Microgrids for Critical Facility Resiliency in New York State

Final Report Summary

December 2014

Report Number 14-36s

New York State Department of Public Service Commission

nyserda Energy. Innovation. Solutions.

Division of Homeland Security and Emergency Services New York State

Microgrids For Critical Facility Resiliency in New York State

Final Report Summary

Prepared for:

New York State Legislature

Albany, NY

Prepared by:

New York State Energy Research and Development Authority

Albany, NY

and

New York State Department of Public Service (DPS)

Albany, NY

and

New York State Division of Homeland Security and Emergency Services (DHSES)

Albany, NY

NYSERDA Report 14-36s

December 2014

Notice

This report was prepared by the New York State Energy Research and Development Authority (NYSERDA), the New York State Department of Public Service (DPS), and New York State Division of Homeland Security and Emergency Services (DHSES) (hereafter the "Sponsors"). The opinions expressed in this report do not necessarily reflect those of the Sponsors or the State of New York, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, the Sponsors and the State of New York make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. The Sponsors and the State of New York make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

The Sponsors make every effort to provide accurate information about copyright owners and related matters in the reports they publish. If you are the copyright owner and believe a NYSERDA report has not properly attributed your work to you or has used it without permission, please email print@nyserda.ny.gov

Table of Contents

List of Figures

List of Tables

1 Background

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."[1] 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 Legislation specifically posed the following questions:

- 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 2011 and 2012, the two years prior to the effective date of this Legislation[2].
- The regulatory structure under which microgrid systems would operate.
- How the operation of microgrids would conform with the current requirements of utilities to provide safe and adequate service to ratepayers.
- 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.
- The technical and regulatory aspect of how a microgrid will be interconnected to the power grid.
- 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.
- 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.

NYSERDA, DHSES, and the DPS (the Project Team) endeavored to fulfill the Legislature's mandates while also broadening the effort to study several specific sites where microgrids ensuring critical infrastructure might flourish. The Project Team performed engineering and cost-benefit analyses at each site to accurately inform the report's findings and recommendations. Details on these sites and the process to select them follow in this report summary.

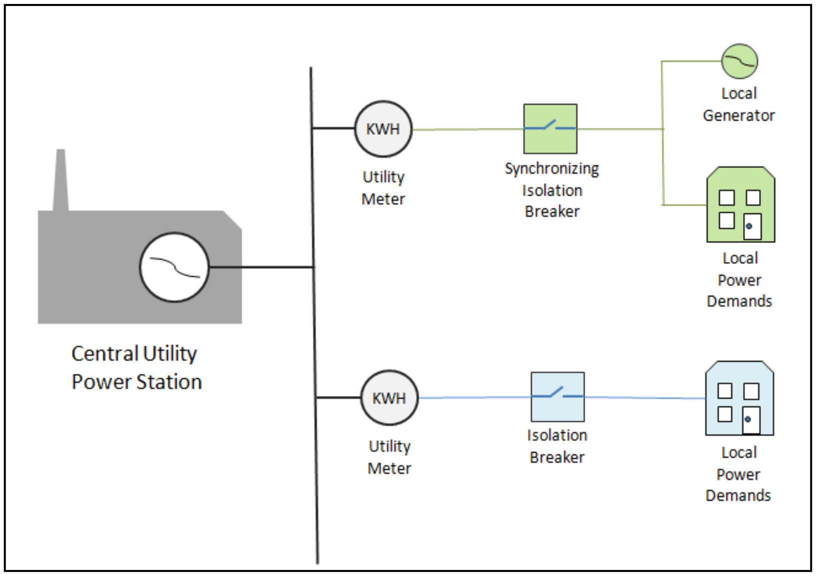
1 Budget Bill 2013 NY A.B. 3008, Part T. See Appendix F
2 Ibid.

2 What is a microgrid?

A microgrid is essentially a self-sustaining, small electric grid with its own generation resources and internal loads that may or may not be connected to the larger (utility) macrogrid.

Figure 1. 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.



There is no standard, 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."

Microgrids can help minimize the impact of outages by localizing power generation, distribution, and consumption so that a fallen tree or downed wire miles away will not interrupt critical services elsewhere.

