total modeled capacity of 3.25 MW.<sup>15</sup> This capacity would be sufficient to meet the critical load from all facilities.

The results of the engineering analysis indicate that it would not be cost-effective to operate the DER at the Rockland County site on a continuous basis. Instead, the benefit-cost assessment focuses on two operating scenarios:

- Operation of the DER solely in the event of a power outage, in islanded mode.

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<sup>15</sup> As noted in the previous chapter, the capacity of the emergency generators available at the New City Fire Department and Rockland Town Hall differs slightly from the modeled capacity. The BCA's analysis of the microgrid's costs is based on the modeled capacity; the analysis of the benefits of a microgrid in the event of a major power outage is based on capacity figures provided by town officials in communications with DHSES. The discrepancies are minor and unlikely to have a material impact on the results of the analysis.

- Provision of peak load support via participation in a demand response program.

E.2.2 Fixed Cost Factors

The best estimate of initial design and planning costs for development of a microgrid at the Rockland County site is approximately \$2.6 million. This figure includes approximately \$2.0 million in site-specific planning and administrative costs as well as \$554,000 in engineering design costs. The project’s capital costs are estimated at approximately \$1.4 million, including \$727,000 for electrical infrastructure and \$676,000 for control and communications systems. Fixed O&M costs are estimated at approximately \$43,000 per year.

E.2.3 Variable Cost Factors

The analysis relies on information provided by the Project Team’s design consultants and projections of fuel costs from the SEP to estimate the variable costs of operating the microgrid. Variable O&M costs, excluding fuel, are estimated at \$17.75 per MWh; weighted average fuel costs for the microgrid’s first year of operation are estimated at approximately \$237 per MWh.

The analysis of variable costs also considers the environmental damages associated with emissions from distributed energy resources, based on the understanding that the generators at the Rockland County site would not be subject to emissions allowance requirements. The estimate of environmental damages relies on the weighted average pollutant emissions factors provided by the project’s design consultants, as specified in Table E-13.

**Table E-13: Pollutant Emissions Factors for the Rockland Microgrid**

<b>Pollutant</b>	<b>Emissions (Tons/MWh)</b>
CO <sub>2</sub>	0.74
SO <sub>2</sub>	0.0016
NO <sub>x</sub>	0.0142
PM	0.0002

E.2.4 Analysis of Reliability Benefits

The analysis estimates that development of a microgrid at the Rockland County site would yield reliability benefits of approximately \$143,000 annually. This estimate is based on the following indicators of the likelihood and average duration of outages in the service area:

- System Average Interruption Frequency Index (SAIFI) – 0.94 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 100.8 minutes.<sup>16</sup>

The estimate of reliability benefits takes into account the capabilities of the backup power systems already available at the Rockland County site. It also takes into account the variable costs of operating all generators, both in the baseline scenario and as integrated components of a microgrid. As in previous case studies, the analysis assumes a 15 percent failure rate for backup generators under baseline conditions. It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

#### E.2.5 Analysis of Benefits in the Event of a Major Power Outage

The estimate of reliability benefits presented above does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the analysis assesses the impact of a total loss of power – including the failure of backup generators – on the facilities the Rockland County microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.

##### *E.2.5.1 New City Fire Department*

The New City Fire Department (NCFD) is one of seven all-volunteer departments that provide fire and rescue service to the 86,000 residents of Clarkstown. Its fire house is equipped with a 60 kW natural gas-fired emergency generator. This generator is capable of meeting approximately 50 percent of the facility’s normal load, excluding air conditioning. If its backup generator were to fail, NCFD would rent a portable generator with sufficient capacity to meet the facility’s normal load. NCFD estimates that the portable generator would be online within 12 hours.

To estimate the value of services that would be lost if NCFD were affected by a major power outage, the analysis applies a methodology developed by FEMA. The methodology calculates the impact of the loss of service from a fire station on the time required to respond to a fire and the resulting effect on fire-related damages, including deaths, injuries, and property losses. In applying this method to NCFD, the analysis makes the following assumptions about operations in the absence of a microgrid:

- The NCFD is the primary service provider for one-seventh of Clarkstown’s population, or about 12,300 people.
- NCFD can maintain 50 percent of its ordinary level of service when forced to rely on its backup generator.
- There is a 15 percent probability that its backup generator will fail.
- If NCFD’s backup generator fails, it would take 12 hours for a portable generator to be installed.
- During this 12-hour period, the calls NCFD ordinarily would handle would instead be handled by the Congers Fire Department, which is located approximately 3.2 miles away.

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<sup>16</sup> The SAIFI and CAIDI values employed in the Rockland County analysis are the values for Orange and Rockland Utilities, Inc. in 2012, as reported in State of New York Department of Public Service, *2012 Electric Reliability Performance Report*, June 2013.

- Once the portable generator is online, full service from NCFD would be restored.

Based on these assumptions, the analysis estimates that the value of lost services attributable to failure of NCFD's backup generator would be approximately \$1,000. To this figure it adds the cost of installing and removing the portable generator, which NCFD estimates at approximately \$4,000, and the cost of renting the generator, which NCFD estimates at approximately \$700 per day. The analysis assumes that development of a microgrid would avoid these costs and allow NCFD to maintain its standard level of service for the duration of any power outage.

#### *E.2.5.2 Clarkstown Police Department*

Clarkstown's police headquarters is the base of operations for the town's police department. The building is equipped with a 300 kW diesel emergency generator, which is capable of meeting the facility's peak load, excluding air conditioning. If the backup generator were to fail, portable generators are available and could be brought online relatively quickly (within six hours). The department's call center is also backed by a UPS that can maintain service for four to 12 hours.

The department's contingency plans for a power outage call for doubling its regular patrol staff, from 24 to 48 officers. If its backup generator failed, the department would shift an additional 10 detectives to patrol duty. Given these staffing plans and the backup capabilities described above, the analysis assumes that the Clarkstown Police Department would be able to maintain all services during a major power outage, with or without a microgrid. The only effect of a microgrid would be to avoid the cost of bringing the portable generator online should the primary backup fail. The town estimates this cost at approximately \$4,000.

#### *E.2.5.3 Clarkstown Town Hall*

Clarkstown's town hall normally provides office space for approximately 150 municipal employees. As noted above, the facility serves as a staging point for the distribution of supplies during emergencies. If necessary, it can also serve as an emergency operations center. The building is equipped with a newly installed 60 kW natural gas emergency generator, which is designed to provide electricity to the facility's data processing center; the data processing center is also equipped with a UPS system, which can maintain service on its own for up to 90 minutes. Additional emergency generating capacity is available from a town-owned 254 kW portable diesel unit. The portable generator ties into an automatic transfer switch and can be brought online in approximately one hour; it provides sufficient capacity to meet the building's normal load, with the exception of air conditioning. If the 254 kW unit failed, other portable generators are available and could be brought online relatively quickly (within six hours).

Given these backup capabilities, the analysis assumes that the Clarkstown Town Hall would be able to maintain all services during a major power outage, with or without a microgrid. The only effect of a microgrid would be to avoid the cost of bringing a portable generator online should the primary backup fail. The town estimates this cost at approximately \$4,000.

#### *E.2.5.4 Rockland County Sheriff's Office and Correctional Center*

The Rockland County Sheriff's Office has a broad range of responsibilities, including civil and criminal law enforcement; coordination of police, fire, and other emergency radio communications for Rockland County; and emergency response planning. The Sheriff's Office also operates and maintains the Rockland County Correctional Center. The Sheriff's Office is backed by a 250 kW natural gas-fired

emergency generator, while the Correctional Center is served by a 1.5 MW diesel generator. The generator at the Sheriff's Office is capable of powering all essential operations. The generator at the Correctional Center powers its security systems but does not provide HVAC service.

The Sheriff's Office did not provide detailed information on the effect that failure of its backup generator would have on operations at its headquarters facility. In lieu of this information, the analysis focuses on the potential effect of a prolonged power outage on the Correctional Center. There, a loss of power during the heating season would necessitate evacuation of the inmate population, which, according to the Sheriff's Office, numbers approximately 300; this would be the case even if the backup generator continues to function, since the generator does not support the facility's heating system. The analysis assumes that the cost of transferring the inmates would be proportional to the cost of evacuating the Broome County Jail: approximately \$120 per prisoner, for a total relocation cost of approximately \$36,000. This includes both transportation costs and incremental costs for medical and correctional personnel during the transfer. To this figure the analysis adds the cost of reduced prison capacity, which it values at \$96 per prisoner-day. For 300 prisoners, this translates to a cost of approximately \$29,000 for each day the Correctional Center is closed.

#### *E.2.5.5 Rockland County Courthouse*

The Rockland County Courthouse is served by a 400 kW emergency diesel generator, which is sufficient to power the building's life safety equipment (approximately 60 percent of the facility's average load). Information on the emergency measures that might be taken in the event this generator fails is not available. In lieu of this information, the analysis estimates the impact of a microgrid based on the following assumptions:

- The total value of the services provided by the courthouse is approximately \$135,000 per day. This value is estimated using the U.S. Department of Energy (DOE) Interruption Cost Estimate (ICE) calculator, treating the courthouse as a medium to large customer in the public administration sector.<sup>17</sup>
- When relying on its backup generator, the value of service the courthouse provides is reduced by 40 percent, to approximately \$81,000 per day.
- In the baseline scenario, there is a 15 percent probability that the courthouse's backup generator will fail.
- If the backup generator fails, the courthouse will be left completely without power, resulting in a total loss of service.
- Development of a microgrid would reduce the risk of a total loss of power to near zero.
- Like the current backup system, the microgrid would sustain the building's critical load (*i.e.*, 60 percent of the average load), maintaining a level of service valued at \$81,000 per day.

The resulting impact estimate – an expected value of approximately \$12,000 per day – represents the benefit of a microgrid in sustaining the courthouse's critical load for the duration of any power outage.

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<sup>17</sup> See the Appendix J for additional information on the ICE Calculator.

#### *E.2.5.6 Other Rockland County Facilities*

The Rockland site includes three other county government facilities: the Allison-Parris County Office Building; the Rockland County Highway Department Garage; and the Sain Building. These facilities have no backup generators, and information on the emergency measures they might take in the event of a prolonged power outage is not available. In lieu of this information, the analysis estimates the impact of a loss of power using the DOE ICE calculator. In applying this methodology it makes the following assumptions:

- It assigns all three facilities to the public administration sector.
- Based on information provided on the facilities' annual demand for electricity, it treats the highway department garage as a small customer and the two office buildings as medium to large customers.

Based on this approach, the analysis estimates the impact of a power outage at approximately \$138,000 per day. The Rockland County microgrid would be designed to sustain only half of the typical load from these facilities. Accordingly, the analysis of these facilities estimates that a microgrid would cut the losses attributable to a power outage by half, to approximately \$69,000 per day.

#### *E.2.5.7 Verizon*

The Verizon switching station in Clarkstown is similar to the station in New York City. It is equipped with a 200kW diesel backup generator that is capable of maintaining service in the event of a power outage; an emergency battery system provides additional resilience and is capable of maintaining the facility's operations for up to eight hours. In the event of a major power outage and failure of its backup generator, Verizon would dispatch a generator truck which, it estimates, would be able to restore operations within 24 hours; thus, the analysis assumes that the maximum duration of any loss of service would be 16 hours. During this period, the switching station would lose the ability to handle local voice and data traffic. All other traffic ordinarily handled by the station would be rerouted to other facilities.

The benefits analysis assumes, in the baseline scenario, that there is a 15 percent probability that Verizon's backup generator will fail, and that this failure would lead to a loss of local voice and data service for 16 hours. Further, it assumes that establishment of a microgrid would eliminate the risk of failure. To value this impact it relies on the same methods used to value reliability benefits, setting SAIFI and CAIDI values to estimate the economic losses that a medium to large customer in the transportation, communication, and utilities sector would experience as a result of a 16-hour outage. The resulting figure, \$76,000, represents the estimated benefit the microgrid would provide by keeping the Verizon station fully operational.

#### E.2.6 Analysis of Peak Load Support Scenario

The benefits of developing a microgrid at the Rockland County site would be enhanced if the system could provide peak load support to the macrogrid via participation in a demand response program. Participating in this program would reduce demand to expand the macrogrid's generating capacity, thus providing capacity cost savings. Providing peak load support would increase the microgrid's annual operating costs (including variable O&M costs, fuel costs, and environmental costs). These costs, however, would be offset in part by a reduction in demand for electricity from the macrogrid, which would lead to energy cost savings and environmental benefits associated with the operation of bulk energy facilities.

The analysis estimates the benefits of the Rockland County project's participation in a demand response program based on a peak load for participating facilities of approximately 2,183 kW. Given this figure, the project would generate capacity cost savings of approximately \$198,000 per year. If the system were called upon to provide support for 20 hours a year, its operating costs would increase by approximately \$15,000 annually. These costs would be offset by a reduction of approximately \$5,000 per year in the macrogrid's operating costs. Under this set of assumptions, the system's participation in a demand response program would yield benefits of approximately \$187,000 annually.

#### E.2.7 Summary of Results

The analysis of the Rockland County site indicates that without participation in some type of demand response program, the benefits of a microgrid are unlikely to exceed its costs. Absent involvement in such a program, benefits would exceed costs only if the probability of a major power outage is assumed to be consistently high. As Table E-14 shows, the expected number of days without power would have to be on the order of one to three *each year* in order for the project to be cost-effective.

Participating in a demand response program would greatly improve the economic case for development of a microgrid at the Rockland County site. In the low cost/peak load support scenario, benefits exceed costs even if the analysis assumes a zero probability of a prolonged power outage. In contrast, the breakeven conditions for the average and high cost scenarios include a non-zero chance of a prolonged outage. The expected number of days without power, however, would need to be no greater than 0.30 to 0.71 annually for the project to be cost-effective.

As previously noted, the analysis of the peak load support scenario assumes that all generators at the Rockland County site would meet eligibility requirements for participation in a demand response program. Additionally, it assumes that the facilities served by the microgrid would be willing to participate in such an arrangement. These issues are important to the outcome and should be investigated further before any action on development of a microgrid at the site.

**Table E-14: BCA Results for the Rockland County Site: Breakeven Conditions (7% Discount Rate)**

<b>Scenario</b>	<b>Annual Probability of Specified Outage</b>	<b>Duration of Specified Outage</b>	<b>B/C Ratio</b>
Low Cost/No Peak Load Support	100%	1 day	1.08
Average Cost/No Peak Load Support	100%	2 days	1.11
High Cost/No Peak Load Support	100%	3 days	1.13
Low Cost/Peak Load Support	NA	NA	1.06
Average Cost/Peak Load Support	30%	1 day	1.00
High Cost/Peak Load Support	71%	1 day	1.00

## Appendix F **Microgrid Case Study: Suffolk County (Yaphank)**

### **F.1 Feasibility Study**

#### F.1.1 Site Characteristics

The goal of site characterization activity is to understand the particular operating and emergency response missions of facilities composing the proposed microgrid site and to gather data describing the facilities requirements for power and the specific physical characteristics and constraints of the buildings and their power systems infrastructure. On-site interviews and phone calls were held with various facility, utility, state officials and business stakeholders involved with this site. The following sections of this report provide a summary of the site visits and present an overview of the various data collected.

The principal site entities are:

- Public Works (C0010)
- Board of Election (C0011)
- Minimum and Maximum Security Facility, Pumper Test Building, VEEB Training Building (C0012)
- Central Purchasing (C0014) – (originally referred as Home & Infirmary)
- Slaughter House (C0106)
- Probation Building / FRES (C0110)
- Doctor's Cottage (C0161)
- DPW Garage (C0342)
- Police Headquarters Building (C0356)
- Control Building (C0490)
- Pump Station (Sewage Treatment) (C0492)
- Police Radio Tower (C0718)
- FRES Radio Tower (C0736)
- Police Property Bureau (C0753)
- Police Garage (C0850)
- SC Department of Health (C0898) – (originally referred as Skilled Nursing Facility)
- Quartermaster Building (C0975)

A high level view of the Suffolk County site is provided in Figure F-1.



**Figure F-1: Suffolk Site**

*F.1.1.1 Site Visit Summary*

The Yaphank complex is comprised of over 100 buildings and facilities spread over a distance of about 2 miles along Yaphank Avenue between the Long Island Expressway and Sunrise Highway. Nine of these

facilities were initially identified as a part of Suffolk County Microgrid site. An onsite interview was conducted on December 5th, 2013 at the Suffolk County Department of Public Works to understand and characterize the site. The interview was attended by representatives from DHSES, NYSERDA, DPS, Suffolk County and GE.

The site is comprised of a cluster of county facilities on either side of approximately 1.5 miles section of Yaphank Avenue.

The key findings from the site visit are:

- The site is 40-50 feet above sea-level, was not flooded during Sandy, and was operational for 9 days with backup during the event.
- It is easily accessible by major highways and county roads, and is bisected by a railway line.
- The electrical supply is conventional 15-kV class overhead radial service, transitioning to underground at some locations.
- There is a LIPA substation on the premises and a main natural gas line to the site.
- Onsite fuel storage is 10,000 gallons, enough for a few days of supply to nominal loads or over a week on reduced/emergency loading.
- There is a cell tower and are several radio communication towers onsite.
- Twenty of the buildings on the site use 75% of the energy in the county.
- There is a cluster of three critical buildings (Probation Building / FRES, Minimum and Maximum Security Facility and SC Department of Health) with a total ~8MW of distributed backup generation that could form the core of a micro grid.
- These three buildings are within a radius of 1000 feet and are located about 3000-4000 feet from the LIPA substation.
- The fourth critical load is the Fueling Dispensing Facility (C0342), about a mile to the north of the cluster and about 1500 feet from the LIPA substation.
- A 100kW roof-top PV installation is planned near this location.
- Several buildings were identified as possible shelter sites, including FRES and Central Purchasing.

#### *F.1.1.2 Data Collection for Site Characterization*

GE team worked with site contacts, LIPA, NYSERDA, NYS DHSES, and NYS DPS, to collect detailed data for the Suffolk site. Their assistance and collaboration were essential in collection of the necessary data and in helping form the needed characterization of the Suffolk site for the microgrid design. The site contact provided a master spreadsheet with answers to the survey questions and pertinent data for the buildings identified as part of the microgrid. The data collected included:

- Generation, and load, including two years of monthly electrical demand and gas usage.
- Rate class for all facilities from LIPA using each facility's account number.
- Load research data with hourly load profile for similar rate class loads from LIPA.
- One-line diagram of feeders serving the identified microgrid site facilities including one-line diagram of the buildings.

Additional information needed to construct the energy balance model, fuel data, and generation operational and cost parameters were collected by the GE team, some from public data, and others from internal GE sources. Some of the values used in the analysis are based on unofficial, non-public, and subjective assessments, but provide a best estimate tempered by the availability of data.

*F.1.1.3 Suffolk Site Constituents, Generation, and Infrastructure*

The following table provides a summary of the primary/critical activities on site.

**Table F-1: Suffolk Site Principal Entities**

Facility Name	Mission/Role
Public Works (C0010)	Economic Dev. & Planning, Health Services, IT, Public Works, S.C. Ethics Commission
Board of Elections (C0011)	Board of Elections, Public Works
Minimum and Maximum Security Facility (C0012)	Jail, Health Services, Public Works, Sheriff
Central Purchasing (C0014)	Economic Dev. & Planning, Health Services, IT, Public Works, Sheriff
Slaughter House (C0106)	Food Distribution Facility
Probation Building / FRES (C0110)	FRES, IT, Police, Probation, Public Works
Doctor's Cottage (C0161)	Shelter
DPW Garage (C0342)	Garage Facility, Public Works
Police Headquarters Building (C0356)	Police, Public Works
Control Building (C0490)	Telecom & Data Center
Pump Station (Sewage Treatment) (C0492)	Water / Wastewater Treatment Plants
Police Radio Tower (C0718)	Telecom & Data Center
FRES Radio Tower (C0736)	Telecom & Data Center
Police Property Bureau (C0753)	Police
Police Garage (C0850)	Public Works
SC Department of Health (C0898)	Health Facility, Health Services
Quartermaster Building (C0975)	Office

The following table summarizes the existing generation resources at the Suffolk site.

**Table F-2: Suffolk Site Existing Generation Resources**

Facility Name	Mission/Role
Public Works (C0010)	385 kW Diesel generator
Board of Elections (C0011)	750 kW Diesel generator 100 kW PV array
Minimum and Maximum Security Facility (C0012)	Diesel generators Min Security: 1,500 kW Max Security Primary: Three (3) 2 MW units Max Security Backup: 350 kW
Probation Building / FRES (C0110)	Diesel generators Primary: 150 kW Backup: 400 kW
DPW Garage (C0342)	125 kW Diesel generator
Police Headquarters Building (C0356)	Diesel generators Building: 1250 kW 911: 125 kW
Control Building (C0490)	Diesel generator
Pump Station (Sewage Treatment) (C0492)	(No size or rating information)
Police Garage (C0850)	55 kW Diesel generator
SC Department of Health (C0898)	1500 kW Diesel generator
Quartermaster Building (C0975)	180 kW Diesel generator

GE was unable to get information of existing electrical and control infrastructure of the Suffolk site. Table F-3 shows limited information extracted from the feeder online obtained from the utility.

**Table F-3: Suffolk Site Infrastructure Characterization**

Facility Name	Power Distribution & Control Systems
Public Works (C0010)	Electrical <ul style="list-style-type: none"> <li>• LIPA Distribution Feed</li> </ul> Control <ul style="list-style-type: none"> <li>• BEMS running HVAC (Johnson Controls Metasys)</li> <li>• Lights on motion sensors</li> <li>• Some components network addressable</li> </ul>
Board of Elections (C0011)	Electrical <ul style="list-style-type: none"> <li>• LIPA Distribution Feed</li> </ul> Control <ul style="list-style-type: none"> <li>• BEMS running HVAC (Johnson Controls Metasys)</li> <li>• Lights on motion sensors</li> </ul>
Minimum and Maximum Security Facility (C0012)	Electrical <ul style="list-style-type: none"> <li>• LIPA Distribution Feed</li> </ul> Control <ul style="list-style-type: none"> <li>• BEMS running HVAC (Johnson Controls Metasys)</li> <li>• Lights on motion sensors</li> </ul>
Central Purchasing (C0014)	Electrical <ul style="list-style-type: none"> <li>• LIPA Distribution Feed</li> </ul> Control <ul style="list-style-type: none"> <li>• BEMS running HVAC (Johnson Controls Metasys)</li> <li>• Lights on motion sensors</li> </ul>
Slaughter House (C0106)	Electrical <ul style="list-style-type: none"> <li>• LIPA Distribution Feed</li> </ul> Control <ul style="list-style-type: none"> <li>• No BEMS</li> <li>• Lights on motion sensors</li> </ul>
Probation Building / FRES (C0110)	Electrical <ul style="list-style-type: none"> <li>• LIPA Padmount Transformer</li> </ul> Control <ul style="list-style-type: none"> <li>• BEMS running HVAC (Johnson Controls Metasys)</li> <li>• Lights on motion sensors</li> </ul>
Doctor's Cottage (C0161)	Electrical <ul style="list-style-type: none"> <li>• LIPA Distribution Feed</li> </ul> Control <ul style="list-style-type: none"> <li>• No BEMS</li> <li>• Lights on motion sensors</li> </ul>
DPW Garage (C0342)	Electrical <ul style="list-style-type: none"> <li>• LIPA Padmount Transformer</li> </ul> Control

Facility Name	Power Distribution & Control Systems
	<ul style="list-style-type: none"> <li>• No BEMS</li> <li>• Lights on motion sensors</li> </ul>
Police Headquarters Building (C0356)	Electrical <ul style="list-style-type: none"> <li>• LIPA Padmount Transformer</li> </ul> Control <ul style="list-style-type: none"> <li>• BEMS running HVAC (Johnson Controls Metasys)</li> <li>• Lights on motion sensors</li> </ul>
Control Building (C0490)	Electrical <ul style="list-style-type: none"> <li>• LIPA Padmount Transformer</li> </ul>
Pump Station (Sewage Treatment) (C0492)	Control <ul style="list-style-type: none"> <li>• No BEMS</li> <li>• Lights on motion sensors</li> </ul>
Police Radio Tower (C0718)	Electrical <ul style="list-style-type: none"> <li>• Fed from Police Headquarters Building</li> </ul> Control <ul style="list-style-type: none"> <li>• Lights on motion sensors</li> </ul>
FRES Radio Tower (C0736)	Electrical <ul style="list-style-type: none"> <li>• Fed from FRES Building</li> </ul> Control <ul style="list-style-type: none"> <li>• Lights on motion sensors</li> </ul>
Police Property Bureau (C0753)	Electrical <ul style="list-style-type: none"> <li>• LIPA Pole Distribution</li> </ul> Control <ul style="list-style-type: none"> <li>• No BEMS</li> <li>• Lights on motion sensors</li> </ul>
Police Garage (C0850)	Electrical <ul style="list-style-type: none"> <li>• LIPA pole mounted Transformer</li> </ul> Control <ul style="list-style-type: none"> <li>• No BEMS</li> <li>• Lights on motion sensors</li> </ul>
SC Department of Health (C0898)	Electrical <ul style="list-style-type: none"> <li>• LIPA Padmount Transformer</li> </ul> Control <ul style="list-style-type: none"> <li>• BEMS running HVAC (Johnson Controls Metasys)</li> <li>• Lights on motion sensors</li> </ul>
Quartermaster Building (C0975)	Electrical <ul style="list-style-type: none"> <li>• LIPA Padmount Transformer</li> </ul> Control <ul style="list-style-type: none"> <li>• No BEMS</li> <li>• Lights on motion sensors</li> </ul>

## F.1.2 Site Modeling and Analysis

### *F.1.2.1 Modeling of Generation Supply and Demand*

To develop a Microgrid Functional Design, GE performed a detailed supply and demand study of each site using the HOMER model.