3 How did the project team select study sites?

To test the microgrid concept against potential sites representing a variety of different kinds of infrastructure, environments, and interconnection conditions, 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.

DPS provided power outage data over a 24-month period that covered calendar years 2011 – 2012. This 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 6 days (144 hours). 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 most significant criteria in selecting sites were the number and density of critical infrastructure (CI) facilities at each nominated site. The specific sites selected and evaluated in each County are:

- **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 SUNY Broome campus, and the Elizabeth Church Nursing Home facilities.
- **Nassau County:** Critical infrastructure cluster including the Cedar Creek Water Pollution Plant, the Wantagh FD 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.

4 What types of microgrid projects may be implemented?

Because there is not industry-accepted definition of a microgrid, the Project Team identified several different parameters on which to identify microgrid "typologies," including:[3]

- Generation types (i.e., distributed generation technologies).
- Loads/Customers types.
- Interconnection arrangement with the macrogrid.
- Ownership structures.

Common generation types that are able to serve the base load of a microgrid include gas turbines, reciprocating engines, microturbines, and steam turbines. A microgrid may also employ emergency generators and intermittent generators, which include renewable power sources such as wind and solar. More information on these generation types is included in Section 2.1 of the full report.

The loads and customers that a microgrid serves may be distinguished by the number and relation of the customers served by the microgrid. For example, single-customer microgrids like Cornell University may present a much simpler regulatory regime for developers, while microgrids that connect together multiple unrelated customers, such as the Burrstone LLC microgrid in Utica, NY, may present a more complicated picture. More information on loads and customer types is included in Section 2.2 of the full report.

The types of interconnection arrangements with the macrogrid that may be used refers to the interplay between microgrid infrastructure and the existing utility infrastructure surrounding the microgrid. More information on interconnection is included in Section 2.3 and Section 5 of the full report.

Microgrids can also 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. More information on ownership structures is included in Section 2.5 and Section 7 of the complete report.

[3] While these parameters are the primary focus of this study, they are not necessarily exhaustive.

5 How will microgrids interact with utility requirements?

There are several ways that the New York State Public Service Commission (PSC) may require microgrid sites to provide safe and adequate service to ratepayers, as utilities are required to do under New York State Public Service Law (PSL).

The Public Service Commission may consider the microgrid a stand-alone utility and thus subject to all of the provisions of Article 4. These provisions are discussed in Section 3.1 of the report. 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. The pathways under which this may be achieved are discussed more thoroughly in Section 4.2 of the complete report.

Providing direction and guidance in this area is a major focus of the current Reforming the Energy Vision (REV) proceedings currently underway at the PSC.

6 What regulatory structure will microgrids operate under?

The Project team separately considered the type of regulatory structure a utility microgrid and a nonutility microgrid would likely operate under. A utility microgrid includes those microgrids that operate on utility-owned wires and, potentially, utilize utility-owned generation and other distributed energy resources (DERs). A nonutility microgrid is one that operates on privately-owned wires and utilizes privately-owned generation and other DERs.

6.1 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 model 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 New York Public Service Law and the PSC. Utility microgrids will 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.

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." More discussion of the VMPP is included in Section 4.1 of the full report.

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 standby rates, net-metering laws, and buy-back tariffs.

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. In New York, standby rates consist of three distinct charges: customer charges, contract demand charges, and daily as used demand charges. These charges are discussed further in Section 4.1.2.1 of the full report.

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. New York has enacted legislation allowing eligible farm-based and nonresidential customer-generators to engage in "remote" net metering of solar, wind, hydroelectric, and farm-based biogas systems. Remote net metering permits eligible customer-generators to designate net metering credits from equipment located on property that 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. Net metering is discussed further in Section 4.1.2.2 of the full report.

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 at the Locational Based Marginal Price (LBMP) set by the New York Independent System Operator (NYISO). This reflects the wholesale price of energy offered to generators that sell power through NYISO's bulk power markets at the transmission level. Buyback tariffs are discussed in Section 4.1.2.3 of the full report.