The HOMER model inputs include:

- The microgrid projected load data, up to two sets of hourly (24 x 365) or 12 x 24 load profiles representing the microgrid facilities (i.e., the microgrid total load, separated or aggregated into one or two load profiles),
- Existing and proposed distributed generation sets of different kinds and sizes,
- Generation cost characteristics, including capital costs, fixed operations and maintenance (FOM) costs, and variable operations and maintenance (VOM),
- Fuel costs,
- Criteria Pollutants and Greenhouse Gas emissions, and
- HOMER variability and operating reserve margins and other modeling parameters.

HOMER finds the least cost of generation mix to meet the hourly load for every hour of the year. One can assign different capacity sizes, operating reserve levels, and other parameters as “sensitivities” and Homer determines best generation mix for each sensitivity assumption.

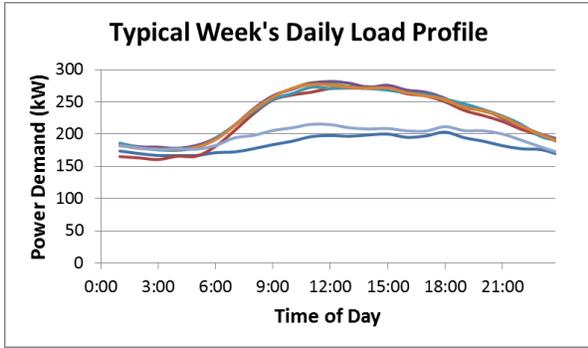
The model outputs information on the selected generation mixes, energy produced, fuel consumption, and emissions. Some of the model outputs are shown in the tables and charts of the following sections.

### *F.1.2.2 Model Load Data*

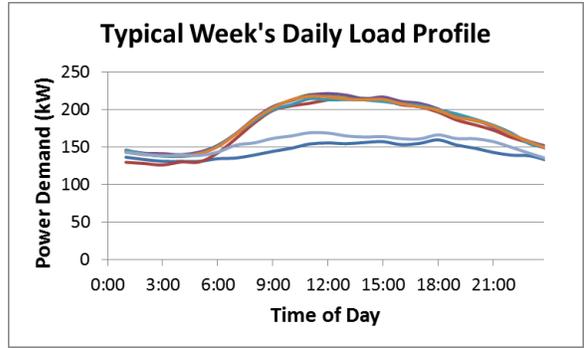
#### F.1.2.2.1 Base Load

The Suffolk site load data consists of load for Public Works, Board of Elections, Minimum and Maximum Security Facility, Central Purchasing, Slaughter House, Probation Building / FRES, Doctor's Cottage, DPW Garage, Police Headquarters Building, Control Building, Pump Station (Sewage Treatment), Police Radio Tower, FRES Radio Tower, Police Property Bureau, Police Garage, SC Department of Health, and Quartermaster Building. Control Building and Pump Station share same meter and are represented as single load for the purpose of load profile model. Similarly, Police Radio Tower and FRES Radio Tower are fed from Police Headquarters and FRES building respectively and are not included with those buildings for the purpose of load profile model.

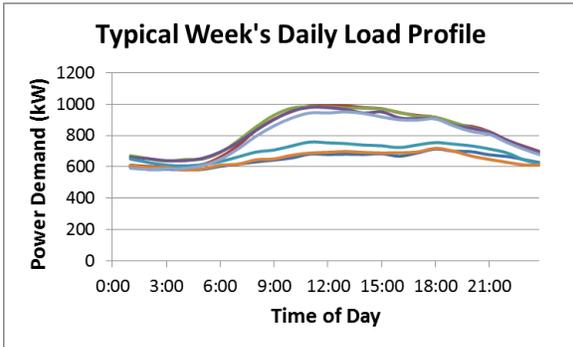
The monthly demands for all facilities were obtained from the site. The load research data for similar facilities based on rate class for the area obtained from LIPA was used to create a 365 x 24 hour load profile. Figure F-2 shows a typical week's (mid-January) load profiles for all the facilities.



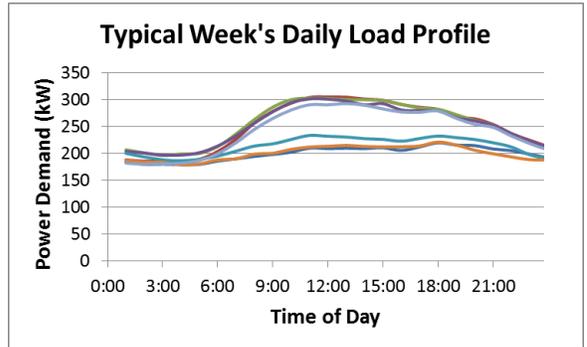
a) Public Works



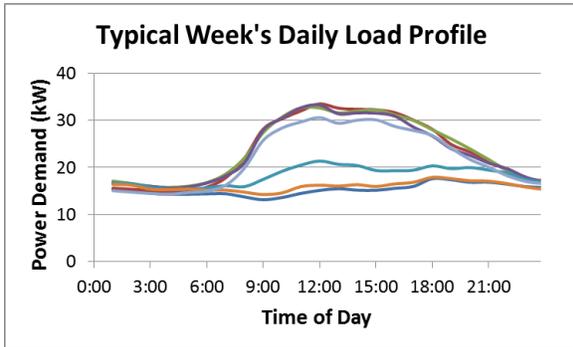
b) Board of Election



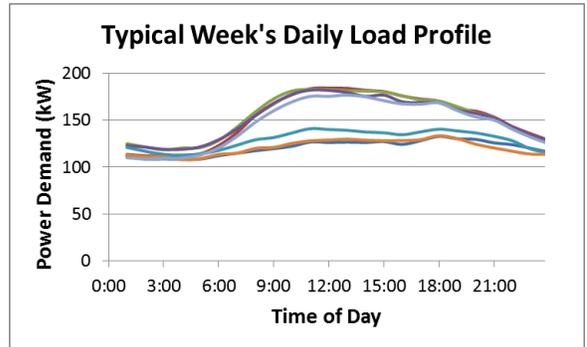
c) Min. & Max. Security Facility



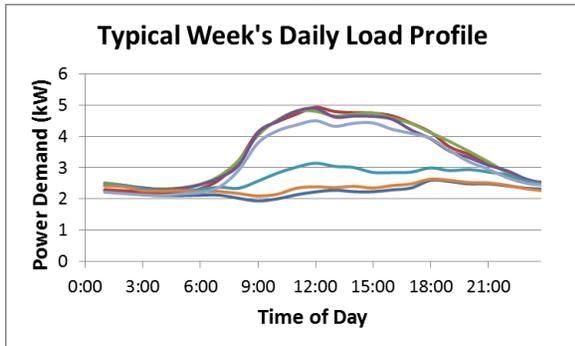
d) Central Purchasing (Home & Infirmary)



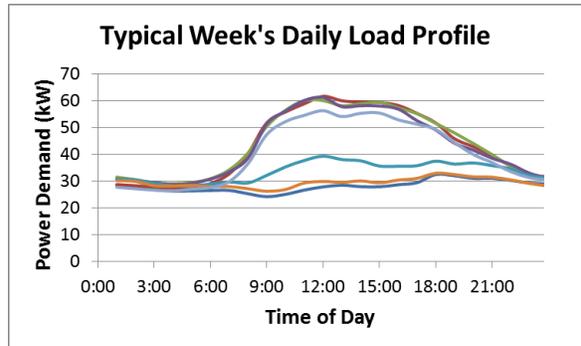
e) Slaughter House



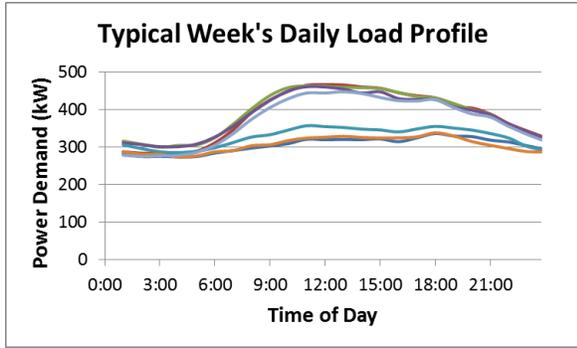
f) Probation/FRES



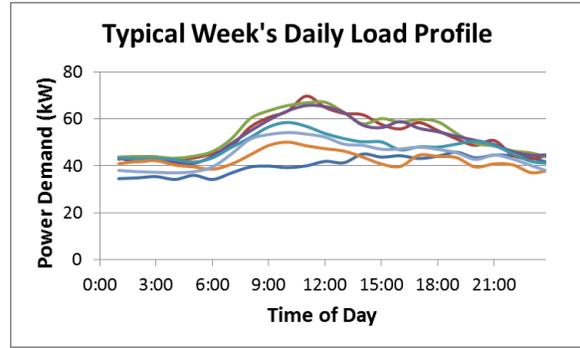
g) Doctor's Cottage



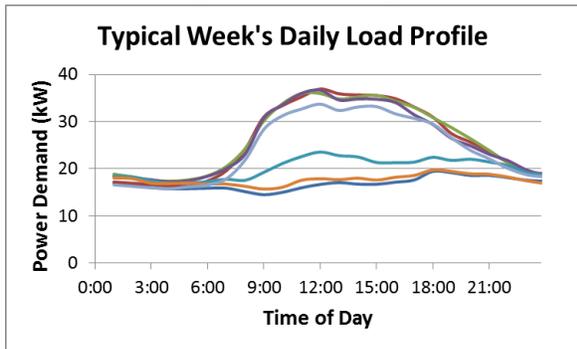
h) DPW Garage



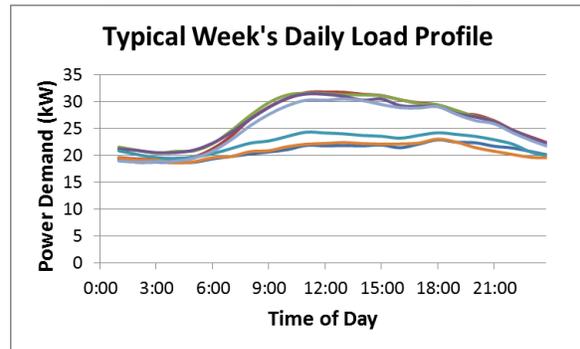
i) Police Headquarters



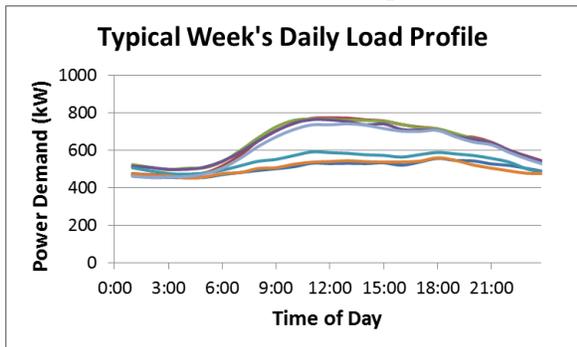
j) Control Building and Pump Station



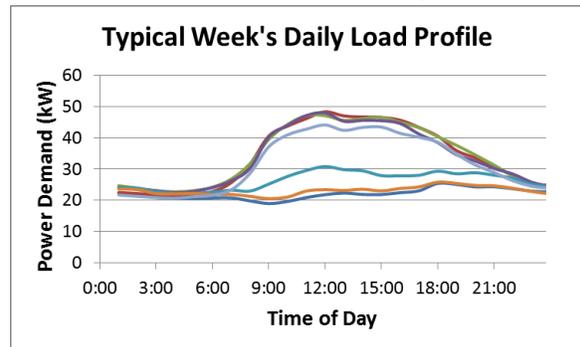
k) Police Property



l) Police Garage



m) SC Department of Health



n) Quartermaster Building

**Figure F-2: Typical Load Profile (a week in January) for all Facilities**

Since HOMER could only accept two separate load profiles for analysis, the load for Public Works, Board of Elections, Central Purchasing (Home & Infirmary), Probation Building/FRES, DPW Garage, Police Headquarters Building, and Police Garage was aggregated into one group and the load for Minimum and Maximum Security Facility, Slaughter House, Doctor's Cottage, Control Building and Sewage Treatment (Pump Station), Police Property Bureau, SC Department of Health (Skilled Nursing), and Quartermaster Building into another group.

The facilities/loads were characterized as either L1: Critical or L2: Discretionary, and also given score from 1 to 6 based on criticality, 1 being the most critical. An assumption for critical load percentage was

made for each facility and only the critical load share was used for aggregate load. The following criteria was used for the assumed critical load share,

- If a facility did not have a backup generator then the critical load is 50% of maximum demand,
- If the facility had one or more backup generator but the generation capacity is less than the maximum, then the percentage of annual peak load equal to generation capacity is critical load, and
- If the facility had one or more backup generator and the generation capacity is sufficient to support maximum demand, then 100% of load is critical load.
- An exception to above was the SC Department of Health (Skilled Nursing), which has sufficient generation but is not currently in use.

In addition, there are some loads/facilities that require additional electrical hardware (switches and controls) to isolate from the microgrid. Although a detailed analysis is not done, the isolation of these loads/facilities is considered not economical and included in load profile as “unintentional” load. To account for these unintentional loads, the load profile was marked up by 5% before feeding to Homer.

Table F-4 shows the critical load percentage per facility for Suffolk site facilities and Figure F-3 and Figure F-4 show the aggregate load profile of two load groups for the typical week.

**Table F-4: Critical load percentage per facility**

Facility	Critical Load Percentage
Public Works	75%
Board of Election	105%
Max/Min Security (Jail)	105%
Central Purchasing (Home & Infirmary)	55%
Slaughter House	55%
Probation/FRES	105%
Doctor's Cottage	55%
DPW Garage	105%
Police HQ	105%
Control & Sewage	105%
Police Property Bureau	55%
Police Garage	105%
SC Dept. of Health (Skilled Nursing)	55%
Quartermaster Building	105%
Public Works	75%

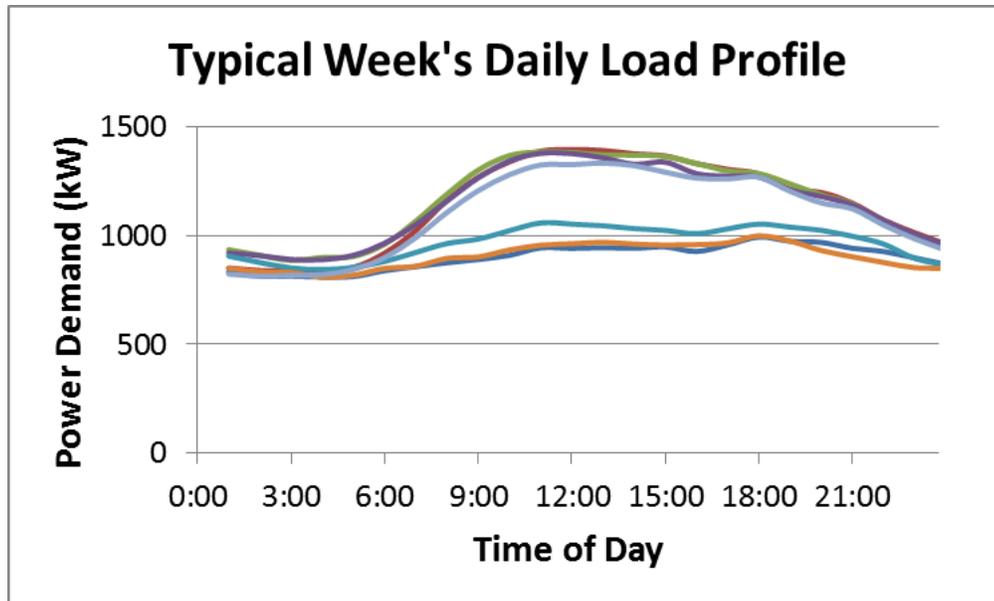


Figure F-3: Typical Load Profile (a week in January) for group one

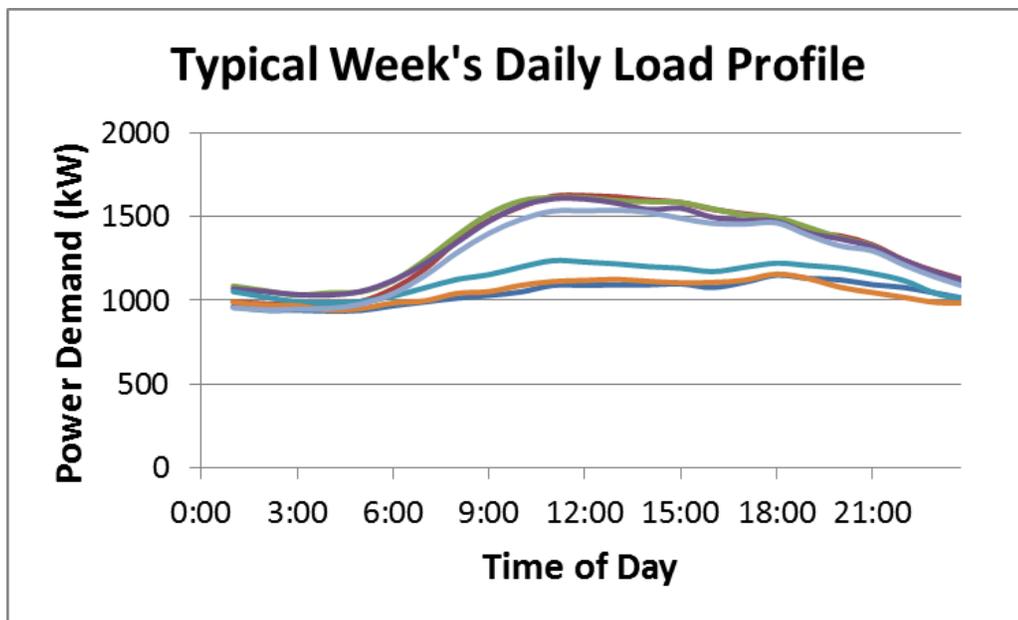


Figure F-4: Typical Load Profile (a week in January) for group two

F.1.2.2.2 Emergency Premium

To account for additional load over the base load in times of emergency, GE assumed a 20% emergency premium. This is the assumed additional load that may materialize during emergency periods resulting from the additional activity, personnel, and accommodation for emergency operations. The 20% emergency premium was applied to all hour loads, and hence the generation requirements are sized to this emergency load (i.e., Base Load + 20%). HOMER performs additional scaling and massaging of load to create the hourly load shapes and the resulting load characteristics (with and without the 20% emergency premium) are in Table F-5.

**Table F-5: Total Demand for Rockland Site**

Load Name	Hourly Peak (kW) without 20% premium	Hourly Peak (kW) with 20% premium
Group One	3,364	4,037
Group Two	2,640	3,168
<b>Total</b>	<b>6,004</b>	<b>7,205</b>

**Table F-6: Existing Generation Resources at Suffolk Site**

Facility	Capacity (kW)
Public Works (C0010)	385
Board of Elections (C0011)	750
Board of Elections (C0011) – PV Array	100
Minimum and Maximum Security Facility (C0012)	7,500
Central Purchasing (C0014)	-
Slaughter House (C0106)	-
Probation Building / FRES (C0110)	150
Doctor's Cottage (C0161)	-
DPW Garage (C0342)	125
Police Headquarters Building (C0356)	1,250
Control Building (C0490)	100 <sup>18</sup>
Pump Station (Sewage Treatment) (C0492)	-
Police Radio Tower (C0718)	-
FRES Radio Tower (C0736)	-
Police Property Bureau (C0753)	-
Police Garage (C0850)	55
SC Department of Health (C0898)	1,500
Quartermaster Building (C0975)	180
<b>Total</b>	<b>12,095</b>

*F.1.2.3 Model Generation and Fuel Data*

The existing generation capacity at Suffolk Site is shown in Table F-6.

Secondary backup generators at maximum security facility (350 kW), Probation/FRES (400 kW) and Police Headquarters (125 kW) are not assumed as available resources for the microgrid and not considered in HOMER modeling. The reason for this assumption are (a) these generators are designated as secondary backup and come into operation to serve pre-defined critical loads only when primary

<sup>18</sup> Assumed based on the peak demand due to lack of data from the site

backup fails, and (b) the site has enough generation to sustain the total microgrid load without these secondary backup generators.

From the above two tables it is apparent that the collective existing generation can cover the total microgrid load at the Suffolk site. The critical load in facilities with backup generator will be able to sustain an outage even without microgrid interconnection without considering the added emergency premium during such events. However, it should be noted that without the interconnection, the facilities with no backup generation will not have any service in an event of grid outage.

### F.1.3 Microgrid Infrastructure Configuration

#### F.1.3.1 *Model Generation Options*

HOMER produced results for generator energy production, their O&M and Fuel costs, fuel consumption, and emissions. It is assumed that the Microgrid will be functional for a minimum duration of one month – although there is no reason to assume that the microgrid cannot run for longer periods of time if the generators are regularly supplied with fuel. Hence, the following results are for a one-month operation of the microgrid.

**Table F-7: Suffolk Site Generation Performance**

Type of Distributed Energy Resource	Nameplate Capacity (kW)	Production (kWh/Month)	Capacity Factor (%)	Fuel Consumption (Gallons/Month)
Board of Elections – PV Array	100	10,266	14.1%	0
SC Department of Health	1,500	741,000	67.7%	53,440
Public Works	385	146,106	52.0%	10,537
Board of Elections	750	267,418	48.8%	19,286
Minimum and Maximum Security Facility	7,500	363,571	6.6%	26,220
Probation Building / FRES	150	56,178	51.3%	4,051
DPW Garage	125	42,002	46.0%	3,029
Police Headquarters	1,250	568,179	62.3%	40,977
Control Bldg. & Pump Station	100	30,130	41.3%	2,173
Quartermaster Bldg.	180	65,521	49.9%	4,725
Police Garage	55	13,767	34.3%	993
<b>Total</b>	<b>12,095</b>	<b>2,304,136</b>	<b>26.1%</b>	<b>165,432</b>

It should be noted that since all generation resources are diesel-fueled, and have similar assumed characteristics, they are actually interchangeable and similar electricity generation, fuel consumption, and O&M and fuel costs can be achieved if total generation is redistributed differently among different plants.

Table F-8 presents the monthly emissions by the Suffolk site generation set.

**Table F-8: Monthly Emissions**

Pollutant	kg/MWh
Carbon dioxide	715.44
Carbon monoxide	1.77
Unburned hydrocarbons	0.20
Particulate matter	0.13
Sulfur dioxide	1.44
Nitrogen oxides	10.80

#### *F.1.3.2 Electrical Infrastructure*

The following approach was taken for the electrical infrastructure design

- Assessment of existing electrical infrastructure in and around the proposed site. The assessment included both site (customer) owned and utility owned infrastructures.
- Analysis of one-lines to determine the PCC (point of common coupling) with the utility and to define the electrical boundary of Microgrid.
- Assessment of voltage levels, existing distribution system routes and distance between various buildings/facilities to determine interconnection options. The initial options included different voltage levels and different routes, both with and without the usage of existing utility or facility assets. Utility and site supplied one-lines and maps were used to determine the voltage levels and existing routes. Aerial and satellite maps were used to calculate approximate distance between various buildings and facilities of the Microgrid. A similar approach was used for selection of route for new distribution lines.
- Assessment and evaluation of different interconnection options (voltage level and route) for optimal system operation. The selection of optimal voltage level is based on engineering judgment and industry practice to maintain the power quality and minimize line loss. Routes were selected to minimize the total length of each new distribution line. The right of way is assumed to be available.
- Cable, switches, circuit breakers, transformers and other electrical equipment were selected based on the proposed power flow, selected voltage level, layout and connection scheme. The existing backup generators were considered to be equipped with circuit breaker(s) or transfer switch/switches and other equipment necessary to perform break-before-make switching operation.





- There was no input from the utility on existing communications platforms and no input from site detailing controllable loads. The site, however does have a Building Energy Management System (BEMS)
- Based on lack of technical or interoperability requirements, GE approached the architecture definition as a new system design with a goal to keep costs minimum and select control and communications devices which supported multiple protocols to enable interoperability across the largest array of devices and platforms.

Given the information above, for this prototypical example and high level estimate, GE selected wireless field networks as the communications backbone. This is a common solution for utility neighborhood area networks (NAN) and field area networks (FAN). This solution also allows ease of integration with modern AMI solutions that may be in the area. Another approach would be underground cabling or fiber optic networks. The fiber approach is the highest performing when it comes to bandwidth and reliability however it is a very large cost commitment for the utility. Underground copper cable is also high performing and very expensive. The lack of physical details concerning area-specific trenching requirements and length of cable runs and lack of input from the utility regarding network requirements ruled out estimating cost for both underground and fiber networks.

Control design was based on the GE Microgrid Reference Architecture (See Appendix B). The Microgrid Reference Architecture divides the microgrid into 3 control zones (shed-able load, discretionary load, critical load) and 5 formal control types (Utility Control Interface, Master MG controller, Smart Building, Raw Building, and sub or feeder IED's and switches).

To support the 5 control abstractions in the Microgrid Reference Architecture GE crafted a solution that included the notion of:

- Microgrid Energy Management System (MG EMS) which would serve as the master control application and orchestrate all control actions as well as provide the utility interface. The MG EMS would be developed per the software design bid listed in the C&C BOM table. This could include integration of some existing control platforms and a lot of new system level control orchestration services.
- Microgrid Master Control Station (1 per site): host MG EMS, orchestrate all control nodes and DG optimizer/dispatch controller.
- Microgrid Campus Control Node (1 per facility): coordinate control across multiple buildings composing a specific facility.
- Microgrid Edge Control Node (1 per building): direct interface to any controllable device in a building.
- All hardware level control was architected using programmable, multi-protocol, IED's to enable broadest support of industry standard protocols and interfaces (e.g. IEC61850, DNP3, Modbus TCP/IP, Modbus Serial, or Ethernet as interface to control ports on microgrid deployed devices such as IED's, PLC, switchgear, relay, sensors, meters, digital governors, etc.)

New developed MG EMS monitoring/control services will use 61850 communications to a Protocol gateway which maps 61850 logical nodes to the specific control interfaces on the MG components/devices.



#### F.1.4 Microgrid Cost Summary

##### F.1.4.1 *Microgrid Cost Estimate Development*

Based on the analysis performed and details of the functional design, GE developed its “best estimates” of the cost of microgrid development, using public and non-public sources, with an expected accuracy of +/- 30%.

Additional information needed to construct the energy balance model, fuel data, and generation operational and cost parameters were collected by the GE team, some from public data, and others from internal GE sources. Some of the values used in the analysis are based on unofficial, non-public, and subjective assessments, but provide a best estimate tempered by the availability of data.

The microgrid development cost components included (but not limited to) the following:

- Microgrid DG Costs (Capital, Fixed, Operations and Maintenance, Fuel, Etc.)
- Microgrid Control and Communications Infrastructure (components and installation)
- Microgrid Electrical Infrastructure Costs (components and Installations)
- Annual Microgrid Operations and Maintenance Costs

##### F.1.4.2 *Electric Generation Cost*

Since the existing on-site generation is sized large enough to cover the designated critical microgrid load, the generation costs do not include any capital costs. The only generation cost components are the O&M and fuel costs, as shown in Table F-9.

**Table F-9: Suffolk Site Generation Costs**

Generation	Capacity (kW)	O&M Costs (\$/Month)	Fuel Costs (\$/Month)	Total Variable Costs (\$/Month)
Board of Elections – PV Array	100	0	0	0
SC Department of Health	1,500	12,597	161,776	174,373
Public Works	385	2,484	31,897	34,381
Board of Elections	750	4,546	58,385	62,932
Minimum and Maximum Security Facility	7,500	9,084	79,375	88,459
Probation Building / FRES	150	956	12,265	13,221
DPW Garage	125	715	9,170	9,884
Police Headquarters	1,250	9,667	124,045	133,712
Control Bldg. & Pump Station	100	522	6,578	7,100
Quartermaster Bldg.	180	1,141	14,305	15,446
Police Garage	55	269	3,006	3,274
<b>Total</b>	<b>12,095</b>	<b>41,982</b>	<b>500,801</b>	<b>542,783</b>

*F.1.4.3 Electrical Infrastructure Cost*

The following table summarizes the Suffolk microgrid electrical infrastructure average cost estimates.

The cost for all electrical infrastructure components are the best estimates obtained from GE internal sources and verified from utility engineers (not related to Microgrid site).

Based on the methodology used for the electrical infrastructure cost estimation, the values presented should be assumed to be the “average” cost estimates. A 10% low and high adjustment was used to calculate the Low and High bookends of electrical infrastructure costs.

**Table F-10: Suffolk Microgrid Electrical Infrastructure Average Cost Estimates**

SN	Item	Description	Quantity	Unit	Unit Price (Installed) (\$)	Cost (\$)
1	15 kV Class 3-Ph Cable	Cable to interconnect two feeders	100	Ft.	30	3,000
2	600 V Class 3-Ph Cable	LV cable	0	Ft.	30	0
3	Medium Voltage (15kV class) Switch/Circuit Breakers	Switches at various locations	5	Nos.	20,000	100,000
4	Low Voltage Circuit Breakers	LV Circuit Breakers at various locations	0	Nos.	10,000	0
5	Protection System Evaluation	Model the existing system with new infrastructure and evaluate the protection system	1	unit	50,000	50,000
<b>Total</b>						<b>153,000</b>

#### *F.1.4.4 Control & Communications Cost*

Similar to the approach for electrical infrastructure cost estimation, to get component costing, GE referred to its internal sources. GE utilized its information (documents, website, internal communication), and used the online purchase menus to configure the devices per the store menus and ascertain a price for all communications and control hardware and supporting software applications. GE used list price in all cases to stay at a relatively conservative level.

To estimate system and project costs, GE first created the control/communication costing spread sheets to establish a list of required engineering, design, integration, and site activities. Details of each are described in the notes column. Based on the engineering activities GE estimated number of labor/months per tasks and used GE commercial rates to get a number.

To validate costs GE compared its derived numbers to some industry sources. Two sources in particular were noted: 1) Minnesota Microgrid Project, and 2) DOE Microgrid workshops. This study's cost numbers were somewhat higher, but that was due to the fact GE had originally used its commercial consulting rates for engineering design labor. GE finalized its numbers using a Low, Average, and High estimates in order to provide a range.

Table F-11 summarizes the Suffolk Microgrid Control & Communications Infrastructure "High" cost estimates. Estimates of integration cost were developed separately for the facilities with existing Building Energy Management Systems (BEMS), versus the facilities with little or no existing BEMS capability. The integration costs are expected to be much higher for buildings that have existing BEMS (which already provide a high level of operational visibility and control), as the Microgrid would need to be integrated within the complex systems and interfaces already present within these facilities. For the case of a highly automated building, the MG would need to be gracefully integrated with the existing BEMS platform and in some cases require more formal integration with control devices and other systems located throughout the building.

Based on the methodology used for the electrical infrastructure cost estimation, the values presented should be assumed to be the "high" cost estimates. The "average" cost estimate is 10% lower than the high cost estimate. Similarly, the "low" cost estimate is 10% lower than the average cost estimate.

**Table F-11: Suffolk Microgrid Control & Communications High Cost Estimates (Rounded to the Nearest \$100)**

Item - P/N	Description	Unit Price (\$)	QTY	Cost (\$)	Notes
MG Master Control Station					
MG Control Station Computer	MG Station Computer: Hosts MG EMS application. Hardened computer with processor/comm/interface expansion ports. Rack system.	15,000	1	15,000	Dell PowerEdge R270 Rackmount Server. Racks, Displays, Peripherals. SQL Server DBMS. Priced to approximate a hardened computer to host MG substation applications and support NERC compliance and multiple I/F options
GE EnerVista Engineer	MG Configuration Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Maintenance	MG Maintenance Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Monitoring	MG Monitoring Utility	2,000	1	2,000	MG controller HMI and configuration app
GE EnerVista Integrator	MG Device Integration	1,500	1	1,500	MG controller HMI and configuration app
GE Cimplicity	Cimplicity Globalview and Cimplicity Development	100,000	1	100,000	HMI/SCADA framework providing event/alarm monitoring, logging, and SCADA configuration tools.
GE Multilin U90+	MG Generation Controller/Optimizer	25,000	1	25,000	MG Generation Controller via Multilin UR family. Forecasting and optimal dispatch functions
GE D400	Advanced Protocol Gateway	9,000	1	9,000	Multifunction intelligent gateway. Provides control

					interface and data collection from protection, control, monitoring, RTU, IED's. Configured using Logixlinx software.
System Integration & I/F Modules	Integration & Control Software: Application functions, control functions, component adapters, and automation scripts	115,000	1	115,000	Engineering labor estimate for code development/integration of site-specific control and automation of buildings, systems, devices, and generators. (TBD scope: depending on requirement for monitoring and automated control of buildings and electrical infrastructure)
MG Campus Ctl Station (Facilities with BEMS)					
Control Station Computer	Application Host Computer	5,000	7	35,000	Dell PowerEdge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	7	3,500	Smart meter monitors main facility load. BEMS I/F provides detailed monitoring.
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	7	63,000	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
BEMS Integration	Configuration/Integration	25,000	7	175,000	BEMS configuration and integration with campus controller. Requires technical discussions with

					BEMS vendor and facility energy manager.
MG Campus Ctl Station (Facilities w/o BEMS)					
Control Station Computer	Application Host Computer	10,000	7	70,000	Dell PowerEdge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	7	3,500	interval load monitoring
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	7	63,000	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
Control Node Integration	Integration/Configuration	20,000	7	140,000	Integration/Configuration/Unit-Testing Multifunction controller at campus stations
MG Communications					
GE MDS orbit - MCR-4G access point	MG Control Station network access point: (900Mhz,3G/4G,WiFi, 10-100Ethernet, VoIP, Serial RS232/485)	2,200	1	2,200	Wireless access point for MG control station. Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900Mhz Mesh or 3G/4G as needed for linking to utility field network. Use 900Mhz mesh to MG control nodes at buildings.
GE MDS orbit - remote mxnx-u91-s1n	MG remote control point : MG Sub/FacilityDevice/DG link: ( 900Mhz,WiFi, 10-100Ethernet)	1,500	14	21,000	Wireless remote node (1 per building)... Hybrid comms platform providing support for a variety of network

						interfaces and transport protocols. Use 900 MHz Mesh network back to MG control station. Use Wi-Fi or Ethernet for points inside or near buildings.
GE MLS2400 Ethernet Switch	Network switch panel for MG substation. VoIP/SCADA/Relay data connected via Ethernet	3,000	15	45,000		Ethernet switch, rack, power (1 per building). Wireless access point goes into switch then Wireless or Ethernet to any controllable elements in building.
Total				891,700		

*F.1.4.5 Total Microgrid Cost Estimates*

In addition to the generation costs and the costs of the physical elements used in the control & communications infrastructure and the electrical infrastructure, there are additional costs associated with initial microgrid controller development, engineering specification and design, and actual installation and project management. The following table provides a detailed listing of all the elements of the installed microgrid system costs.

**Table F-12: Suffolk Microgrid Full System Cost Estimates (Rounded to the Nearest \$1000)**

Project Activity	Description	Low (\$)	AVG (\$)	High (\$)	Type
Amortized Development of the MG Energy Management System	Integrate U90 master controller and the D400 control nodes with the PCMS EMS. Develop any extra system orchestration functions not native to the off the shelf commercial EMS that are required to perform NYSEERDA MG operations. -MG System Orchestration -Control Loads -Control Generators -Planning/Forecasting/Scheduling -Monitoring/Diagnostics -Utility Data Exchange -Grid PCC Mgmt. -Utility Baseline Integration	396,000	554,000	710,000	General Development
MG Communications Fabric Planning/Installation/Configuration	All wireless communications platforms -Communications from the MG control room to MG control nodes. -Communication from MG control room to utility	0	0	0	Site Specific Planning & Development

MG Test Plan Development	Design evaluation and stress tests to validate every function and every protection and safety scheme in the system. -develop formal test plan -design test and validation control and workflows - write corresponding code/scripts	374,000	512,000	648,000	Site Specific Planning & Development
MG System Integration & Site Certification	Run tests to validate every function, system and device in the entire system. All facilities, buildings, BEMS, Generators, MG control fabric, MG electrical fabric, and MG communications fabric. - Execute tests and document results - Orchestrate formal acceptance process - Obtain formal site sign off	95,000	133,000	170,000	Site Specific Planning & Development
Project Management	Program Management, Administration, and Technical interchange meetings -Technical interchange with utility/vendors/NYSERDA/DHS/Gov/etc. -Requirements collection and scope definition for complete system - Developing and Reviewing SOWS/RFP/Proposals to subs and vendors -Manage multiple subs and vendor -Manage technical development -Manage internal GE teams -Program interface with sponsors -Reporting and accounting	504,000	696,000	888,000	Site Specific Planning & Development
Site Design Engineering and Construction	Microgrid Detailed Systems Design -Develop formal technical specification -Power Systems Analysis -Power Systems Simulation -Site Planning & Licensing -Site Construction	518,000	716,000	912,000	Site Specific Planning & Development
Distributed Generation BOM	New Distributed Generation	0	0	0	CAPEX
Control & Communications BOM	CAPEX for the control and communications subsystem	722,000	802,000	892,000	CAPEX
MG Electrical Infrastructure	All required electrical distribution components - /xformers/feeders/switching/protection/ss integration/etc.	138,000	153,000	168,000	CAPEX
Microgrid Maintenance and Support	All software licenses and tech support - maintain MG system - provide 24/7 tech line support - perform routine software maintenance and upgrade	91,000	101,000	113,000	Annual O&M
<b>Total MG One-Time Cost</b>		<b>2,747,000</b>	<b>3,566,000</b>	<b>4,389,000</b>	
<b>Annual MG O&amp;M Cost</b>		<b>91,000</b>	<b>101,000</b>	<b>113,000</b>	

### F.1.5 One-Time Cost Considerations

Some of the costs are one-time costs, because off-the-shelf and commercially turn-key microgrid controllers are still at development state, and functioning microgrids for the multi-entity sites considered in this study are still being developed.

This study assumed that such a functioning microgrid controller will be developed from scratch for these 5 sites. This will be a one-time development cost consisting of the software and code design to enable currently existing and commercially available hardware to be linked in an optimal manner with enabled communication throughout the network and to provide optimal control and dispatch functions. It is expected that the developed software and codes can then be more easily modified and applied at future sites at a fraction of the initial development costs.

## F.2 **Benefit-Cost Assessment**

### F.2.1 Overview

The feasibility study for the Suffolk County site examines the development of a microgrid designed to support 15 county government buildings and two radio towers at a government complex in Yaphank, a hamlet in the Town of Brookhaven. The facilities include:

- The Suffolk County Police Department (SCPD) Headquarters, Property Bureau, and Garage.
- Yaphank Correctional Facility, which houses approximately 700 inmates.
- A Control Building and Pump Station for the complex's sewer system.
- A cluster of other county facilities identified as the Department of Public Works (DPW); DPW Garage; Board of Elections; Suffolk County Probation Department/Fire, Rescue, and Emergency Services (FRES); Home & Infirmary; Slaughter House, Doctor's Cottage; Skilled Nursing; and Quartermaster Buildings.

Many of these facilities are currently equipped with diesel backup generators. The microgrid design for the Suffolk site draws upon these generators, as well as a 100 kW photovoltaic (PV) array at the Board of Elections Building. In total, the system would incorporate distributed energy resources (DER) with a combined capacity of 12.095 MW. This capacity would be sufficient to support all critical loads. Critical loads are deemed to be equivalent to 100 percent of each facility's normal load, with the following exceptions:

- SCPD Property Bureau – 50 percent.
- DPW Building – 70 percent.
- Home & Infirmary Building – 50 percent.
- Slaughter House – 50 percent.
- Doctor's Cottage – 50 Percent.
- Skilled Nursing Building – 50 percent.

With the exception of the PV array, the results of the engineering analysis indicate that it would not be cost-effective to operate the distributed energy resources at the Suffolk County site on a continuous basis. Instead, the benefit-cost assessment focuses on two operating scenarios:

- Operation of the DER solely in the event of a power outage, in islanded mode.

- Provision of peak load support via participation in a demand response program.

#### F.2.2 Fixed Cost Factors

The best estimate of initial design and planning costs for development of a microgrid at the Suffolk County site is approximately \$3.6 million. This figure includes approximately \$2.0 million in site-specific planning and administrative costs as well as \$554,000 in engineering design costs. The project’s capital costs are estimated at approximately \$955,000, including \$153,000 for electrical infrastructure and \$802,000 for control and communications systems. Fixed O&M costs are estimated at approximately \$101,000 per year.

#### F.2.3 Variable Cost Factors

The analysis relies on information provided by the Project Team’s design consultants and projections of fuel costs from the SEP to estimate the variable costs of operating the microgrid. Variable O&M costs, excluding fuel, are estimated at \$18.22 per MWh; fuel costs for the diesel generators during microgrid’s first year of operation are estimated at approximately \$286 per MWh.

The analysis of variable costs also considers the environmental damages associated with emissions from distributed energy resources, based on the understanding that the generators at the Suffolk County site would not be subject to emissions allowance requirements. The estimate of environmental damages relies on the weighted average pollutant emissions factors provided by the project’s design consultants, as specified in Table F-13.

**Table F-13: Pollutant Emissions Factors for the Suffolk Microgrid**

<b>Pollutant</b>	<b>Emissions (Tons/MWh)</b>
CO <sub>2</sub>	0.79
SO <sub>2</sub>	0.0016
NO <sub>x</sub>	0.0119
PM	0.0001

#### F.2.4 Analysis of Reliability Benefits

The analysis estimates that development of a microgrid at the Suffolk County site would yield reliability benefits of approximately \$58,000 annually. This estimate is based on the following indicators of the likelihood and average duration of outages in the service area:

- System Average Interruption Frequency Index (SAIFI) – 0.67 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 75.6 minutes.<sup>19</sup>

<sup>19</sup> The SAIFI and CAIDI values employed in the Suffolk County analysis are the values for the Long Island Power Authority in 2012, as reported in State of New York Department of Public Service, *2012 Electric Reliability Performance Report*, June 2013.

The estimate of reliability benefits takes into account the capabilities of the backup power systems already available at the Suffolk County site. It also takes into account the variable costs of operating all generators, both in the baseline scenario and as integrated components of a microgrid. As in previous case studies, the analysis assumes a 15 percent failure rate for backup generators under baseline conditions. It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

#### F.2.5 Analysis of Benefits in the Event of a Major Power Outage

The estimate of reliability benefits presented above does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the analysis assesses the impact of a total loss of power – including the failure of backup generators – on the facilities the Suffolk County microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.

##### *F.2.5.1 Suffolk County Police Department*

The Suffolk County Police Department's facilities at the Yaphank complex include the department's Headquarters, Property Bureau, and a garage. These facilities serve the entire county, which has a population of approximately 1.3 million.

SCPD's Headquarters is equipped with a 1,250 kW diesel generator, which serves as the main backup source of power and is capable of supporting the building's normal load; the garage is backed by a 55 kW unit (there is no generator at the Property Bureau). Additional reliability at the Headquarters building is provided by a 125 kW emergency generator, which maintains all essential services (approximately 75 percent of the normal load). If the emergency generator were to fail, the department would bring in a portable generator from Verizon, which would be sufficient to maintain telephone service. In the event these systems were to fail, SCPD would relocate its operations to a backup center at the Yaphank complex or to another facility approximately three miles away.

Normal staffing at the Yaphank complex is approximately 500 personnel; this figure would increase to approximately 600 during an emergency. Given these staffing plans and the backup capabilities described above, the analysis assumes that the SCPD would be able to maintain all services during a major power outage, with or without a microgrid. The only effect of a microgrid would be to avoid the cost of installing and removing a portable generator in the event both its main and emergency backup generators fail. Consistent with the Rockland case, the analysis estimates this cost at approximately \$4,000.

##### *F.2.5.2 Yaphank Correctional Facility*

The Yaphank Correctional Facility, one of two Suffolk County correctional units, is operated by the Suffolk County Sheriff's Office. The facility reported an average daily inmate population of 678 in March, 2014. It is equipped with four diesel generators with a total generating capacity of 7.5 MW, enough to maintain all services during a power outage.

If the Yaphank Correctional Facility's backup generators failed and evacuation of its inmates became necessary, the Sheriff's Office indicates that a significant share of the population could likely be housed at Riverhead, Suffolk County's other correctional center. Based on recent headcounts, the office estimates

that 318 of 678 inmates could be transferred to Riverhead; it would be necessary to transfer the remaining 360 inmates to facilities elsewhere, such as Nassau County or Rikers Island (New York City's main correctional complex). The county estimates the cost of transferring these prisoners at \$70,000. It also estimates the value of the lost prison capacity at \$120 per inmate-day; assuming an average population of 678 inmates, this translates to an economic value of approximately \$81,000 per day.

The Suffolk County Sheriff's Office did not provide further information on the potential impact of a failure of its backup generators. Consistent with information provided for similar facilities at other sites, the analysis assumes that the loss of backup generators would lead to a loss of space heat and air conditioning, but that the facility would otherwise remain secure; thus, it would be necessary to transfer inmates to an alternative facility only during the heating season. This would trigger the costs detailed above. The analysis assumes that development of a microgrid would avoid these costs and allow the Correctional Facility to remain fully operational for the duration of any power outage.

#### *F.2.5.3 DPW Control Building and Pump Station*

Sewage service for the Yaphank complex is maintained by operation of a pump station that shares a utility account with the DPW Control Building. According to DPW, this station serves a work-day population of 2,700 to 3,000 county employees. The analysis assumes that a 100 kW backup generator at the Control Building is sufficient to maintain operation of the pump station during a major power outage.

Information on emergency measures that might be taken if the Control Building's backup generator fails is not available. In lieu of this information, the analysis applies a FEMA methodology to estimate the impact of a loss of wastewater services on economic activity, assuming a service population of 2,850. The method estimates the impact at approximately \$125,000 per day for the duration of the outage. In characterizing baseline conditions, the analysis assumes this impact would occur only if the Control Building's backup generator fails. It assumes that development of a microgrid would reduce the risk of a total loss of wastewater services to near zero.

#### *F.2.5.4 Other Suffolk County Facilities*

The Suffolk site includes nine other county government facilities:

- The DPW Building, DPW Garage, Board of Elections Building, Probation/FRES Building, and Quartermaster Building, all of which have backup generators.
- The Home & Infirmary Building, Slaughter House, Doctor's Cottage, and Skilled Nursing Building, none of which have backup generators.

Information on the emergency measures these facilities might take in the event of a prolonged power outage is not available. In lieu of this information, the analysis estimates the impact of a loss of power using the DOE ICE calculator. In applying this methodology it makes the following assumptions:

- It assigns all nine facilities to the public administration sector.
- Based on information provided on the facilities' annual demand for electricity, it treats the Doctor's Cottage as a small customer and the remaining facilities as medium to large customers.

Based on this approach, the analysis estimates the total value of services provided by these facilities at \$748,000 per day. For the baseline scenario, it assumes that a major power outage would lead to a complete loss of services at facilities without backup generators. In contrast, it assumes that facilities

equipped with backup generators would be able to provide 80 percent of the value of service they ordinarily provide during a major power outage; this figure is based on a weighted average of the normal load the backup generators at these facilities can meet. For facilities in this group, a total loss of service would occur only if the facility's backup generator fails.

The analysis assumes that a microgrid would maintain a level of service proportional to the share of each facility's load that is deemed critical, as indicated below:

- DPW Building – 70 percent.
- DPW Garage – 100 percent.
- Board of Elections Building – 100 percent.
- Probation/FRES Building – 100 percent.
- Quartermaster Building – 100 percent.
- Home & Infirmary Building – 50 percent.
- Slaughter House – 50 percent.
- Doctor's Cottage – 50 Percent.
- Skilled Nursing Building – 50 percent.

Based on these assumptions, the analysis indicates that the net benefit of a microgrid, on an expected value basis, would be approximately \$145,000 per day for the duration of each outage.

#### F.2.6 Analysis of Peak Load Support Scenario

The benefits of developing a microgrid at the Suffolk County site would be enhanced if the system could provide peak load support to the macrogrid via participation in a demand response program. Participating in this program would reduce demand to expand the macrogrid's generating capacity, thus providing capacity cost savings. Providing peak load support would increase the microgrid's annual operating costs (including variable O&M costs, fuel costs, and environmental costs). These costs, however, would be offset in part by a reduction in demand for electricity from the macrogrid, which would lead to energy cost savings and environmental benefits associated with the operation of bulk energy facilities.

The analysis estimates the benefits of the Suffolk County project's participation in a demand response program based on a coincident peak load for participating facilities of approximately 6,632 kW. Given this figure, the project's participation in a demand response program would generate capacity cost savings of more than \$1.0 million per year. If the system were called upon to provide support for 20 hours a year, its operating costs would increase by approximately \$49,000 annually. These costs would be offset by a reduction of approximately \$15,000 per year in the macrogrid's operating costs. Given these assumptions, the system's participation in a demand response program would yield net benefits of approximately \$999,000 per year.

#### F.2.7 Summary of Results

The analysis of the Suffolk County site indicates that without participation in some type of demand response program, the benefits of a microgrid are unlikely to exceed its costs. Absent involvement in such a program, benefits would exceed costs only if the probability of a major power outage is assumed to be consistently high. As Table F-14 shows, the expected number of days without power would have to be on the order of two to three *each year* in order for the project to be cost-effective.

Participating in a demand response program would greatly improve the economic case for development of a microgrid at the Suffolk County site. In all three peak load support scenarios, the estimate of benefits is substantially greater than estimated costs, even if the analysis assumes no chance of a prolonged power outage. These results suggest a strong likelihood that development of the Suffolk microgrid, coupled with participation in a demand response program, would be cost-effective. This is a function of a number of factors, including the relatively high load the microgrid could support, the high value the SEP assigns to generating capacity on Long Island (Zone K), and the relatively small investment in electrical infrastructure required at the Suffolk site.

As previously noted, the analysis of the peak load support scenario assumes that all generators at the Suffolk County site would meet eligibility requirements for participation in a demand response program. Additionally, it assumes that the facilities served by the microgrid would be willing to participate in such an arrangement. Subsequent discussions with Suffolk County officials indicate that at least three facilities at the Suffolk County site – the DPW Building, the DPW Garage, and SCPD Headquarters – currently participate in NYISO’s demand response program. This suggests that Suffolk County already recognizes the potential economic value of such programs and might be willing to expand its participation to other facilities, particularly if those facilities could count on the relatively seamless backup service that a microgrid is designed to provide. At the same time, it illustrates that development of a microgrid is not necessarily a precondition for participation in a demand response program, and suggests that in this case the net benefits of developing a microgrid may be overstated. The capacity that currently participates in the demand response program, however, is relatively modest: a total of 600 kW, less than 10 percent of the coincident peak load (6,632 kW) of the facilities that would be served by the microgrid. Thus, adjusting the analysis to account for current participation in the demand response program would have only a minor impact on the benefits estimate, and would not fundamentally alter the conclusion that the economic case for development of a microgrid at the Suffolk County site rests primarily upon the system’s ability to support broader participation in NYISO’s demand response program.

**Table F-14: BCA Results for the Suffolk County Site: Breakeven Conditions (7% Discount Rate)**

Scenario	Annual Probability of Specified Outage	Duration of Specified Outage	B/C Ratio
Low Cost/No Peak Load Support	100%	2 days	1.10
Average Cost/No Peak Load Support	100%	3 days	1.24
High Cost/No Peak Load Support	100%	3 days	1.03
Low Cost/Peak Load Support	NA	NA	2.70
Average Cost/Peak Load Support	NA	NA	2.21
High Cost/Peak Load Support	NA	NA	1.86

## Appendix G Microgrid Case Study: Nassau County

### G.1 Feasibility Study

#### G.1.1 Site Characterization

The Nassau County site consists of three facilities within the adjacent communities of Wantagh and Seaford, along the South shore of Long Island, in an area that was heavily flooded by Superstorm Sandy. The “anchor tenant” in this area is Cedar Creek Wastewater Treatment Plant, which is a critical, self-powering facility with an excess of existing generation. The Wantagh Fire Department (WFD) Administration building at 2045 Wantagh Ave - which does not house a fire station, but has a 24/7 emergency response center serving both Wantagh and Seaford Fire Departments (SFD) - has a relatively new 130 kW backup generator that kept it continuously powered through Sandy. Seaford Harbor Elementary (SHE) at 3500 Bayview Street in Seaford is an elementary school that has no existing backup. It is not a critical emergency load in its primary, educational mission and was closed during Sandy, though it sits above the floodplain. Proposed site access improvements would allow it to serve as an emergency shelter to feed and house refugees or emergency responders during future emergency events.

##### *G.1.1.1 Cedar Creek Wastewater Treatment Plant*

A site visit was conducted on December 3, 2013.

Cedar Creek is a self-powering facility, which uses its existing LIPA connection for backup only. The wastewater plant covers 77 acres and includes approximately 26 buildings, all connected through underground tunnels – all space is conditioned and lighted, though only approximately 20 buildings are occupied by about 100 employees. The site is elevated (18 feet above flood plain) and surrounded by green space. The Plant was up and running during Sandy when the surrounding Bay Park neighborhood was submerged. The only issue during Sandy was physical access to the site, as the vehicle entrance is via Merrick Road which was flooded. It was noted by Plant staff that the elevated Wantagh Parkway runs by the rear side of the facility and, if a new access point could be constructed over the ditch, it would solve this issue.

Cedar Creek is designed to process 72 million gallons of wastewater per day with an average of about 50 million. During Sandy, it saw a peak of 184 million gallons due to the excess storm run-off. The critical load is pumping in and out, however, everything in between is one continuous treatment process (with different stages in different buildings) that cannot be neatly broken up. There is not much seasonality to load, as storm run-off is normally separated from the sewage stream.

There are 5 on-site generators and 3 are used in normal operation ( $n + 2$  redundancy). Daily peak is approximately 6 MW out of 15 MW of nameplate generation capacity. The highest annual peak demand is approximately 9 MW, so there is a considerable (6 MW) reserve margin. Two generators run on diesel (plus 1% fuel oil for ignition), while the third runs on landfill methane. They have 100,000 gallons of on-site fuel storage, which is enough for 10 days operation at full load.

LIPA service is connected via a dedicated underground feeder from the substation outside the fence, but this is very rarely used. There is room for 2 x 13 kV/3kV service but only one transformer was built (there

is a pad poured with all connections laid for a second transformer to support any future additions). The site pays standby and demand charges. Voltage is stepped down to 480V for pumps and 277V for lighting, as well as 120V for AC. There is a master meter at the LIPA interconnect but no building metering.

The site manages its own electric distribution; they have transfer switches to configure service to each building/process step. All switches are automated. There are uninterruptible power supplies (UPS) on 7 units with 92 battery cells each (enough for 1 hour of plant controls). The Plant has been down twice in the last four years (due to an oil leak in the governor); both were less than 10 minutes of interruption. These are the only occasions when the site reverted to LIPA service.

There is no card key required for entry, but the entire site is fenced and a guard monitors access to the facility.

The site captures recuperator heat from the generators but not the waste heat jacket. This provides enough heat for summer (process heat load) but in winter they run natural gas boilers (3 units plus a spare, 700 hp, 23 million BTU). There is both chilled and hot water distribution between all buildings. If additional thermal capacity were added, the site could dry sludge and avoid expensive tipping of wet sludge from the site (costs about \$500,000/year).

In terms of potential to house emergency services, the site has many favorable attributes:

- Available conditioned building space, including unoccupied space that could accommodate emergency workers,
- Cellphone tower on site with dedicated backup power for emergency communications,
- Available green space and interconnect capacity, including an extra transformer pad for siting PV or other additional generation that could operate in tandem with the existing plant generation to provide very high reliability.

However, the one physical issue that would need to be overcome is vehicular access likely through the construction of an entry from the elevated Wantagh parkway.

#### *G.1.1.2 Wantagh Fire Department (WFD) Administration Building*

Information about the facility was collected via a phone interview with Mr. Mike Antonucci, Superintendent, on May 16, 2014.

The Administration Building is not an operating fire station, but houses the emergency dispatch center for both Seaford and Wantagh Fire Districts and handles about 3,000 alarm calls a year. The building is staffed 24/7 by at least one dispatcher although six dispatchers were used during the response to Superstorm Sandy. The building also operates as a command post during emergencies, so there is some extra load for the additional computers and lights. Total, there were about 15-20 people in the building during Sandy.

There is a 130 kW natural gas back-up generator that is tested weekly. It is new since Hurricane Irene (2011) and was running for a week solid during Superstorm Sandy. It serves the whole load of the building, even with the “emergency premium” described above.

The generator is sited in the parking lot which has limited space. The Superintendent believes that it would be difficult to dedicate any further space for additional infrastructure (e.g., to site additional generation) in/around the building.

During Sandy, the facility itself was dry but the area between it and Cedar Creek (five city blocks including Merrick Road) were all submerged.

#### *G.1.1.3 Seaford Harbor Elementary (SHE)*

Information about the school was obtained via a phone interview with the School District Facilities Manager on May 16, 2014.

Seaford Harbor has 700 students, grades 1-6. There are only limited off-hour uses of the building (for evening meetings or school events) but no summer school or night/weekend occupancy. The only heavy equipment present is a couple of gas boilers; there is no central AC and no on-site generation.

The biggest electric loads are the kitchen and lighting. There are about 40 classrooms and a computer lab. Approximately 50% of the load is critical to maintain comfort (kitchen, lighting) during an emergency.

The building is slightly elevated and suffered no damage from Sandy but was surrounded by flooded area, so travel in/out was difficult.

The County is currently looking at a new access road from the North that could address the site access problem and potentially allow emergency shelter use. Since the educational function of the school is suspended during an emergency, emergency shelter use would be in lieu of normal operations (not additive).

There is sufficient space to accommodate on-site distributed generation and this would probably not be an issue with the neighbors as the school is bounded by wetland on two sides.

#### *G.1.1.4 Data Collection*

Several data elements were transmitted by the facility personnel to aid the analysis:

- Two years of monthly billing kWh for Seaford Harbor Elementary and Wantagh Fire Department
- One day's sample breaker level load and generator logs for Cedar Creek

Because Cedar Creek is almost entirely self-powering, there is no consistent source of utility revenue meter data for the entire facility.

LIPA interconnection data was not available; however, this data was not necessary for the analysis, as the microgrid electrical interconnection model did not assume the ability to leverage the existing utility infrastructure.

### G.1.2 Site Modeling and Analysis

The Nassau site presents unique challenges for microgrid development. First, the Cedar Creek plant is already a large, self-powering critical facility – essentially a microgrid unto itself. Because Cedar Creek's existing generation maintains and operates a significant redundant backup to meet the facility's own

needs, far in excess of the peak loads of the other two facilities combined, the analysis did not consider scenarios of new generation<sup>20</sup>. Rather, two scenarios were examined that allowed Cedar Creek to power the other two facilities. These scenarios provide an upper and lower bound to the likely costs of MG development:

- Scenario 1 is a “high” estimate – where dedicated distribution lines and equipment are added to connect Cedar Creek and allow its existing excess generating capacity to power both WFD and SHE. WFD benefits from a redundant backup, to allow downtime on its existing backup generator during an extended emergency outage. SHE can serve as an emergency evacuation shelter and emergency responder staging area.
- Scenario 2 is a “low” estimate and includes only the connection to SHE.

Finally Section G.1.5 evaluates the cost of a stand-alone backup generator at SHE, as an alternative to microgrid development.

Because the analysis for the Nassau site did not involve consideration of new generation options, HOMER analysis was not performed.

### G.1.3 Microgrid Infrastructure Configuration

#### *G.1.3.1 Electrical Infrastructure*

Given that Cedar Creek is primarily self-powering and interconnects with LIPA only at transmission voltage, the analysis did not assume any use of existing utility infrastructure. The microgrid design overlays a dedicated overhead distribution feeder and interconnect hardware between Cedar Creek and each of the two other facilities, following the rights-of-way along city streets.

Each of the three facilities was above flood level during Sandy, however, the intervening low-lying areas, including Merrick Road were submerged. The design assumes storm hardened poles to span the flood zone.

#### *G.1.3.2 Control & Communications Infrastructure*

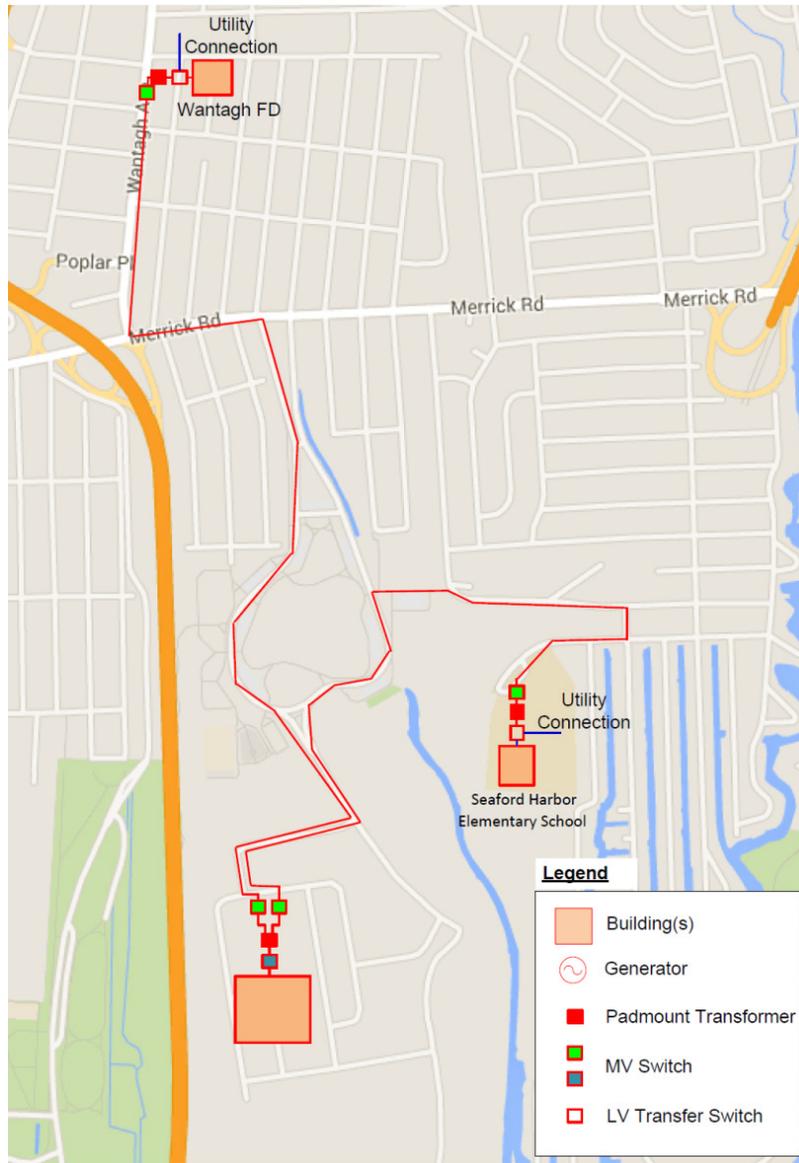
The MG Architecture includes the following Control & Communications design elements:

- MG Master Control Station
  - Located in nearby substation or Cedar Creek facility
  - Serving both Cedar Creek and School
  - Communication link to utility WAN/FAN
  - Communication link to Wantagh DG controller and MG automation and switching
- Campus Control Station
  - Serving Wantagh FD
  - Multifunction automation controller supporting MG switching and protection control actions

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<sup>20</sup> Note that there is no practical MG scenario in which WFD or SHE, the two smaller facilities, would house sufficient generation to provide further redundancy to Cedar Creek; nor does Cedar Creek appear to require additional reserves, given its existing multiple redundant backup capacity.

- Located near DG providing generator control interface



**Figure G-1: Nassau MG Electrical Infrastructure**



Figure G-2: Nassau MG C&C Infrastructure

G.1.4 Microgrid Cost Summary

G.1.4.1 *Electrical Infrastructure Costs*

G.1.4.1.1 Scenario 1: High Estimate

**Table G-1: Nassau MG EI Cost - High**

SN	Item	Description	Quantity	Unit	Unit Price (Installed) (\$)	Cost (\$)
1	15 kV Class 3-Ph Line	OH conductor to connect Cedar Creek to Elementary School and Wantagh FD	18500	Ft.	12	222,000
2	600 V Class 3-Ph Cable	LV cable	100	Ft.	60	6,000
3	Medium Voltage Switch/Circuit Breakers	Switches at Cedar Creek, Elementary School and Wantagh FD (for 13 kV connection)	4	Nos.	20,000	80,000
4	Medium Voltage (5kV class) Switch/Circuit Breakers	Switch at Cedar Creek (for 4.16kV side of transformer)	1	Nos.	15,000	15,000
5	Low Voltage Circuit Breakers	LV Circuit Breakers/Transfer Switches at Elementary School and Wantagh FD	2	Nos.	10,000	20,000
6	300 kVA Transformer	Padmount transformer at Elementary School and Wantagh FD	2	Nos.	10,000	20,000
7	500 kVA Transformer	Padmount transformer at Cedar Creek	1	Nos.	13,000	13,000
8	Transition Compartment	One each at Cedar Creek, Elementary School and Wantagh FD	3	Nos.	10,000	30,000
9	Protection System Evaluation	Model the existing system with new infrastructure and evaluate the protection system	1	unit	20,000	20,000
<b>Total</b>						<b>426,000</b>

G.1.4.1.2 Scenario 2: Low Estimate

Scenario 1 considered two connections together as part of the MG solution: Cedar Creek-WFD and Cedar Creek-SHE. These two circuits share common infrastructure elements at the Cedar Creek end (e.g.,

transformer, switchgear, protection system). In creating Scenario 2, these common costs now have to be allocated.

In the table below, costs are shown for just the Cedar Creek-SHE circuit alone. The two columns on the far right show the common costs on a “shared” (i.e. WFD and SHE each assume an equal allocation of the common costs) and a “stand alone” basis (SHE bears the entire cost). The latter is the appropriate basis for Scenario 2, which assumes only the Cedar Creek-SHE connection is built.

**Table G-2: Nassau MG EI Cost – Low**

SN	Item	Description	Quantity (Share)	Quantity (Standalone)	Unit	Unit Price (Installed) (\$)	Cost (Share) (\$)	Cost (Standalone) (\$)
1	15 kV Class 3-Ph Line	OH conductor to connect Cedar Creek to Elementary School	7500	7500	Ft.	12	90,000	90,000
2	600 V Class 3-Ph Cable	LV cable	50	50	Ft.	60	3,000	3,000
3	Medium Voltage Switch/Circuit Breakers	Switches at Cedar Creek and Elementary School (for 13 kV connection)	2	2	Nos.	20,000	40,000	40,000
4	Medium Voltage (5kV class) Switch/Circuit Breakers	Switch at Cedar Creek (for 4.16kV side of transformer)	0.5	1	Nos.	15,000	7,500	15,000
5	Low Voltage Circuit Breakers	LV Circuit Breakers/Transfer Switches at Elementary School	1	1	Nos.	10,000	10,000	10,000
6	300 kVA Transformer	Padmount transformer at Elementary School	1	1	Nos.	10,000	10,000	10,000
7	500 kVA	Padmount	0.5	1	Nos.	13,000	6,500	13,000

	Transformer	transformer at Cedar Creek						
8	Transition Compartment	One each at Cedar Creek, Elementary School	1.5	2	Nos.	10,000	15,000	20,000
9	Protection System Evaluation	Model the existing system with new infrastructure and evaluate the protection system	0.5	1	unit	20,000	10,000	20,000
<b>Total</b>							<b>192,000</b>	<b>221,000</b>

*G.1.4.2 Control & Communications Infrastructure Costs*

G.1.4.2.1 Scenario 1: High Estimate

Table G-3 below presents the Scenario 1 High estimate of control and communications costs, using the MG Reference Architecture similar to the other sites.

G.1.4.2.2 Scenario 2: Low Estimate

Table G-4 below presents the Scenario 2 Low estimate of C&C costs.

Scenario 2 is scaled back from Scenario 1 and includes only a minimal control and communications architecture for the Nassau MG site. The intent was to derive a minimum cost, “no frills”, design to ascertain what would be the low-end cost estimate. To facilitate this, the total number of campus control stations was reduced and only minimal automation was considered.

Hardware

1. Located the MG Master Control Station at Cedar Creek. This still provided the U90+ MG controller, but in this case it will serve as both the Nassau master site controller and the local campus controller for Cedar creek.
2. No Campus control station located at the School. Any required feeder automation will come directly from the MG Master Control Station located at Cedar Creek.
3. Basic wireless mesh networks for the Field Area Network (FAN) and optionally Microwave or 3G/4G for utility Backhaul network.
4. Assumes the switching controllers that configure the MG feeders which serve the school can be reached wirelessly (Modbus over TCP) from the MG Master Control Station located at the Cedar Creek facility.

Software

1. Basic MG control configuration. Includes only DG control, MG feeder switching and automation, and protection control logic.
2. Absolutely no building automation.
3. Assumes load is well defined across a specific range. No custom code or DG integration software developed to perform dynamic supply/demand balancing or automated demand response functions.
4. No utility integration.
5. Uses the stock U90+ MG controller and it controls a fairly static MG configuration and DG control. Assumes that it requires a typical and standard configuration of the stock U90+.

**Table G-3: Nassau Microgrid Control & Communications Cost Estimates - High (Rounded to the Nearest \$100)**

Item - P/N	Description	Unit Price	QTY	Cost(\$)	Notes
MG Master Control Station					
MG Control Station Computer:	MG Station Computer : Hosts MG EMS application. Hardened computer with processor/comm/interface expansion ports. Rack system.	15,000	1	15,000	Dell Poweredge R270 Rackmount Server. Racks, Displays, Peripherals. SQL Server DBMS. Priced to approximate a hardened computer to host MG substation applications and support NERC compliance and multiple I/F options
GE EnerVista Engineer	MG Configuration Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Maintenance	MG Maintenance Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Monitoring	MG Monitoring Utility	2,000	1	2,000	MG controller HMI and configuration app
GE EnerVista Integrator	MG Device Integration	1,500	1	1,500	MG controller HMI and configuration app
GE Cimplicity	Cimplicity Globalview and Cimplicity Development	100,000	1	100,000	HMI/SCADA framework providing event/alarm monitoring , logging, and SCADA configuration tools.
GE Multilin U90+	MG Generation Controller/Optimizer	25,000	1	25,000	MG Generation Controller via Multilin UR family.

					Forecasting and optimal dispatch functions
GE D400	Advanced Protocol Gateway	9,000	1	9,000	Multifunction intelligent gateway. Provides control interface and data collection from protection, control, monitoring, RTU, IED's.. Configured using Logixlinx software.
System Integration & I/F Modules	Integration & Control Software: Application functions, control functions, component adapters, and automation scripts	200,000	1	200,000	Engineering labor estimate for code development/integration of site-specific control and automation of buildings, systems, devices, and generators. (TBD scope: depending on requirement for monitoring and automated control of buildings and electrical infrastructure)
MG Campus Ctl Station (BEMS Integration)					
Control Station Computer	Application Host Computer	5,000	0	0	Dell Poweredge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	0	0	Smart meter monitors main facility load. BEMS I/F provides detailed monitoring.
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	0	0	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.

BEMS Integration	Configuration/ Integration	50,000	0	0	BEMS configuration and integration with campus controller. Requires technical discussions with BEMS vendor and facility energy manager.
MG Campus Ctl Station (w/o BEMS)					
Control Station Computer	Application Host Computer	10,000	3	30,000	Dell Poweredge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	3	1,500	interval load monitoring
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	3	27,000	Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
Control Node Integration	Integration/ Configuration	20,000	3	60,000	Integration/Configuration/Unit-Testing MultiFunction controller at campus stations
MG Communications					
GE MDS orbit - MCR-4G access point	MG Control Station network access point: (900Mhz,3G/4G,WiFi, 10-100Ethernet, VoIP, Serial RS232/485)	2,200	1	2,200	Wireless access point for MG control station. Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900Mhz Mesh or 3G/4G as needed for linking to utility field network. Use 900Mhz mesh to MG control nodes at buildings.
GE MDS orbit - remote mxnx-	MG remote control	1,500	3	4,500	Wireless remote node

u91-s1n	point : MG Sub/FacilityDevice/DG link: ( 900Mhz,WiFi, 10- 100Ethernet)				(1 per building)... Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900 MHz Mesh network back to MG control station. Use WiFi or Ethernet for points inside or near buildings.
GE MLS2400 Ethernet Switch	Network switch panel for MG substation. VoIP/SCADA/Relay data connected via Ethernet	3,000	4	12,000	Ethernet switch, rack, power (1 per building). Wireless access point goes into switch then Wireless or Ethernet to any controllable elements in building.
Total				492,700	

**Table G-4: Nassau Microgrid Control & Communications Cost Estimates - Low (Rounded to the Nearest \$100)**

Item - P/N	Description	Unit Price	QTY	Cost(\$)	Notes
MG Master Control Station					
MG Control Station Computer:	MG Station Computer : Hosts MG EMS application. Hardened computer with processor/comm/interface expansion ports. Rack system.	15,000	1	15,000	Dell Poweredge R270 Rackmount Server. Racks, Displays, Peripherals. SQL Server DBMS. Priced to approximate a hardened computer to host MG substation applications and support NERC compliance and multiple I/F options
GE EnerVista Engineer	MG Configuration Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Maintenance	MG Maintenance Utility	1,500	1	1,500	MG controller HMI and configuration app
GE EnerVista Monitoring	MG Monitoring Utility	2,000	1	2,000	MG controller HMI and configuration app
GE EnerVista Integrator	MG Device Integration	1,500	1	1,500	MG controller HMI and configuration app
GE Cimplicity	Cimplicity Globalview and Cimplicity Development	50,000	1	50,000	HMI/SCADA framework providing event/alarm monitoring , logging, and SCADA configuration tools.
GE Multilin U90+	MG Generation Controller/Optimizer	25,000	1	25,000	MG Generation Controller via Multilin UR family. Forecasting and optimal dispatch functions
GE D400	Advanced Protocol Gateway	9,000	1	9,000	Multifunction intelligent gateway. Provides control interface and data collection from protection, control, monitoring, RTU, IED's.. Configured using Logictlinx software.
System Integration & I/F Modules	Integration & Control Software: Application functions, control	50,000	1	50,000	Engineering labor estimate for code development/integratio

	functions, component adapters, and automation scripts					n of site-specific control and automation of buildings, systems, devices, and generators. (TBD scope: depending on requirement for monitoring and automated control of buildings and electrical infrastructure)
MG Campus Ctl Station (BEMS Integration)						
Control Station Computer	Application Host Computer	5,000	0	0		Dell Poweredge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	0	0		Smart meter monitors main facility load. BEMS I/F provides detailed monitoring.
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-site generation controllers, and networked devices	9,000	0	0		Multifunction IED for MG control nodes (1 control node per facility - or building if widely distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
BEMS Integration	Configuration/Integration	50,000	0	0		BEMS configuration and integration with campus controller. Requires technical discussions with BEMS vendor and facility energy manager.
MG Campus Ctl Station (w/o BEMS)						
Control Station Computer	Application Host Computer	10,000	1	10,000		Dell Poweredge R270 Rackmount Server & Rack.
GE Smart Meter	Load Metering	500	3	1,500		interval load monitoring
GE D25 Multifunction Controller	DER Control, Monitoring & Sensing. Connectivity to on-	9,000	2	18,000		Multifunction IED for MG control nodes (1 control node per facility - or building if widely

	site generation controllers, and networked devices					distributed). General controller, multi-protocol I/F to MG components, I/F to underlying switchgear and transformers for component automation.
Control Node Integration	Integration/Configuration	20,000	1	20,000		Integration/Configuration/Unit-Testing MultiFunction controller at campus stations
MG Communications						
GE MDS orbit - MCR-4G access point	MG Control Station network access point: (900Mhz,3G/4G,WiFi , 10-100Ethernet, VoIP, Serial RS232/485)	2,200	1	2,200		Wireless access point for MG control station. Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900Mhz Mesh or 3G/4G as needed for linking to utility field network. Use 900Mhz mesh to MG control nodes at buildings.
GE MDS orbit - remote mxnx-u91-s1n	MG remote control point : MG Sub/FacilityDevice/D G link: ( 900Mhz,WiFi, 10-100Ethernet)	1,500	3	4,500		Wireless remote node (1 per building)... Hybrid comms platform providing support for a variety of network interfaces and transport protocols. Use 900 MHz Mesh network back to MG control station. Use WiFi or Ethernet for points inside or near buildings.
GE MLS2400 Ethernet Switch	Network switch panel for MG substation. VoIP/SCADA/Relay data connected via Ethernet	3,000	2	6,000		Ethernet switch, rack, power (1 per building). Wireless access point goes into switch then Wireless or Ethernet to any controllable elements in building.
Total				217,700		

*G.1.4.3 Variable Costs*

The variable cost estimate assumes incremental operation of Cedar Creek’s existing diesel generation to serve emergency loads. Scenario 1 includes variable costs for both Seaford Harbor and Wantagh FD, while Scenario 2 includes only Seaford. The estimate assumes one month’s continuous operation of each of the facilities, based on their average monthly kWh. No emergency premium is assumed, however, the size of both excess generating capacity and interconnects is sufficient to handle considerably more load than is present at the two smaller facilities.

Based on values developed for the diesel generators at the other sites, fuel costs are assumed to be \$230/MWh and O&M costs are \$17/MWh.

Total Variable Costs (in \$ per month of MG operation) are shown in Table G-5.

**Table G-5: Nassau Total Variable Costs (Not Rounded)**

	Average Monthly Energy (kWh)	Average Monthly Energy (MWh)	Variable Fuel Cost (\$/Month)	Variable O&M Cost (\$/Month)	Total Cost (\$/Month)
Seaford	21,236	21.24	4,884	361	5,245
Wantagh	10,940	10.94	2,516	186	2,702

*G.1.4.4 Total Microgrid Cost Estimates*

The total high and low cost estimates for the full MG system are provided in Table G-6 and Table G-7.

**Table G-6: Nassau Microgrid Full System Cost Estimates - High (Rounded to the Nearest \$1000)**

Scenario 1 (High)	
El Cost	\$426,000
C&C Cost	\$493,000
Total Fixed Cost	\$919,000
Total Variable Cost/Month	\$8,000

**Table G-7: Nassau Microgrid Full System Cost Estimates - Low (Rounded to the Nearest \$1000)**

Scenario 2 (Low)	
El Cost	\$221,000
C&C Cost	\$218,000
<b>Total Fixed Cost</b>	<b>\$439,000</b>
<b>Total Variable Cost/Month</b>	<b>\$5,000</b>

**G.1.5 Comparison with non-Microgrid Alternatives**

The largest benefit of the proposed Microgrid scenarios above is the provision of backup power from the existing generators at Cedar Creek to Seaford Harbor Elementary in support of future emergency services. This same benefit could alternatively be achieved with a stand-alone diesel generator, located on site at SHE. For purposes of comparison with the costs of the MG scenarios presented above, the following are rough cost estimates of this non-MG alternative.

Based on current load levels, it is estimated that a 100 kW generator would be sufficient to serve emergency loads at SHE, including a “premium” for loads that are not normally present.<sup>21</sup>

Table G-8 shows the total costs of the non-microgrid alternative, using the same capital cost of \$850/kW for diesel generation as in the other sites, with some additional overhead for siting and permitting, and assuming the same variable costs for fuel and O&M as in Scenario 2 above.

**Table G-8: Nassau Costs of Non-MG Alternatives**

Stand-alone Diesel Generator at SHE	
Capital Cost of generation	\$85,000
Siting, Permitting, Installation, Etc.	\$15,000
<b>Total Fixed Cost</b>	<b>\$100,000</b>
<b>Total Variable Cost/Month</b>	<b>\$5,200</b>

<sup>21</sup> Since the emergency scenario is predicated on provision of services outside the school’s normal educational functions, e.g., evacuee or first responder food and shelter, billing history is not a good predictor. Many of the school’s ordinary end uses – cafeteria appliances and lighting -- would likely see increased usage due to higher occupancy (especially off-hours), though this would contribute to higher kWh, not necessarily higher peak kW. In addition, however, unknown additional loads, such as rechargeable battery devices or portable medical or communications equipment brought in by emergency personnel might constitute an “emergency premium” above and beyond the normal building demand.

Even with a wide margin of error in the above estimate, it is clear that the cost of a stand-alone DG solution is likely to be significantly lower than a microgrid – on the order of \$100,000 fixed cost, as compared to a projected range of \$440,000-920,000.

## **G.2 Benefit-Cost Assessment**

### **G.2.1 Overview**

The feasibility study for the Nassau County site examines two alternative microgrid designs. The first, referred to as Option 1, would support the following facilities:

- ***The Cedar Creek Wastewater Treatment Plant (WWTP)***, a self-powering facility that processes an average of 50 million gallons of wastewater per day.
- ***The Wantagh Fire Department Administrative Building (FDAB)***, which serves as the emergency dispatch center for the Wantagh and Seaford fire departments.
- ***Seaford Harbor Elementary School***, which serves approximately 700 students and may be able to provide shelter to first responders in the event of an emergency.

The second design, Option 2, would support only the Cedar Creek WWTP and Seaford Harbor Elementary School.

The Cedar Creek Wastewater Treatment Plant has five generators that provide a total of 15 MW of generating capacity and allow the plant to rely on the Long Island Power Authority (LIPA) solely for standby service. The facility's daily peak load is approximately 6 MW. To meet this demand, the plant normally operates three generators: two diesel units and a third powered by methane from a nearby landfill. The remaining two units, both diesels, are available as backup.

The other facilities included in the feasibility study for the Nassau County site are not self-powering. Seaford Harbor Elementary School has no backup generator, while the Wantagh FDAB is currently equipped with a 130kW natural gas unit. The microgrid design for Option 1 would incorporate this generator, as well as the five generators at the Cedar Creek WWTP. In total, the system would rely on distributed energy resources (DER) with a combined capacity of 15.13 MW. The microgrid design for Option 2 would incorporate only the five generators at the Cedar Creek WWTP, for a total generating capacity of 15 MW. Under both options, the capacity of the generators incorporated into the microgrid would be more than sufficient to support 100 percent of each facility's normal load.

A comparison of operating costs for the Nassau County DER to the energy price forecast for Long Island (Zone K) indicates that it would not be cost-effective to generate energy in excess of the WWTP's requirements in order to participate in the energy market. The benefit-cost assessment therefore focuses on two operating scenarios:

- Operation of the microgrid in islanded mode, in the event of a major power outage.
- Provision of peak load support via participation in a demand response program.

The benefit-cost assessment evaluates these scenarios for both design options (i.e., Option 1 and Option 2).

### G.2.2 Fixed Cost Factors

The development of a microgrid at the Nassau County site would not require the development of sophisticated control and communications systems; therefore, the analysis includes no site-specific planning or engineering design costs. Under Option 1, the Project Team’s design consultants estimate capital costs at approximately \$919,000, including \$426,000 for electrical infrastructure and \$493,000 for control and communications systems. Under Option 2, capital costs are estimated at approximately \$439,000, including \$221,000 for electrical infrastructure and \$218,000 for control and communications systems. Under both options, fixed O&M costs are estimated at approximately \$45,000 per year. This figure represents the average value of fixed O&M costs from the Broome County, New York City, and Rockland sites, and is assumed to be a reasonable estimate of fixed O&M costs at the Nassau site.

### G.2.3 Variable Cost Factors

The analysis relies on information provided by the Project Team’s design consultants and projections of fuel costs from the SEP to estimate the variable costs of operating the microgrid. These estimates are identical under both design options. Variable O&M costs, excluding fuel, are estimated at \$17.13 per MWh. Fuel costs for the diesel generators during the microgrid’s first year of operation are estimated at approximately \$285 per MWh. Fuel costs for the natural gas and methane generators during the microgrid’s first year of operation are estimated at approximately \$100 per MWh.<sup>22</sup>

The analysis of variable costs also considers the environmental damages associated with any changes in emissions from distributed energy resources, based on the understanding that the generators at the Nassau County site would not be subject to emissions allowance requirements. The estimate of environmental damages relies on the weighted average pollutant emissions factors provided by the project’s design consultants, as specified in Table G-9.

**Table G-9: Pollutant Emissions Factors for the Nassau Microgrid**

<b>Pollutant</b>	<b>Emissions (Tons/MWh)</b>
CO <sub>2</sub>	0.79
SO <sub>2</sub>	0.0016
NO <sub>x</sub>	0.015
PM	0.0001

<sup>22</sup> The Cedar Creek WWTP obtains its methane free of charge; nonetheless, the fuel has an economic value that is taken into account in assessing a microgrid’s potential costs and benefits. The figure cited above (\$100 per MWh during the first year of operation) is based on the SEP’s forecast of natural gas prices. In the absence of more detailed information, it also assumes that the heat rate for the methane generator is the same as that of the diesel generators at the Cedar Creek WWTP.

#### G.2.4 Analysis of Reliability Benefits

The analysis assumes that development of a microgrid would have no impact on the reliability of service for the Cedar Creek WWTP; as noted above, this facility already provides its own power, relying on LIPA solely for standby service. Participation in the development of a microgrid, however, would yield reliability benefits for the Wantagh FDAB and the Seaford Harbor Elementary School. These benefits are estimated at approximately \$800 annually under Option 1 and \$400 annually under Option 2. These estimates are based on the following indicators of the likelihood and average duration of outages in the service area:

- System Average Interruption Frequency Index (SAIFI) – 0.67 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 75.6 minutes.<sup>23</sup>

The estimate of reliability benefits takes into account the capabilities of the backup power systems already available at the Nassau County site. It also takes into account the variable costs of operating backup generators, both in the baseline scenario and as integrated components of a microgrid. As in previous case studies, the analysis assumes a 15 percent failure rate for backup generators under baseline conditions. It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

#### G.2.5 Analysis of Benefits in the Event of a Major Power Outage

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

##### *G.2.5.1 Cedar Creek WWTP*

The Cedar Creek WWTP is one of two sewage treatment plants in Nassau County. It has a maximum design flow of 72 million gallons per day and averages approximately 50 million gallons per day under normal operation. As noted above, the facility is self-powered. It houses five generators, though only three are used during normal operation: two diesel generators and one that burns methane. The remaining two units, both diesels, are available as backup generators. The total nameplate capacity of the generators, 15 MW, is well in excess of the plant's typical daily peak demand (6 MW). Additional resilience is provided by a battery-powered UPS, which is sufficient to power the plant's control systems for up to an hour. The reliability of the system is high; the plant has sustained only two interruptions in service in the

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<sup>23</sup> The SAIFI and CAIDI values employed in the Nassau County analysis are the values for the Long Island Power Authority in 2012, as reported in State of New York Department of Public Service, *2012 Electric Reliability Performance Report*, June 2013.

last four years, both for less than 10 minutes. Most notably, the plant was able to maintain operations during Sandy, despite flooding and a loss of power in the surrounding community.

The design of the microgrid at the Nassau site relies extensively upon the generators that currently power the Cedar Creek WWTP. As the discussion above suggests, these generators are well maintained and have proved to be extremely reliable. It is unlikely that incorporation of these generators into a microgrid would reduce the risk that the Cedar Creek WWTP would experience a total loss of power. Accordingly, the benefit-cost analysis does not estimate any major power outage benefits for this facility.

#### *G.2.5.2 Wantagh Fire Department Administrative Building*

Wantagh's FDAB is the emergency dispatch center for both the Wantagh and Seaford fire departments. The building does not house vehicles or firefighters, but rather manages dispatch of firefighters from other facilities, handling about 3,000 alarm calls per year. The building is equipped with a new 130 kW natural gas backup generator, which is capable of meeting the facility's peak load. The backup generator is tested weekly, but if it were to fail the department would bring in a portable generator that could be installed by on-site personnel, without the need for an electrician. In the event of a total loss of power, the building's dispatch services could be moved to a mobile unit, with no anticipated loss of functionality. Because of the extensive contingency plans in place, with no costs or loss of service anticipated even if the backup generator were to fail, the analysis assumes that development of a microgrid would have no impact on the ability of this facility to maintain operations during a major power outage.

#### *G.2.5.3 Seaford Harbor Elementary School*

Seaford Harbor Elementary school serves 700 students, grades 1-6. The county is exploring options for using the school building as an emergency shelter. To date, however, the susceptibility of the site to flooding has precluded that use. As previously noted, the school currently has no backup generator.

Given the uncertainty surrounding the potential use of the school as an emergency shelter, the analysis focuses on the benefits a microgrid would offer by enabling the school to maintain its normal operations in the event of a major power outage. To estimate these benefits, the analysis examines the impact of a school closure on the productivity of parents or other adult caregivers, on the assumption that a closure would require some share of these individuals to miss work. It estimates the total value of this potential loss in productivity to be approximately \$235,000 per day. This estimate is based on the assumption that approximately 545 parents or other adult caregivers would miss a day of work for each day that the school is closed; this figure is based on the national average employment-population ratio for parents of school-aged children (from the Bureau of Labor Statistics Current Population Survey). The analysis also estimates that the average productivity for an employed adult caregiver in Nassau County is \$874 per day, based on a national estimate of GDP per hour worked (from the Organization for Economic Cooperation

and Development) adjusted to reflect local income levels.<sup>24</sup> Finally, based on a school year of 180 days, the analysis assumes that 49.3 percent of major power outages would occur on a school day.

The estimate of productivity losses employed in the analysis rests on the assumption that, with a microgrid in place, employed parents or adult caregivers would be able to work during outages that would otherwise prevent them from doing so. It is important to note that the cause of a major power outage (e.g., a major storm event) might itself prevent parents or adult caregivers from working, even if the school remained fully operational. Furthermore, if the school were inaccessible due to flooding or other factors, there would be no productivity benefit to maintaining electric service. *It is therefore likely that the analysis overstates the benefits of enabling the school to maintain normal operations in the event of a major power outage.*

#### G.2.6 Analysis of Peak Load Support Scenarios

The benefits of developing a microgrid at the Nassau site would be enhanced if the system could provide peak load support to the macrogrid via participation in a demand response program. Participating in this program would reduce demand to expand the macrogrid's generating capacity, thus providing capacity cost savings. Providing peak load support would increase the microgrid's annual operating costs (including variable O&M costs, fuel costs, and environmental costs). These costs, however, would be offset (at least in part) by a reduction in demand for electricity from the macrogrid, which would lead to energy cost savings and environmental benefits associated with the operation of bulk energy facilities.

The benefit-cost analysis considers a peak load support scenario in which the level of support provided is equal to the peak demand for the facilities that currently rely on LIPA service (i.e., the Wantagh FDAB and Seaford Harbor Elementary School). This scenario is roughly consistent with current eligibility requirements for demand response programs. The Team's design consultants estimate peak demand for the FDAB at 130 kW, and peak demand for Seaford Harbor Elementary School at 100 kW. Thus, under Option 1, the peak load eligible for participation in a demand response program is estimated at 230 kW. In contrast, under Option 2, the peak load eligible for participation is limited to the 100 kW of peak load associated with the Seaford Harbor Elementary School.

Under Option 1, the analysis estimates that the Nassau County project's participation in a demand response program would generate capacity cost savings of approximately \$36,000 per year. If the system were called upon to provide support for 20 hours a year, its operating costs would increase by approximately \$1,600 annually. These costs would be offset by a reduction in the macrogrid's operating costs of approximately \$500 per year. Under this set of assumptions, the system's

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<sup>24</sup> In the absence of productivity data at the county level, the analysis relies on household income data to adjust the national estimate of GDP per hour worked to a local estimate. Specifically, the analysis divides median household income for Nassau County families by median household income for the U.S. as a whole (using data from the U.S. Census American Community Survey), after adjusting for differences in labor force participation (using data from the Bureau of Labor Statistics Current Population Survey). It then multiplies this ratio by the national average GDP per hour worked to obtain an estimate of hourly productivity for employed adult caregivers in Nassau County.

participation in a demand response program would yield benefits of approximately \$35,000 per year.

The benefits of participation in a demand response program would be lower under Option 2. Under this option, the analysis estimates capacity cost savings of approximately \$16,000 per year. Providing support for 20 hours a year would increase the system's operating costs by approximately \$700 annually. These costs would be offset by a reduction in the macrogrid's operating costs of approximately \$200 per year. Under these assumptions, the system's participation in a demand response program would yield benefits of approximately \$15,000 annually.<sup>25</sup>

#### G.2.7 Summary of Results

As Table G-10 indicates, the breakeven conditions for the Nassau County site absent participation in a demand response program are less extreme than is the case for the other sites analyzed. For Option 1, the analysis suggests that benefits would exceed costs if the annual probability of a one-day outage is equal to or greater than 0.53; this figure declines to 0.35 for Option 2. This is due in large part to the system's relatively low capital costs, coupled with the assumption that site specific planning costs and engineering design costs would be minimal. In addition, the findings hinge on the assumption that maintaining electric service to Seaford Harbor Elementary School during a major power outage would yield significant benefits with respect to the productivity of adult caregivers. If this is not the case – e.g., if the cause of a major power outage prevents adult caregivers from working or makes the school inaccessible to students and staff – then the benefits of maintaining electric service to the school would be negligible. Moreover, it is important to recognize that development of a microgrid is unlikely to be the most cost-effective option for providing backup power to Seaford Harbor Elementary; installation of one or more conventional backup generators to provide power to the school would likely prove to be a far less expensive solution.

The analysis of the Nassau County case indicates that participation in a demand response program is less critical to the cost-effectiveness of a microgrid than are the issues noted above; participation in such a program has only a modest impact on the system's breakeven conditions. This reflects the relatively modest capacity the analysis assumes would be available to provide peak load support.<sup>26</sup>

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<sup>25</sup> It is interesting to note that the capacity of the generators at the Cedar Creek WWTP is significantly underutilized. These generators are currently not eligible to participate in a peak load support program. If they were, the value of the excess capacity available at the facility (approximately 9 MW) would be substantial: approximately \$1.4 million per year, based on SEP capacity values for Long Island (Zone K).

<sup>26</sup> The analysis of the peak load support scenarios assumes that the generators incorporated into the microgrid would meet eligibility requirements for participation in a demand response program. Additionally, it assumes that the facilities analyzed in each case would be willing to participate in such an arrangement.

**Table G-10: BCA Results for the Nassau Site: Breakeven Conditions (7% Discount Rate)**

<b>Scenario</b>	<b>Annual Probability of Specified Outage</b>	<b>Duration of Specified Outage</b>	<b>B/C Ratio</b>
Option 1/No Peak Load Support	53%	1 day	1.01
Option 2/No Peak Load Support	35%	1 day	1.00
Option 1/Peak Load Support	38%	1 day	1.00
Option 2/Peak Load Support	29%	1 day	1.01

# Appendix H Sample Solicitation Materials Sent to Counties

## H.1 Sample Solicitation Letter



NEW YORK STATE  
DIVISION OF HOMELAND SECURITY AND EMERGENCY SERVICES

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Andrew M. Cuomo, Governor

Jerome M. Hauer, Ph.D, MHS, Commissioner

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August 2, 2013

The Honorable Michael R. Bloomberg  
Mayor, New York City  
City Hall  
New York, New York 10007

Dear Mayor Bloomberg:

The New York State Energy Research and Development Authority (NYSERDA), in conjunction with the Division of Homeland Security and Emergency Services (DHSES) and the Division of Public Service (DPS), is conducting a study regarding the feasibility of establishing "micro-grids" to provide electric power to essential public services after a natural or man-made disaster. In this scenario, a "micro-grid" is an independent electricity/power provider including power generation and distribution which provides services on a small scale to a specific geographic area. Micro grids already exist in New York, for example at New York University. By being separate from the public electric grid, the critical infrastructure within a micro-grid may be better able to maintain electric power and essential services.

The general audience which the study is being applied to includes hospitals, first responder headquarters (such as police and fire stations), emergency shelters, schools, water filtration plants, sewage treatment plants, municipalities, critical commercial entities and nonprofit organizations.

**One of the requirements of the study is to determine who in New York may desire to collaborate on establishing a successful micro-grid.**

Although we are not excluding other options, past and current analysis of micro-grids indicate that they may be best suited for a "cluster" of significant public services, for example a hospital, police headquarters, emergency operations center and an evacuation shelter in close proximity to one another. For the purpose of the study, we are assuming that public utility power is not available for an extended period of time.

Please have your representative contact Mr. Chuck Phillips at [cphillips@dhSES.ny.gov](mailto:cphillips@dhSES.ny.gov) if you are interested in exploring the concept of establishing a micro-grid and locations that seem plausible for further study. There is no commitment – we are only gauging interest in the project.

Thank you for your time and interest.

Sincerely,

Jerome A. Hauer, Ph.D, MHS  
Commissioner

cc: Commissioner Joseph F. Bruno, NYC Office of Emergency Management

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1220 Washington Avenue, State Office Building Campus  
Building 7A, Suite 710  
Albany, NY 12242

## H.2 Sample Notice of Selection Letter



NEW YORK STATE  
DIVISION OF HOMELAND SECURITY AND EMERGENCY SERVICES

Andrew M. Cuomo, Governor

Jerome M. Hauer, Ph.D., MHS, Commissioner

October 30, 2013

The Honorable Steve N. Bellone  
Suffolk County Executive  
100 Veterans Memorial Highway  
PO Box 6100  
Hauppauge, New York 11788-0099

Dear Mr. Bellone:

I am pleased to inform you that Suffolk County's nomination of the cluster of critical infrastructure sites in Yaphank has been approved to participate in a State funded "micro-grid" study.

The New York State Energy Research and Development Authority (NYSERDA), in conjunction with the Division of Homeland Security and Emergency Services (DHSES) and the Department of Public Service (DPS) is conducting the study to determine the feasibility of establishing "micro-grids" to provide electric power to essential public services after a natural or man-made disaster. In this scenario, a "micro-grid" is an independent electricity/power provider including power generation and distribution which provides services on a small scale to a specific geographic area. As you are aware, some micro grids were able to operate when utility power failed after Superstorm Sandy. By being separate from the public electric grid, critical infrastructure within a micro-grid may be better able to maintain electric power and essential services.

**Next steps include a kick-off meeting with representatives from Suffolk County, NYSEDA, DHSES, DPS and the various organizations along Yaphank Avenue including Suffolk County Corrections, Police, Sheriff, Fire Rescue, and Health to gather data on power requirements. A consultant hired by NYSEDA is then responsible for conducting a feasibility study of potential micro-grid designs for the site.**

Thank you for your interest in participating in this important work and for your support of the work ahead. Staff from NYSEDA will be arranging with the respective parties regarding the kick-off meeting.

Sincerely,

A handwritten signature in black ink, appearing to read "Jerome A. Hauer".

Jerome A. Hauer, Ph.D., MHS  
Commissioner

cc: Commissioner Joseph F. Williams, Suffolk County Fire, Rescue and Emergency Services  
President/CEO John B. Rhodes, NYSEDA  
Chair Audrey Zibelman, New York PSC

1220 Washington Avenue, State Office Building Campus  
Building 7A, Suite 710  
Albany, NY 12242

**NYSERDA/DPS/DHES**  
**Critical Infrastructure**  
**Assessment**

*Site Interview and Microgrid  
Characterization*

## **NDA and Data Protection**

An NDA can be executed between GE and the building owner to protect the data provided in response to this questionnaire.

## **Definitions and Context for Terms in the Questionnaire**

**Microgrid** : A group of interconnected loads and distributed energy resources that form a single controllable entity capable of operating continuously in both grid-connected and islanded mode to support mission critical loads.

**Site**: A specific grouping of facilities to be included in the Microgrid configuration and operations assessment.

**Facility**: A specific operational entity considered part of the Microgrid site. (e.g. The Metropolitan Hospital).

**Building**: A stand-alone structure which is part of a specific facility.

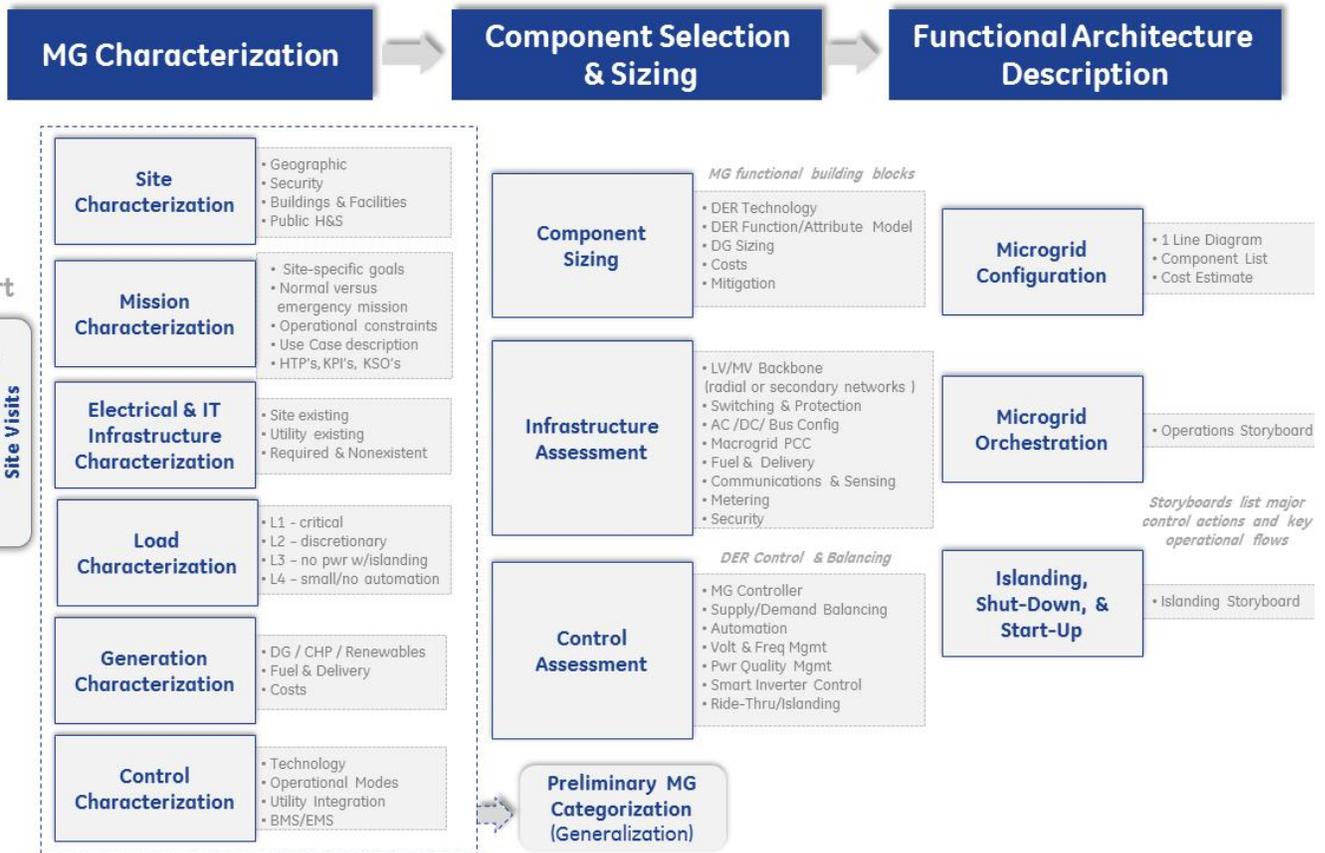
**Loads**: The devices and systems consuming energy at a facility.

**Electrical Infrastructure**: The wires, pipes, conduits, switches, transformers, etc., used to deliver power to loads at a facility.

**On-Site Generation**: The systems at a facility which produce power (e.g. CHP, rooftop solar panels).

**Building Energy Management System (BEMS)**: A system used to automatically monitor and control the energy demand and consumption of loads at a facility.

# Microgrid Assessment & Task Workflow



## General Facility Characterization

**Site Name:** \_\_\_\_\_

**Site Type:** (check all that apply)

- Residential
- Commercial
- Industrial
- Other: \_\_\_\_\_

**Point of Contact:** \_\_\_\_\_

**Title:** \_\_\_\_\_

**Role:** \_\_\_\_\_

**Electric Distribution Utility:** \_\_\_\_\_

**Energy Provider:** \_\_\_\_\_

## **Gas, water, steam Provider:**

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1. Are there any unique geographic/location constraints that may cause this site to be severely affected or difficult to access during storm or emergency conditions (Flood Zone, Fire Zone, Located near large body of water, etc.).
2. Buildings & Facilities
  - What is the size of the buildings and number of floors?
  - Please provide floor plans and dimensions?
3. How many square feet of conditioned (heated/cooled/lighted) interior floor space are in each building?
  - Are there any large unconditioned areas, such as warehouse space, machine shops, or parking garages?
  - Are there any conditioned areas that could be isolated and curtailed in the event of an emergency to reduce the electrical and thermal demand of the building

## Mission Characterization

### Mission Type (check all that apply)

- Hospitals and healthcare centers
- Water / wastewater treatment plants
- Police, fire, and public safety
- Military/National Security
- Food distribution facilities
- Telecom and data centers
- Other: \_\_\_\_\_

1. What are your primary/critical activities and related equipment and number of people involved? ( For example, Emergency Room in a hospital)
2. What are your non-critical activities and related equipment? ( For example, Starbucks in a hospital )
3. How do these activities change in an emergency situation?
4. Is your facility used as a shelter during emergency situations?
  - What is the shelter used for (e.g. housing general public, first responders site, emergency care site, etc.)?
  - Please provide any emergency response plans that describe your operations when functioning as a shelter.

## **Electrical Infrastructure Characterization**

1. Please supply any maps, drawings, blueprints or electronic models (GIS, AutoCAD, ETAP) of the electrical infrastructure showing circuits, topology, major protection and sectionalizing equipment, conductor types, major loads etc.
  - Please include any maps that show other utilities such as gas, water, steam, etc.
2. From what source (substation, feeder, lateral, spot network or transformer) does this building or campus receive its primary electrical power supply?
  - Does this facility have its own substation or dedicated transformer?
3. What is the primary voltage level to the transformer/substation?
  - What is the secondary service voltage and configuration (e.g. 3-phase 4-wire, 3-phase 3-wire, single-phase 3-wire)?
4. If the facilities that are part of this microgrid (e.g., individual buildings distributed generation, critical customers) are interconnected using existing utility facilities, provide the same information for those utility facilities as described in 1, 2, and 3 above.
5. Is there any existing physical security infrastructure to protect this site's power facilities?
  - Has there ever been any vandalism or attack on this site's power facilities?

## Load Characterization

1. What is the approximate summer/winter breakdown of your energy consumption by electrical and thermal load type?
  - % incandescent lighting
  - % florescent/LED lighting
  - % motor load
  - % heating and cooling
  - % switch-mode power supply
  - % others
  - What type of heating and cooling system is used?
2. Beyond space conditioning, what are the other major electrical and thermal loads within each building? Please include any exterior loads connected to the building circuit, such as walkway and perimeter lighting, loading dock lifts, parking garage operations, and any vehicle charging/fueling facilities?
3. What percentage of your load can be interrupted without severe consequences for short periods?
  - What is the timeline in Minutes/Hours/Days/Weeks?
4. Are you loads more sensitive to voltage sags and momentary interruptions or to sustained interruptions?
  - Do you have sensitive motors or other loads that trip during voltage sags?
  - What magnitude and duration of voltage sag (or interruption) can your operations sustain?
  - Do you often need to switch over to back up generation in cycles, seconds, minutes, or longer?
5. What is your average and peak demand for the building or facility for a typical day, seasonal month, and year?
  - Do you have average load profile data for a typical day, seasonal month and year?
  - Will you give us permission to collect meter and consumption data from your utility (electric/gas/water)?
6. How has your demand changed over the last few years?
  - Do you have near term plans to expand your facility?
7. How would you characterize each of the loads in your facility?
  - **L1: Critical** (a building/load that can never lose power)
  - **L2: Discretionary** (a building/load which may or may not sustain power based on priority during outages)
  - **L3: No power with islanding** (a building/load that does not serve a role in maintaining public health and safety)
  - **L4: Small/No automation** (a load such as a parking lot light that is too small to justify cost of automation)
8. Do you participate in any demand response or dynamic rate programs?

## Generation Characterization

1. Is there a CHP generator onsite?
  - What is the rating (Electrical and Heat output)?
  - What type of unit is it (reciprocating DG, gas turbine, fuel cell etc.)?
  - What is the fuel source for the CHP?

- Is the CHP generator designed to automatically transfer to service site load when there is a power outage?
  - Is your generator ever paralleled with the utility grid? If so, what is the mode of connection (DC or AC)?
2. Is there a backup generator onsite?
    - What is the rating of the backup generator?
    - What type of unit is it (reciprocating, gas turbine, fuel cell etc.)?
    - What is the fuel source? What is the site fuel storage capability?
    - How long does it take to start up the backup generator?
    - What is the backup transfer mechanism?
    - How often has the backup generator been used?
      - In the last one year?
      - In the last 5 years?
    - Do you have any information on the startup reliability of the backup generators?
    - Is there an UPS onsite? What is its rating?
    - How often are these systems inspected and tested?
  3. Is there an energy storage device on site?
    - What is its type (e.g. Ice, thermal storage, battery storage)
    - What is the, rating, and capacity?
  4. Does the site have any solar or wind generation?
  5. Is there a boiler or solar water heater for providing hot water to the site?
    - What is the rating of the boiler or solar system?
    - What is the boiler used for?
  6. Are there any specific interconnection requirements from the local utility for backup generation or cogeneration (e.g. must be inverter-fed to avoid fault-current issues)?

### **Control Characterization**

1. Does your building have a central Building Energy Management System (BEMS)?
  - Please provide the product name and version of your BEMS platform?
  - How is HVAC and Lighting load controlled (e.g. central BEMS, timers, local thermostat, etc.)?
  - Do any of the building controls currently have remote communications capability (e.g. IP-addressable thermostats, mechanical switch panels, user terminals to a central BEMS, Smart Phone Apps, etc.)?
2. What are the operating schedules of Lighting, HVAC, and Power for the various resources in your building? How are they different for emergency and non-emergency situations?
  - To support on-site residents
  - To support employee work shifts
  - To run factory/machinery
  - To run office/computers

### **BEMS IT Infrastructure Characterization**

1. Please provide any blueprints, drawings, or technical documents describing the IT/Telecommunications Infrastructure supporting your BEMS
  - Do you have any type of network interface with your utility or energy provider?

- Are there network sensors or data acquisition services used to monitor your electrical infrastructure?
- Does your building have internal advanced metering?
- Are there any special security restrictions when working with your BEMS or LAN/WAN?

### **Supporting Data Requests from Utility and Others<sup>27</sup>**

1. One-line diagrams of distribution system serving the Microgrid site.
2. List of Utility owned DG serving the Microgrid site.
3. Meter and Consumption data for all buildings on the Microgrid site.
4. Demand Response data for all participating loads within the Microgrid site.
5. Planned infrastructure changes affecting the Microgrid site.

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<sup>27</sup> Not required to be answered by Facility Owners

## Appendix I Protections for Residential Customers

This Appendix serves to supplement this discussion in Section 4 of this Report with discussion of the additional regulations that the Public Service Law (PSL) places on those providing service to residential customers. These considerations may impact microgrids that provide residential service.

The Public Service Commission's (PSC) regulatory functions include representing consumer interests with regard to electric and gas services. Transactions between residential electricity consumers and suppliers are regulated through the PSL; The Home Energy Fair Practices Act (HEFPA); the Energy Consumer Protection Act of 2002 (ECPA); the New York Codes, Rules and Regulations; utility tariffs and supplier contracts; and PSC Commission orders and opinions.<sup>28</sup>

The Home Energy Fair Practices Act, adopted in 1981 as New York Public Service Law Article 2, is New York's "utility service bill of rights."<sup>29</sup> It is one of the most protective statutes for electric and gas customers in the country.<sup>30</sup> The law addresses, among other things, applications for termination of and restoration of service; deferred payment agreements; budget payment plans; service deposits; metering and billing requirements; late payment charges and interest rates; bill content; notification requirements; and complaints.<sup>31</sup> The Energy Consumer Protection Act of 2002 ensured that contracts between competitive power suppliers and residential customers had to comply with HEFPA and other New York PSC regulations.<sup>32</sup>

### I.1 Application of Residential Protections: Who Is "Residential"?

PSL protections apply whenever an electric corporation or other entity "in any manner, sells or facilitates the sale or furnishing of gas or electricity to residential customers."<sup>33</sup> A residential customer is any person who, pursuant to an application for service or an agreement for the provision of commodity supply, is supplied directly with all or any part of the gas, electric, or steam service at a premise used in whole or in part as his or her residence where: 1) the distribution utility's effective tariff specifies a residential rate for such service or 2) such service is primarily used for his or her residential purposes, and the customer has so notified the utility.<sup>34</sup>

New York State Multiple Dwelling and Multiple Residence Law define what constitutes a dwelling or residence. A dwelling is a "building or structure, which is occupied in whole or in

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<sup>28</sup> For more information, *see*

[www.narucpartnerships.org/Documents/Raj\\_Addepalli\\_Consumer\\_Protections\\_in\\_NY.pdf](http://www.narucpartnerships.org/Documents/Raj_Addepalli_Consumer_Protections_in_NY.pdf).

<sup>29</sup> "Rights of Residential Gas and Electric Consumers: Home Energy Fair Practices Act," Public Utility Law Project, at HEFPA-1, *available at*

[http://www.pulp.tc/DocViewer.aspx?FileName=Docs/HEFPA\\_09032008.pdf](http://www.pulp.tc/DocViewer.aspx?FileName=Docs/HEFPA_09032008.pdf).

<sup>30</sup> *Id.*

<sup>31</sup> Raj Addepalli, Presentation, Consumer & Utility Rights & Obligations (National Association of Regulatory Utility Commissioners, June 2007), *available at*

[www.narucpartnerships.org/Documents/Raj\\_Addepalli\\_Consumer\\_Protections\\_in\\_NY.pdf](http://www.narucpartnerships.org/Documents/Raj_Addepalli_Consumer_Protections_in_NY.pdf).

<sup>32</sup> *Id.*

<sup>33</sup> N.Y. Public Service Law § 53.

<sup>34</sup> 16 NYCRR § 11.2.

part as the home, residence, or sleeping place of one or more persons.”<sup>35</sup> A “multiple dwelling” is a dwelling that is “either rented, leased, let or hired out, to be occupied, or is occupied as the residence or home of three or more families living independently of each other.”<sup>36</sup> A “Class B” multiple dwelling is a multiple dwelling that is occupied, as a rule transiently, including hotels, lodging houses, rooming houses, boarding houses, boarding schools, furnished room houses, lodgings, club houses, college and school dormitories.<sup>37</sup> A “multiple dwelling” does not include a hospital, convent, monastery, asylum or public institution, or a fireproof building used wholly for commercial purposes.<sup>38</sup>

With regard to submetered residential buildings, landlords, ESCOs and utilities must all provide the same consumer protections and complaint adjudication procedures of HEFPA.<sup>39</sup> Master-metered residential rental units owned or operated by private or government entities are permitted by the PSC, upon application. An application must include, among other things, the method for calculating rates to tenants with a rate cap not to exceed the utility’s tariffed residential rate; complaint procedures and tenant provisions consistent with HEFPA; provisions for tenant notice and comment; and an enforcement mechanism for plaintiffs to ensure that their rights are protected under the law.<sup>40</sup> Still, a conversion from submetering to master metering may not be permitted by the PSC, which has stated a policy preference for improving the amount of information residential customers have about their energy use through practices like submetering.<sup>41</sup> The PSC has used its broad discretion in such instances to deny applications for master metering on these grounds, as it did in an application filed by NYU in 2007.

As contrasted with residential customers, the relevant PSL does not provide non-residential customers the same degree of procedural protections as afforded to residential customers.<sup>42</sup> A nonresidential customer is a person, corporation or other entity, supplied by a utility with gas, electric or steam service under the utility’s tariff, and pursuant to an accepted application for service, who is not a residential customer as so defined.<sup>43</sup> Provision of service to non-residential customers is also regulated by the PSL and governs, among other things, application and termination of service, billing, and complaint-handling procedures.

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<sup>35</sup> NY CLS Mult R § 4 (13).

<sup>36</sup> *Id.* at (33).

<sup>37</sup> NY CLS Mult D § 4(9).

<sup>38</sup> NY CLS Mult D § 4(7).

<sup>39</sup> *See generally*, “PSC Warns Landlords to Follow Submetering Orders Allowing Sale of Electric Service to Residential Tenants,” Public Utility Law Project of New York, *available at* <http://pulpnetwork.blogspot.com/2013/04/psc-warns-landlords-to-follow.html>.<sup>40</sup> 16 NYCRR § 96.2.

<sup>40</sup> 16 NYCRR § 96.2.

<sup>41</sup> Case No. 07-E-0820, Petition of New York University to Remove the Individual Apartment Meters and Consolidate the Meters Pursuant to Service Classification SC-9 Located at 334 East 26<sup>th</sup> Street Dormitory in the Territory of Consolidated Edison Company of New York, Inc., Order Denying Petition for Waivers. (Issued February 21, 2008).

<sup>42</sup> 16 NYCRR § 13.1-.16.

<sup>43</sup> 16 NYCRR § 13.1.

## **I.2 Application of Residential Protections to Microgrids**

Because any residential customer who purchases electricity from any provider is entitled to statutory protections, a microgrid that serves residential customers will likely be required to comply with these requirements and cannot be exempted by the PSC. Nevertheless, it appears that in the “single landlord/campus model” of microgrids, *e.g.* the systems of Cornell University and NYU, provision of electric commodity to dormitories does not trigger statutory customer protections even though the dormitories are likely Class B Multiple Dwellings, and thus residential. Many dormitories are master metered and residents do not pay their energy bills directly; instead, dormitory residents are charged the average cost of energy service to a dorm room, which is included in the rent. Accordingly, service under a campus model, where the microgrid is serving loads all under the control of a single owner, may be afforded different treatment under the PSL than direct service to other residential customers under an independent provider model.

## Appendix J **Benefit-Cost Assessment Model**

To facilitate evaluation of the economic viability of microgrids, the New York State Energy Research and Development Authority (NYSERDA) – with the cooperation and assistance of the New York State Department of Public Service (DPS) and the State’s Division of Homeland Security and Emergency Services (DHSES) – has developed a benefit-cost assessment (BCA) model designed for application to individual sites. The model estimates the costs and benefits of a microgrid from the perspective of society as a whole, taking into account the benefits of maintaining first-response capabilities and other public services in the event of a prolonged emergency.

The BCA model considers the following aspects of a microgrid’s costs:

- Initial design and planning costs.
- Capital costs.
- Operation and maintenance (O&M) costs.
- Environmental costs.

Similarly, the model quantifies the following potential benefits of developing and operating a microgrid:

- Energy benefits.
- Reliability benefits.
- Power quality benefits.
- Environmental benefits.
- Public health and safety benefits.

As described below, the model incorporates standardized calculations for the analysis of all costs and for the analysis of energy benefits, reliability benefits, power quality benefits, and environmental benefits. The analysis of public health and safety benefits, however, is tailored to each case study; thus, this appendix provides only a general overview of the factors the model considers in evaluating these benefits. More detailed information on the calculation of public health and safety benefits is presented in the discussion of each case.

### **J.1 Model Overview**

The BCA model is a spreadsheet tool comprising 35 linked worksheets developed in Microsoft Excel. 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. The model analyzes discrete operating scenarios specified by the user; it does not identify an optimal project design or operating strategy.

The 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 the annual discount rate the user specifies. It also calculates an annualized estimate of costs and benefits based on the anticipated engineering life 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 costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the present value of the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2013 dollars.<sup>44</sup>

## **J.2 Cost Analysis**

### **J.2.1 Initial Design and Planning Costs**

The costs of developing a microgrid include an initial investment in the project's design, as well as costs associated with obtaining building and development permits, securing financing, and establishing contracts with the local utility and/or bulk energy suppliers.<sup>45</sup> The magnitude of these costs may be substantial, particularly if the project's design is complex or presents novel challenges. The microgrid's developers – including the owner/operator of the distributed energy resources within a proposed microgrid, the owner/operator of the distribution network within the microgrid, and any others engaged in the project's development – are likely to bear the majority of these costs. Costs may also be borne by local utilities and/or bulk energy suppliers to negotiate contracts or develop plans for connecting the microgrid to the macrogrid (NYSERDA, 2011).

The BCA model requires the user to provide an aggregate estimate of a microgrid's design and planning costs. These costs are treated as an initial investment, and thus are not discounted in the model's calculation of present values. In calculating annualized values, planning and design costs are amortized over the life of the project.

### **J.2.2 Capital Investments**

Capital investments must be made to purchase and install the equipment to be incorporated into the microgrid. These costs fall into two general categories: those associated with power generation and energy storage, and those associated with distribution services.

The capital costs for microgrid power generation and energy storage include the cost of the equipment itself and the costs associated with its installation (Herman, 2003a). The magnitude of

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<sup>44</sup> Values are adjusted for inflation using the Gross Domestic Product Implicit Price Deflator, as reported by the U.S. Department of Commerce, Bureau of Economic Analysis on January 30, 2014.

<sup>45</sup> Interest expenses associated with a project's financing are not included in evaluating project costs from a social welfare standpoint; the equivalent value of such expenses is already captured in the BCA through the application of the discount rate. The transaction costs (*e.g.*, management time) incurred in *securing* financing, however, represent a real resource cost. The model treats these costs as an element of project design and planning.

these costs depends primarily on the type and capacity of distributed energy resources and storage technologies employed.

The capital costs for microgrid distribution services include the costs associated with acquisition and installation of the infrastructure that (1) connects distributed energy resources to the microgrid, and (2) connects the microgrid to the macrogrid. The equipment that comprises this infrastructure may include controllers, communication devices, disconnect switches, transformers and substations, capacitor banks, distribution feeders, and other components (Morris *et al.*, 2011; Morris, 2012). The capital costs of a microgrid project may also include “interconnection costs”; *i.e.*, upgrades to the macrogrid necessary to accommodate connection of the microgrid.

The BCA model asks the user to identify and describe the elements of the microgrid’s power generation and distribution infrastructure, and to specify the cost and engineering life of each component. Based on this information, the model projects the time-stream of capital expenditures the project requires, for each component and for the system as a whole, and calculates the present value of each stream of payments. The model also calculates an annualized cost figure for each component, based on its expected useful life. The annualized capital cost for the system as a whole is the sum of the annualized costs calculated for each component.

### J.2.3 Operation and Maintenance Costs

Once microgrid equipment is purchased and installed, stakeholders must cover the costs of the system’s operation and maintenance (O&M). This includes costs directly associated with power generation and distribution services, as well as costs associated with the provision of ancillary services to the macrogrid (*e.g.*, frequency support, voltage support, peak load support, and black start or system restoration support).

The principal O&M costs associated with a microgrid’s power generation and distribution services include:

- The cost of labor to operate and monitor the system (including operator training costs).
- The cost of fuel consumed by the microgrid’s power generating equipment.
- The cost of other materials consumed in operating the microgrid (*e.g.*, materials such as oil, fuel filters, coolant fluid, and emissions control catalysts).
- The cost of labor and materials for scheduled and unscheduled maintenance (Herman, 2003).

Many of these costs are likely to vary with utilization of the microgrid (*i.e.*, the amount of electricity it produces); the model identifies these as “variable” O&M costs. Other O&M costs, such as the costs associated with software licenses, are unlikely to vary with utilization of the system; the model designates these as “fixed” O&M costs.

In addition to providing power to its own customers, a microgrid can provide ancillary services that support the operations of the larger macrogrid. Providing these services may impose

additional operating costs on microgrid stakeholders. The nature of these costs is described below.

- *Frequency or Real Power Support:* Microgrid operations can provide frequency support to the macrogrid network. To provide this support, microgrids set aside certain reserves that can be made available to the macrogrid when needed. Costs to the microgrid include the opportunity cost of maintaining these reserves as well as any additional fuel or other O&M costs associated with increased utilization of equipment, such as power generators, to provide frequency support (Morris, 2012).
- *Voltage or Reactive Power Support:* Similar to active power support, microgrids can provide voltage or reactive power support to the macrogrid. This support can enhance power quality and stability within the network. For the microgrid, the cost of voltage support stems primarily from reduced power output; this represents an opportunity cost for the owner/operator of distributed energy resources within the microgrid (Morris, 2012).<sup>46</sup>
- *Black Start or System Restoration Support:* Microgrids can mitigate the effects of a power outage by providing black start support to critical loads and other system loads. This involves providing power to certain loads while the larger macrogrid is undergoing black start procedures to restore operations. In this manner, microgrids can improve reliability and reduce the effects of long outages. Given the low frequency of power outages, the variable O&M costs associated with black start support are likely to be relatively minor. Other costs, however, could prove to be more substantial. These costs include staff training, infrastructure maintenance, and fuel storage costs (Morris, 2012).
- *Peak Load Support:* By reducing system loading on the macrogrid, microgrids can support network infrastructure and reduce the possibility of power failures due to peak load congestion. Depending on the configuration of the microgrid, peak load support may or may not impose additional O&M costs. If a microgrid's distributed energy resources are ordinarily all in operation, providing peak load support to the macrogrid may not impose additional O&M costs; however, if a microgrid brings additional distributed energy resources into operation during times of peak load, perhaps exporting power to the macrogrid, additional O&M costs may be incurred for factors such as labor, fuel, and maintenance (Morris, 2012).

The BCA model estimates the O&M costs associated with a project's standard power generation and distribution services and any additional costs associated with the provision of ancillary services. These costs are categorized as follows:

- *Fixed O&M* – costs that are likely to remain constant from year to year.
- *Variable O&M* – costs (other than fuel costs) that are likely to vary with the amount of electricity generated.

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<sup>46</sup> The provision of reactive power support requires equipment with reactive power control, such as an induction machine. This type of equipment, however, is also necessary for a microgrid to be capable of operating in islanded mode. Thus, microgrids designed with the ability to island may be able to provide reactive power support without incurring additional equipment costs.

- *Fuel Costs* – for distributed energy resources powered by natural gas, petroleum, or other fossil fuels.<sup>47</sup>

The model asks the user to provide a direct estimate of fixed O&M costs on an annual basis (\$/year). It estimates variable O&M costs on the basis of two user-specified values: a unit cost factor (\$/MWh generated) and an estimate of the average amount of electricity to be generated annually (MWh/year). Fuel costs are calculated for each natural gas- or petroleum-fired source based on the average amount of electricity to be generated annually (MWh/year), the user's estimate of fuel consumption per unit of production (MMBtu/MWh), and forecasts of natural gas or petroleum prices (\$/MMBtu) developed for New York's Draft 2013 State Energy Plan (SEP).<sup>48</sup> The model also incorporates scaling factors – one for the price of petroleum and one for the price of natural gas - that allow the user to adjust the forecast energy prices relative to the SEP forecast. The model sums across all distributed energy resources to determine total fuel costs (\$/year) for the system as a whole.

#### J.2.4 Environmental Costs

In order to install and operate the distributed energy resources that will serve microgrid projects, the microgrid's developers may incur costs related to acquiring, installing, operating, and maintaining pollution control equipment. In particular, microgrids that rely upon the combustion of fuels to generate power may incur costs to control emissions of carbon dioxide (CO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and/or particulate matter (PM<sub>10</sub> and/or PM<sub>2.5</sub>). These costs will vary with the type of distributed generation technology the project employs, but could prove to be significant (Herman, 2003).

The BCA model asks the user to specify the fully installed cost and engineering life of the emissions control equipment the microgrid requires. It also asks the user to specify the unit cost of operating and maintaining this equipment (\$/MWh), as well as the annual cost of any other expenditures on emissions control (\$/year). Based on this information and an estimate of the average amount of electricity the system will generate (MWh/year), the model calculates the total cost of emissions controls, both on a present value and annualized basis.

In addition to the cost of installing, operating, and maintaining pollution control equipment, microgrid developers may be required to purchase allowances for the emission of certain air pollutants: SO<sub>2</sub> and NO<sub>x</sub>, which are subject to the requirements of the Federal Clean Air Act; and CO<sub>2</sub>, which in New York is subject to the requirements of the Northeast states' Regional Greenhouse Gas Initiative. The applicability of these requirements depends upon the capacity of the distributed generation source and the technology it employs. The BCA model asks the user to

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<sup>47</sup> The model captures any opportunity costs associated with the provision of ancillary services in its estimate of the energy cost savings the microgrid would provide; thus, separate estimation of such costs is not required.

<sup>48</sup> The analysis of fuel costs assumes that the microgrid begins to operate in 2016, assigning projected fuel prices for that year to the system's first year of operation. The estimate of fuel costs in each subsequent year is based upon the corresponding year's price forecast.

indicate if a source is subject to these requirements. If it is, the model calculates the annual cost of obtaining emissions allowances based on (1) the user's estimate of the average amount of electricity the system will generate (MWh/year); (2) the user's estimate of unit emissions factors for CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub> (tons/MWh); and (3) forecasts of allowance prices (\$/ton) for each pollutant, as reported in the Draft 2013 SEP.<sup>49</sup>

When emissions are subject to the allowance programs described above, the development of a microgrid should yield no net increase in air pollution; since the supply of allowances is capped, the acquisition of allowances by the microgrid would be offset by a sale of allowances by other sources, which would need to reduce their emissions accordingly. Thus, the development of the microgrid should have no net impact on public health or environmental quality.<sup>50</sup> Conversely, when emissions are not capped, microgrid operations could result in a net increase in emissions, and thus a negative impact on health or the environment. This is the case for emissions of particulate matter (which may be measured as PM<sub>10</sub> and/or PM<sub>2.5</sub>) and for any emissions of CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub> that are not subject to emission allowance requirements. The BCA model estimates damage values (\$/year) for such emissions based on (1) the user's estimate of the average amount of electricity the system will generate (MWh/year); (2) the user's estimate of unit emissions factors for CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, and/or PM<sub>2.5</sub> (tons/MWh); and (3) the median estimated marginal damage value (\$/ton) presented in a recent report by the Electric Power Research Institute (Wakefield, 2010). For purposes of sensitivity analysis, the model also reports 5<sup>th</sup> and 95<sup>th</sup> percentile marginal damage values for each pollutant; users can employ these values to determine their impact on estimated emissions damage costs.

## **J.3 Benefit Analysis**

### **J.3.1 Energy Benefits**

Microgrids may provide energy benefits both to their customers and to society as a whole (Morris *et al.*, 2011). The analysis distinguishes between two types of energy benefits: energy cost savings and capacity cost savings.

#### *J.3.1.1 Energy Cost Savings*

A microgrid can provide energy cost savings if its operation reduces the variable costs (*e.g.*, the consumption of fuel) incurred in the production of electricity. A number of factors may contribute to such savings, including:

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<sup>49</sup> The analysis of emission allowance costs assumes that the microgrid begins to operate in 2016, assigning allowance prices for that year to the system's first year of operation. The cost of allowances for each subsequent year is based upon the corresponding year's price forecast.

<sup>50</sup> This assumes that the damages attributable to the emissions of a particular pollutant are relatively insensitive to the location of the source. This is arguably the case with emissions of SO<sub>2</sub> and NO<sub>x</sub>, the impacts of which manifest on a regional scale, and is clearly the case with emissions of greenhouse gases like CO<sub>2</sub>, the impacts of which are global.

- Meeting demand for electricity with technologies that operate at a lower marginal cost than the technologies they displace.
- Incorporating CHP/CCHP systems into a microgrid, thus reducing demand for energy from bulk energy suppliers with little or no increase in the energy costs incurred by the operator of the microgrid.
- Reducing transmission and distribution losses as a result of reliance on distributed energy resources located at an end user's site or in close proximity to end users.
- Providing ancillary services (*e.g.*, reserve power, voltage and frequency regulation, black start support, or peak load support) more efficiently than conventional sources (Wakefield, 2010; Morris *et al.*, 2011).

The BCA model's analysis of energy cost savings estimates the impact of the microgrid on demand for electricity from the macrogrid (MWh/year) based on the amount of electricity (MWh/year) to be generated by the microgrid in grid-connected mode. This reduction in demand for electricity from the macrogrid is adjusted upward by a factor of 7.2 percent, based on NYSERDA's estimate of typical losses in the transmission and distribution of electricity in New York State; application of this factor accounts for the additional energy that would be required to supply electricity to microgrid customers via the conventional grid.<sup>51</sup> The model values the reduction in demand for electricity from the macrogrid based on forecasts of energy prices (\$/MWh) developed for the Draft 2013 SEP; these forecasts are differentiated by region.<sup>52</sup> As a default, the user can rely on average energy prices for each region. Alternatively, if the microgrid is likely to generate electricity primarily during periods of peak demand, the user can adjust energy prices to reflect the higher value of this electricity. The adjustment is based on the ratio of peak energy prices to average energy prices in each region. The model allows the user to select one of five options to make this adjustment, based on the number of hours each year that are included in the definition of peak demand: the top one percent; top five percent; top 15 percent; top 40 percent; or top 65 percent.<sup>53</sup>

As noted above, microgrids that incorporate CHP or CCHP systems may generate energy cost savings through more efficient use of fuel. To quantify this impact, the BCA model asks the user to specify the type and amount of fuel saved (MMBtu/year). The model values the annual

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<sup>51</sup> In light of the proximity of distributed energy resources to the loads they serve, the calculation assumes negligible losses in the distribution of electricity from these sources.

<sup>52</sup> The model incorporates forecasts of energy prices for the Capital Region (Zone F); Hudson Valley (Zones G through I); Long Island (Zone K); New York City (Zone J); and Upstate (Zones A through E).

<sup>53</sup> The analysis of energy cost savings assumes that the microgrid begins to operate in 2016, assigning projected energy prices for that year to the system's first year of operation. The estimate of energy cost savings in each subsequent year is based upon the corresponding year's price forecast.

reduction in fuel consumption based on the forecasts of fuel prices (\$/MMBtu) developed for the Draft 2013 SEP.<sup>54</sup>

### *J.3.1.2 Capacity Cost Savings*

Society as a whole will benefit if the development of a microgrid defers the need to invest in expansion of the macrogrid's energy generation, transmission, or distribution systems (Morris *et al.*, 2011). These benefits will be realized, however, only if the impact of the microgrid on demand for capacity can be estimated with reasonable certainty.

The BCA model evaluates potential impacts on generating capacity by asking the user to specify the estimated impact of the microgrid on demand for peaking capacity, either due to the direct provision of peak load support or as a result of the microgrid's participation in a demand response program. This estimate is adjusted upward by 16 percent to reflect the reserve margin that regulated utilities must maintain above anticipated peak load. The value of impacts on generating capacity is calculated based on forecasts of prices for generating capacity developed for the Draft 2013 SEP; like the SEP's forecast of energy prices, its forecasts of capacity prices are differentiated by region.

The evaluation of distribution capacity benefits is similar, relying on the user to specify the potential impact of the microgrid on the distribution capacity the local utility must maintain. The value of impacts on distribution capacity is calculated based on prices for distribution capacity reported by DPS (DPS, 2009) and Con Edison (Con Edison Case 13-E-0573, 2013). The model differentiates prices for New York City from other geographic locations in New York State. For New York City, the model incorporates separate price forecasts for capacity in network and non-network (radial or overhead) distribution areas.

The analysis of capacity cost savings (both for generation and distribution) assumes that the microgrid begins to operate in 2016, assigning projected capacity prices for that year to the system's first year of operation. The estimate of capacity cost savings in each subsequent year is based upon the corresponding year's price forecast. Since capacity impacts may vary over a 20-year operating period, the model also incorporates annual scaling factors – one for generation and one for distribution – that allow the user to specify the percentage of the maximum capacity benefit that would be realized in any given year.

### J.3.2 Reliability Benefits

The reliability benefits of microgrids are those associated with reductions in the frequency or duration of power outages its customers may face. The ability of microgrids to improve system reliability is particularly important to microgrid customers who require uninterrupted power; *e.g.*,

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<sup>54</sup> The analysis of fuel savings assumes that the microgrid begins to operate in 2016, assigning projected fuel prices for that year to the system's first year of operation. The estimate of fuel savings in each subsequent year is based upon the corresponding year's price forecast.

hospitals or public service offices that require uninterrupted computer and telecommunication abilities (Gumerman *et al.*, 2003).

To evaluate reliability benefits, the BCA model incorporates the U.S. Department of Energy (DOE) Interruption Cost Estimate (ICE) Calculator, which Freeman, Sullivan & Company developed for DOE and Lawrence Berkeley National Laboratory. The ICE Calculator is designed to value interruption costs and reliability improvements in static or dynamic environments (DOE, 2011). Use of this calculator requires the following user-specified inputs:

- Baseline values for two measures of service reliability: the System Average Interruption Frequency Index (SAIFI) and the Customer Average Interruption Duration Index (CAIDI) for the facilities the microgrid would serve.<sup>55, 56</sup>
- The number of residential and non-residential customers served by the microgrid.
- The state where the project is located.

Using this information, the ICE Calculator develops state-specific default inputs characterizing the customer base. For example, the calculator considers annual energy use by residential, commercial, and industrial customers; the distribution of commercial and industrial customers by economic sector; the prevalence of backup generation among customers; demographic characteristics, such as the median age and income of residential customers; the type of residential dwellings served (*e.g.*, detached, attached, apartments, mobile homes); and the distribution of annual outages by time of day, time of year, and time of week. The calculator allows these inputs to be tailored, if desired, to incorporate site-specific data for the project area.

Once these inputs are specified, the ICE Calculator estimates the annual cost of service interruptions for each class of customer and for all customers combined. These values are generated using the results of an econometric model of customers' willingness-to-pay to avoid service unreliability or willingness to accept compensation for service interruptions (Sullivan *et*

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<sup>55</sup> As a means of monitoring service reliability, DPS requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions of more than five minutes in length (DPS, 2013). These reports provide a variety of information on each outage, including its duration and cause. This information provides a basis for calculating SAIFI and CAIDI.

<sup>56</sup> The DPS service interruption reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Con Edison's underground network system). SAIFI and CAIDI can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control (a major storm is defined as any storm which causes service interruptions of at least 10 percent of customers in an operating area, and/or interruptions with duration of 24 hours or more). The BCA model treats the benefits of averting lengthy outages caused by major storms or manmade events as a separate category; therefore, the analysis of reliability benefits focuses on the effect of a microgrid on SAIFI and CAIDI values that exclude outages caused by major storms.

*al.*, 2009).<sup>57</sup> The BCA model calculates the benefits of improved service reliability based on this estimate of annual service interruption costs and the user's estimate of the impact of the microgrid on service interruptions (percent reduction in outages). These benefits are calculated net of any additional costs (*e.g.*, variable O&M, fuel) associated with operating the microgrid while service from the conventional grid is out.

### J.3.3 Power Quality Benefits

The power quality benefits of a microgrid may include reductions in the frequency of voltage sags and swells or reductions in the frequency of momentary outages (*i.e.*, outages of less than five minutes). To estimate these benefits, the BCA model first calculates the baseline cost of power quality events (\$/year) for the customers served by the microgrid. These costs are calculated for three groups:

- Small commercial and industrial customers.
- Medium and large commercial and industrial customers.
- Residential customers.

The estimate of baseline power quality costs is based on the number of customers in each class the microgrid would serve; the baseline frequency of power quality events (events/year), as specified by the user; and the cost of a power quality event (\$/event) for the average customer in each class, as reported in Sullivan *et al.* (2009). The annual benefits of improved power quality are calculated based on the percentage of power quality events the microgrid would prevent, as estimated by the user.

### J.3.4 Environmental Benefits

By reducing the demand for electricity from the macrogrid, microgrids may reduce the emission of greenhouse gases and other pollutants from bulk energy suppliers (Morris *et al.*, 2011). The BCA model calculates emissions avoided (tons/year) based on the amount of electricity (MWh/year) to be generated by the microgrid; an adjustment factor of 7.2 percent to account for transmission and distribution losses; and unit emissions factors (tons/MWh) for SO<sub>2</sub>, NO<sub>x</sub>, CO<sub>2</sub>, PM<sub>2.5</sub> and/or PM<sub>10</sub> for natural gas combined cycle units. This approach assumes that the energy generated by the microgrid would otherwise have been generated by natural gas combined cycle units.

The model values reductions in emissions of SO<sub>2</sub>, NO<sub>x</sub>, and CO<sub>2</sub> (tons/year) based on forecasts of allowance prices (\$/ton) for each pollutant, as reported in the Draft 2013 SEP.<sup>58</sup> This approach assumes that the energy generated by the microgrid would otherwise have been generated by

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<sup>57</sup> The data underlying the econometric model were collected through 28 studies of electric utility customers across the U.S. between 1989 and 2005.

<sup>58</sup> The analysis of emissions allowance benefits assumes that the microgrid begins to operate in 2016, assigning allowance prices for that year to the system's first year of operation. The cost of allowances for each subsequent year is based upon the corresponding year's price forecast.

units subject to emissions allowance requirements for these pollutants. In contrast, the model values reductions in emissions of PM<sub>2.5</sub> and/or PM<sub>10</sub> based on the median estimated marginal damage value (\$/ton) presented in a recent report by the Electric Power Research Institute (Wakefield, 2010). For purposes of sensitivity analysis, the model also reports 5<sup>th</sup> and 95<sup>th</sup> percentile marginal damage values for PM<sub>2.5</sub> and/or PM<sub>10</sub>; users can employ these values to determine their impact on estimated emissions reduction benefits.

In addition to reducing the demand for electricity from bulk energy suppliers, microgrids may reduce the emission of greenhouse gases and other pollutants from commercial boilers through the installation of CHP/CCHP systems (Morris *et al.*, 2011). The BCA model calculates emissions avoided (tons/year) based on information provided by the user on the type and amount of fuel saved by the installation of the CHP/CCHP system (MMBtu/year) and unit emissions factors (tons/MMBtu) for SO<sub>2</sub>, NO<sub>x</sub>, CO<sub>2</sub>, PM<sub>2.5</sub> and/or PM<sub>10</sub> for natural gas and distillate oil commercial boilers. Because commercial boilers are not currently subject to emissions allowance requirements, the BCA model values reductions in emissions of all pollutants based on the median estimated marginal damage values (\$/ton) presented in a recent report by the Electric Power Research Institute (Wakefield, 2010). For purposes of sensitivity analysis, the model also reports 5<sup>th</sup> and 95<sup>th</sup> percentile marginal damage values for each pollutant; users can employ these values to determine their impact on estimated emissions reduction benefits.

### J.3.5 Health and Safety Benefits

The potential for microgrids to maintain services that are critical to public health and safety – including fire services, emergency medical services (EMS), hospital services, police services, wastewater services, and water services – was a primary purpose of this study. Maintenance of these services could help to avoid or reduce deaths, injuries, and property damage that might otherwise occur during a power outage. A microgrid capable of operating in islanded mode could continue to supply power to providers of key public services, resulting in a substantial benefit to society as a whole.

To estimate the losses that would occur due to a power outage affecting the facilities providing these critical services, the model incorporates a methodology developed by the Federal Emergency Management Agency (FEMA, 2011). FEMA developed this methodology for use in administering its Hazard Mitigation Grant Program, which employs benefit-cost analysis to determine how to allocate grant funds among competing mitigation projects. The methodology incorporates site-specific data – including the length of time that a service provider is unable to function and the size of the population served by the provider – as well as standard values and formulas to quantify and value the potential impacts of a loss of public services. The service categories covered by the FEMA methodology, as well as the impacts that the methodology estimates for each service category, are listed in Exhibit 1. For fire, emergency medical, and hospital services, the methodology assumes that the population normally served by the non-functioning service provider would rely on the next-closest provider able to serve this population. The increased time that would be required for the next-closest provider to respond to a fire or medical emergency is assumed to result in an increase in property damage and health impacts.

For police services, the methodology estimates the value of an increase in property and violent crime that would result from a marginal reduction in police presence. For wastewater, water, and electric power services, the methodology assumes that the population served by each provider would be left without the service and estimates the impact of the lost service on economic activity (for commercial users) and on social welfare (for residential users).<sup>59</sup>

The BCA model estimates the public health and safety benefits of a microgrid project by calculating the value of all service losses prevented by the microgrid, using the FEMA methodology to estimate the value of the services provided by facilities supplied by the microgrid. For each service provider supplied by the microgrid, the model asks the user to specify the population served by the provider, whether the provider has backup generating capacity, and additional information required by the FEMA methodology, such as the distance to the nearest service provider able to serve this population (for fire, emergency medical, and hospital services). In addition, the model reports the standard values used in the FEMA's formulas, which in many cases are national or regional averages; users can substitute site-specific information for these standard values if such information is available.<sup>60</sup> With this information, the BCA model estimates the expected value of the loss of service that would result from major power outages of different durations, accounting for the expected failure rate of any backup generation in place.<sup>61</sup> The public health and safety benefits of a microgrid project are then estimated as the lost value from any outages that would occur in the absence of a microgrid, adjusted by the percent of each service provider's load that is supported by the microgrid. For example, if a microgrid project is designed to meet only 50 percent of a hospital's load, then the public health and safety benefits of that microgrid project are estimated to equal 50 percent of the lost value that would result from a loss of power to the hospital in the absence of a microgrid.

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<sup>59</sup> In some instances the FEMA methodology risks underestimating the true costs of a loss of public services. In the case of EMS, for example, the methodology only calculates the value of lives lost from cardiac arrest; due to a lack of data, it does not attempt to quantify increases in fatalities attributable to other causes.

<sup>60</sup> Examples of standard values used in the FEMA methodology include annual fire incidence per capita (national average), annual emergency department visits per capita (national average), and incidences of property or violent crimes (New York State data, listed separately for metropolitan statistical areas, cities outside of metropolitan areas, and nonmetropolitan counties).

<sup>61</sup> As a default value, the BCA model assumes that backup generators have a 15 percent likelihood of failing. This assumption is based on an estimate by the Electric Power Research Institute (Kopytoff, 2012). Users can modify this assumption by specifying an alternative failure rate.

<i>Exhibit 1: Service Categories and Benefits Estimated by the FEMA Methodology</i>	
<b>Service Category</b>	<b>Impacts Estimated</b>
Fire Service	<p>1.1.1.1.1.1.1 <i>Value of property losses due to fires, due to increased response time</i></p> <p>1.1.1.1.1.1.2 <i>Value of lives lost and injuries suffered due to fires, due to increased response time</i></p>
Emergency Medical Service	1. Value of lives lost from cardiac arrest, due to increased response time
Hospital Service	<p>1. Value of extra time spent getting to emergency department (ED) or waiting to be seen</p> <p>2. Value of extra distance traveled to get to ED</p> <p>3. Value of lives lost from acute myocardial infarction or unintentional injuries, due to increased time before ED treatment</p>
Police Service	<p>1. Tangible and intangible cost of property crimes</p> <p>2. Tangible and intangible cost of violent crimes</p>
Wastewater Service	1. Lost economic productivity due to a loss of commercial wastewater service
Water Service	<p>1. Lost economic productivity due to a loss of commercial wastewater service</p> <p>2. Welfare loss from lost residential service</p>
Electric Power Service	<p>1. Lost economic productivity due to a loss of commercial electric service</p> <p>2. Welfare loss from lost residential service</p>

Because the services listed in Exhibit 1 are of such crucial importance to society, most service providers have redundant backup generation capacity or contingency plans in place to deal with a major power outage. In cases where it is not reasonable to assume that a power outage would lead to a loss of service, the model asks users to enter the costs (both one-time costs and ongoing costs) of any emergency measures that would be implemented. This functionality also enables the model to estimate the public health and safety benefits of a microgrid project supplying providers of services not covered by the FEMA methodology, such as elder care, correctional services, and telecommunications. The BCA model estimates the health and safety benefits of a microgrid serving such facilities by calculating the total costs of emergency measures that would be

implemented in the absence of a microgrid. For all emergency costs, users can specify scaling factors to test the sensitivity of public health and safety benefits to estimates of costs.

The expected value of public health and safety benefits is dependent upon the anticipated frequency and severity of outages caused by major storms or other events that are difficult to predict. For this reason, the model treats the expected frequency and duration of major power outages as a key input to the analysis. Users can easily explore the implications of alternative assumptions about the frequency and duration of major outages on the cost-effectiveness of a particular project. The case studies explore the sensitivity of results to alternative assumptions concerning these parameters, focusing in particular on the frequency and duration of major outages that must be assumed in order for a project's expected benefits to equal or exceed its costs.

#### J.4 Spreadsheet Tool

The following images showcase some of the parameters that are captured by the spreadsheet tool, as described above. The spreadsheet as a whole is on NYSERDA's webpage at <http://www.nyseda.ny.gov/Publications/Research-and-Development-Technical-Reports/Electric-Power-Delivery-Reports.aspx>.

##### Results Summary

Cost or Benefit Category	Present Value Over 20 Years (2013\$)	Annualized Value (2013\$)
<b>Costs</b>		
Initial Design and Planning	\$0	\$0
Capital Investments	\$0	\$0
Fixed O&M	\$0	\$0
Variable O&M (Grid-Connected Mode)	\$0	\$0
Fuel (Grid-Connected Mode)	\$0	\$0
Emission Control	\$0	\$0
Emissions Allowances	\$0	\$0
Emissions Damages (Grid-Connected Mode)	\$0	\$0
<b>Total Costs</b>	<b>\$0</b>	<b>\$0</b>
<b>Benefits</b>		
Reduction in Generating Costs	\$0	\$0
Fuel Savings from CHP	\$0	\$0
Generation Capacity Cost Savings	\$0	\$0
Distribution Capacity Cost Savings	\$0	\$0
Reliability Improvements	#N/A	#N/A
Power Quality Improvements	\$0	\$0
Avoided Emissions Allowance Costs	\$0	\$0
Avoided Emissions Damages	\$0	\$0
Major Power Outage Benefits	#N/A	#N/A
<b>Total Benefits</b>	<b>#N/A</b>	<b>#N/A</b>
<b>Net Benefits</b>	<b>#N/A</b>	<b>#N/A</b>
<b>Benefit/Cost Ratio</b>	<b>#N/A</b>	
<b>Internal Rate of Return</b>	<b>#VALUE!</b>	

	Population Served by the Facility Experiencing Outage	Backup Generation Present in Baseline Scenario	Level of Service Maintained while Using Backup Generation
	People	Yes/No	Percent
Fire Services			
Emergency Medical Services			
Hospital Services			
Police Services			
Electric Services			
Wastewater Services			
Water Services			
Other Service 1:			
Other Service 2:			
Other Service 3:			
Other Service 4:			
Other Service 5:			

Emissions Allowance Price and Emissions Damages Calculations

Year	Annual Electricity Production (MWh)	Emissions (Tons/Year)					Emissions Allowance Costs*				
		CO <sub>2</sub>	SO <sub>2</sub>	NO <sub>x</sub>	PM <sub>2.5</sub>	PM <sub>2.5-10</sub>	CO <sub>2</sub>	SO <sub>2</sub>	NO <sub>x</sub>	PM <sub>2.5</sub>	PM <sub>2.5-10</sub>
2015	0	0	0	0	0	0	\$0	\$0	\$0		
2016	0	0	0	0	0	0	\$0	\$0	\$0		
2017	0	0	0	0	0	0	\$0	\$0	\$0		
2018	0	0	0	0	0	0	\$0	\$0	\$0		
2019	0	0	0	0	0	0	\$0	\$0	\$0		
2020	0	0	0	0	0	0	\$0	\$0	\$0		
2021	0	0	0	0	0	0	\$0	\$0	\$0		
2022	0	0	0	0	0	0	\$0	\$0	\$0		
2023	0	0	0	0	0	0	\$0	\$0	\$0		
2024	0	0	0	0	0	0	\$0	\$0	\$0		
2025	0	0	0	0	0	0	\$0	\$0	\$0		
2026	0	0	0	0	0	0	\$0	\$0	\$0		
2027	0	0	0	0	0	0	\$0	\$0	\$0		
2028	0	0	0	0	0	0	\$0	\$0	\$0		
2029	0	0	0	0	0	0	\$0	\$0	\$0		
2030	0	0	0	0	0	0	\$0	\$0	\$0		
2031	0	0	0	0	0	0	\$0	\$0	\$0		
2032	0	0	0	0	0	0	\$0	\$0	\$0		
2033	0	0	0	0	0	0	\$0	\$0	\$0		
2034	0	0	0	0	0	0	\$0	\$0	\$0		
2035	0	0	0	0	0	0	\$0	\$0	\$0		

### Other Cost Information

Category	Parameter	Unit
Planning	Initial Design and Planning Costs	\$
O&M Costs	Fixed O&M Costs per Year	\$/year
	<i>Check: Fixed O&amp;M Costs per MW</i>	\$/MW/
	Variable O&M Costs per Unit of Energy Produced	\$/MWh
Fuel Consumption	<i>Islanded Mode</i> : Max. period of time for operating without replenishing fuel supply	Days
	<i>Islanded Mode</i> : Fuel consumption if operating in islanded mode for full duration of design event	Gallons/Month
	Fuel costs per unit of energy produced	\$/MWh
	Fuel savings from new CHP system	MMBtu/year
	Type of fuel offset by new CHP system	
Environmental	Capital costs associated with emissions control equipment, if not included above	\$
	Lifespan of emissions control equipment, if not included above	Years
	O&M costs associated with emissions control equipment, if not included above	\$/MWh
	Other costs associated with emissions control equipment, if not included above	\$/year
Emissions Rates	CO <sub>2</sub>	Tons/MWh
	SO <sub>2</sub>	Tons/MWh
	NO <sub>x</sub>	Tons/MWh
	PM <sub>2.5</sub>	Tons/MWh
	PM <sub>2.5-10</sub>	Tons/MWh

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

### Reliability and Power Quality Information

Category	Parameter	Unit
Reliability	Baseline average frequency of service interruptions per customer (SAIFI)	events/year
	Baseline average interruption duration per customer per event (CAIDI)	minutes
	Estimated reduction in grid interruptions for microgrid customers	percent
Power Quality	Baseline frequency of power quality events (e.g., voltage sags and momentary interruptions) per year	events/year
	Estimated reduction in power quality events for microgrid customers	percent

# Appendix K County Outage Data

County Outages for Sandy, Irene, Lee & October Snow Storm  
 Totals represent the sum of outages for all four storms based on duration

County	Start Ohr	Day 1 24hrs	Day 2 48hrs	Day 3 72hrs	Day 4 96hrs	Day 5 120hrs	Day 6 144hrs	Day 7 168hrs	Day 8 192hrs	Day 9 216hrs	Day 10 240hrs	Day 11 264hrs	Day 12 288hrs	Day 13 312hrs	Day 14 336hrs	Day 15 360hrs	Day 16 384hrs	Day 17 408hrs	Day 18 432hrs	Day 19 456hrs	Day 20 480hrs	Day 21 504hrs	Day 22 528hrs
Albany	1,065	28,847	11,421	5,341	2,099	1,338	20																
Allegany	3	1,541	7																				
Bronx	9,580	38,586	33,594	28,633	25,339	21,070	9,890	7,888	4,758	3,393	3,150	2,049	706	293	17	45							
Broome	7,510	9,506	21,599	14,658	14,328	13,040	6,412	2,162	864	491													
Cattaraugus	50	165																					
Cayuga	33	1,285	214	46																			
Chautauqua	103	991	4																				
Chemung	741	1,683	2,170	946	779	41																	
Chenango	4,075	4,528	3,522	2,333	1,638	929	284																
Clinton	4,118	10,649	7,521	3,212	1,021	38																	
Columbia	3,400	8,852	5,197	894	258																		
Cortland	191	83	16																				
Delaware	6,374	10,341	7,180	4,043	2,695	1,077	1,951	225	213														
Dutchess	97,802	109,314	49,537	22,297	8,177	3,550	1,790	1,712	3,573	439	241	4											
Erie	4	420	7																				
Essex	7,049	8,132	6,949	4,641	976	466	22																
Franklin	3,291	120	74	49	49																		
Fulton	5,910	10,931	3,980	1,057	191	24																	
Genesee	53	135																					
Greene	3,279	21,294	21,242	10,099	5,640	3,257	1,395	551	183														
Hamilton	5,833	3,084	965	878	364	1																	
Herkimer	4,243	3,976	577	103	2																		
Jefferson	8	349																					
Kings	5,146	67,382	105,199	57,399	38,120	28,747	21,778	20,404	20,187	14,248	5,684	20,573	20,729	18,515	14,819	12,616	6,160	6,126	5,976	63			
Lewis	195	93																					
Livingston	4	216	10																				
Madison	1,528	481	763	233	246	40	4																
Monroe	365	18,566	6,974	3,322	1,630	546	1																
Montgomery	26,260	7,563	3,575	920	475	36																	
Nassau	112,179	523,350	564,815	506,499	424,758	322,466	274,705	157,895	104,045	72,515	98,405	116,810	66,985	60,550	43,013	9,489	5,637	1,581	1,355	971	405	132	116
New York	32	234,015	229,275	228,161	226,465	6,195	5,368	3,599	1,262	338	94	42	16	4									
Niagara	154	12	2																				
Oneida	1,112	870	62	19	18																		
Onondaga	764	315	52																				
Ontario	1	187	19																				
Orange	82,007	140,987	106,590	65,734	47,583	29,781	20,768	16,273	10,189	4,749	964	278	85	7									
Orleans	10	306																					
Oswego	224	1,450	8																				
Otsego	11,421	11,645	7,789	6,755	2,466	549	291	33															
Putnam	37,046	89,307	72,376	44,763	28,459	13,855	8,942	3,186	1,246	591	184	190											
Queens	27,022	141,997	164,492	149,045	125,402	107,489	91,462	41,941	26,901	13,262	21,025	56,815	42,189	43,864	14,313	10,718	1,673	1,044	954	250	253	219	141
Rensselaer	2,420	2,262	706	115	8																		
Richmond	19,265	87,310	121,192	87,949	53,855	42,329	24,660	16,369	12,318	3,137	4,470	13,577	11,460	9,923	6,742	3,167	1,750	1,714	1,720	18	18	1	
Rockland	45,080	132,246	106,293	102,246	75,923	53,380	43,135	30,244	15,591	12,780	6,943	2,361	342	24	19								
Saratoga	21,331	22,915	4,472	894	196	3																	
Schenectady	17,291	24,946	7,222	972	54																		
Schoharie	1,466	7,977	6,322	4,724	3,736	2,609	1,383	479															
Schuyler	58	342	256	54																			
Seneca	1	73	1																				
St. Lawrence	12	3,834																					
Steuben	421	1,410	910	149	13	1																	
Suffolk	92,765	618,385	613,545	480,780	335,599	201,600	166,775	130,000	95,951	70,165	85,626	64,609	35,967	16,984	4,258	2,601	1,995	201	74	11	42	18	
Sullivan	4,101	50,034	44,601	34,942	26,315	17,691	11,709	6,047	1,367	648	150	31	6										
Tioga	337	173	92	2																			
Tompkins	779	2																					
Ulster	45,516	102,718	70,650	42,795	28,819	18,852	8,518	5,595	8,116	47	103	14	7										
Warren	3,673	18,440	8,997	3,314	461	3																	
Washington	2,571	5,610	2,110	1,336	513																		
Wayne	3	3,306	828	219	84	60																	
Westchester	108,922	355,648	312,780	246,777	195,152	142,047	113,808	88,653	65,877	49,075	39,373	21,167	9,384	3,143	184	60							
Wyoming	4	83	4																				
Yates	2	841	82																				

## Appendix L Glossary and References

### L.1 Glossary

**Ancillary Services:** The New York Independent System Operator administers competitive markets for services that are required to support the power system. The two most important are reserves and regulation. The reserves market pays resources (e.g., generators) to be available to provide fast ramping power in the event of a unit or line trip. The regulation market pays resources to keep load and generation in constant balance by quickly adjusting their output/consumption in response to constantly changing load conditions (e.g., a large load may decrease its consumption at a time when the system experiences low voltage, thereby restoring adequate voltage on the line).

**Backfeed:** Flow of electricity in the opposite direction from usual flow.

**Black start capability:** A black start is the process of restoring a power generating system to operation without relying on the external electric power transmission network.

**Building Energy Management Systems:** A software control application that enables facility managers to configure, monitor, and automate HVAC, lighting, and programmable building devices.

**Bulk energy** (as in, bulk energy suppliers or bulk energy system): Bulk energy refers to power bought or sold on the wholesale energy market, defined below.

**Capacity market:** A market administered by the New York Independent System Operator designed to pay for sufficient resources (including traditional electric generators, but also demand response resources) to ensure that projected loads can be met on a long-term basis. This market matches buyers and sellers of capacity using the clearing price methodology.

**Demand Response:** The New York Independent System Operator supports a number of programs designed to pay customers to undertake voluntary reductions of their load in a given location based on price and reliability signals.

**Deployment costs:** Deployment costs are a component of overall system costs. Deployment costs refer specifically to costs incurred in order to field the software or hardware components in the target system.

**Distributed Energy Resource (DER):** smaller-scale power generation or storage. It is also known as Distributed Resources or Distributed Generation.

**Distributed Generation (DG):** A generally small (up to 20 MW) electric production facility that is dedicated to the support of nearby associated load.

**Generation Controller:** A hardware platform or software application that manages power generation components.

**Hierarchical control scheme:** A control scheme that distributes control authority and control actions vertically across layers. Usually a top layer, called master control, orchestrates the overall system control. Mid-tier layers coordinate groups and report back to the master control layer. The lowest layers control remote nodes in the system.

**Loop distribution system:** A loop system, as the name implies, loops through the service area and returns to the original point. The loop usually ties into an alternate power source. By placing switches in strategic locations, the utility can supply power to the customer from either direction. See, by contrast, network and radial distribution systems.

**Microgrid Controller:** A hardware platform or software application that manages devices and operations in a Microgrid system.

**Microgrid System Architecture:** The end-to-end structural design and partitioning of a complete microgrid system. Defines the structure of hardware and software components, data, and interfaces.

**Network distribution system:** Network systems are the most complicated distribution systems, as compared to loop or radial distribution systems. They can be thought of as interlocking loop systems. A given customer can be supplied from two, three, four, or more different power supplies. This system will provide the highest power reliability, and is more common in high load density or urban areas. See, by contrast, radial and loop distribution systems.

**PACE Finance:** Property Assessed Clean Energy Financing. This mechanism allows financing of energy efficiency upgrades or renewable energy installations for buildings. Municipal governments will offer a specific bond to investors and then loan the money to consumers and businesses to put towards an energy retrofit. The loans are repaid over the assigned term (typically 15 or 20 years) via an annual assessment on their property tax bill.

**Peak load support:** refers to the ability of generation assets to provide power during hours when energy demand is at its highest across a system. A microgrid may provide peak load support to the macrogrid, e.g., by exporting power onto the macrogrid when the macrogrid is facing its highest demand period.

**Power quality:** The quality of electrical power may be described as a set of parameters, such as the continuity of the power service, or variations in voltage magnitude, under which electrical devices taking power off the system can function properly.

**Pre-paid Power Purchase Agreement (PPA) model:** A power purchase agreement is a type of financing where a third party owns and maintains the DER system, and the end user agrees to pay for that power over a given term (often 15-20 years). Sometimes, a PPA provider will offer the end user the option to pre-purchase all the energy the user is likely to require upfront in exchange for a particularly low rate.

**Radial distribution system:** This distribution system connects multiple users to a single source of power. The distribution system runs from the power source and terminates at the end users, meaning any power failure on that line would cut off power supply to those customers. This system is widely used in sparsely populated areas. See, by contrast, network and loop distribution systems.

**Switching infrastructure:** The components in the electrical design that control and implement connect/disconnect/routing functions.

**System integration:** Part of the overall system design process, referring to the testing and validating of the interoperability of the various software and hardware components that compose the system.

**Transfer trip:** A transfer trip is a protection system that sends a trip command to remote circuit breakers when an electrical fault is detected, thereby helping isolate and clear the fault.

**Transmission and Distribution (T&D) investment deferral:** Electric transmission and distribution systems require periodic upgrades in order to meet increasing demand. T&D investment deferral refers to the benefit microgrids may provide to the utility by reducing the load that the utility must serve in a given area, thereby potentially allowing the utility to make less short-term investment in upgrading its distribution system in that area.

**Urban secondary network system:** A secondary network system refers to the low-voltage circuits supplied by the network units (the network transformer and its associated network protector).

**Urban spot network:** A secondary network distribution system that consists of two or more network units at a single site. The secondary network-side terminals of these network units are connected together with bus or cable. The resulting interconnection structure is commonly referred to as the paralleling bus or collector bus. In spot networks, the paralleling bus does not have low-voltage ties to adjacent or nearby networks. Such spot networks are sometimes called isolated spot networks to emphasize that there are no secondary voltage connections to network units at other sites.

**Utility tie point, or, point of common coupling:** The point at which the interconnection between the electric utility and the customer interface occurs.

**Wholesale energy market:** A market for the sale of large quantities of electricity (1 MW or greater), which is provided from high-voltage transmission lines. This market is operated by the New York Independent System Operator, and provides power to registered market participants, which include investor-owned utilities.

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