Consolidated Edison has filed an "offset" or "campus-style" 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 can make 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. This tariff is discussed further in Section 4.1.2.4 of the full report.

6.2 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.

For nonutility microgrid developers, the fundamental regulatory question is whether a proposed microgrid would be considered an electric or steam plant under NY Public Service Law. As currently codified, PSL provides two exemptions from electric plant consideration:

1. "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").[4]
2. "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").[5]

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.

To achieve QF status 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."[6] The related facilities standard leaves at least two pieces of statutory ambiguity. The first issue is the requirement that distribution infrastructure is located "at or near" the generation source of the facility does not clearly indicate what geographic limits apply to a QF. The second issue is the open-ended term "users" in the definition of "related facilities" does not clearly indicate how many previously unrelated users may be served by a QF.

---

4 PSL §§ 2(2-d).

5 Ibid.

6 Related facilities include "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." NY CLS Pub Ser **§** 2-d.

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. 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 2 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.

If a microgrid provides service only for the use of one landowner or the use of their tenants, it will be able to seek regulatory relief under the landlord-tenant exemption. This exemption might potentially yield broader application than the QF status when the land on which power is distributed is united under common ownership, as discussed in the full report.

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:[7] 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.

Besides the category of regulatory regime that will apply to them, nonutility microgrids face an assortment of other regulatory questions. The microgrid may be deemed a "provider of last resort" by the PSC. If so, it may be subject to an obligation to serve a group of customers. The obligation has yet to be imposed on a microgrid.

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. 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.

---

[7] Subcommittee on Microgrids and Community Grids. 2014. Draft Final Report Reforming the Energy Vision, Working Group 2: Platform Technology,.

Microgrids that use cogeneration technology distribute thermal energy and, therefore, may also 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."[8] 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. In determining whether a cogeneration plant will qualify for regulatory exemption as a steam corporation, a comparable analysis to electric regulatory exemption can be undertaken.

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, for example, the PSC approved a lightened regulatory regime for the project.[9] 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. 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 electrically islanded site that nevertheless extends over several square miles.[10] 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.

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. The legal standards for determining whether the customer receiving service or the utility pays for upgrades to the natural gas system are discussed in Section 4.3.1 of the full report.

---

[8] PSL § 2(21).

[9] 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).

[10] 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).

7 How will microgrids interconnect with the utility system?

In order to install any form of distributed energy resources (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 (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 megawatts (MW) in size. 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.

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. The Working Group and its recommendations are discussed in Section 5.1 of the full report.

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.

A different set of technical requirements will impact the microgrid when it transitions into islanded mode, including:

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

The remainder of this section provides brief descriptions of some of the concerns created by microgrid interconnections.

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 want the rest of the grid is protected from any overcurrent that is created by the microgrid.

Safety: Microgrids must be carefully designed so as not to introduce additional safety hazards during 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 are a hazard to the public.

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.

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 able to absorb all of the loads that may draw power off of the system without substantially dipping or producing irregularities.

Metering and Monitoring: In many scenarios, monitoring is required for control and/or synchronization purposes. 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.

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.

Black Start: Most microgrids will need black-start capability, the ability to energize the microgrid from a de energized state, without help from an external source. 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 after the fault is cleared.

8 What types of interconnection scenarios might microgrids exist in?

The particular safety concerns and technical requirements required to interconnect a microgrid will depend heavily on what kind of DERs are within that microgrid, and what kind of utility distribution system the microgrid is interconnecting with. The type of utility distribution system the microgrid will interconnect with will depend heavily on the environment the microgrid is in, e.g., rural, suburban, and urban. The Project Team broke down microgrid interconnection scenarios, and descriptions of each microgrid style follow later in this section:

- In a rural or suburban setting, the microgrid is likely to be interconnecting with:
  - Radial distribution systems: 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.
  - Loop distribution systems: A loop system, as the name implies, loops through the service area and returns to the original point or another source of power. 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.
  - Types of microgrid configurations that would be suitable to interconnection with radial and loop distribution systems include campus style microgrids (simple), campus style microgrids with multiple generation sources, utility microgrids serving neighboring loads, and microgrids running a parallel electrical system.
- In urban environments, the microgrid is likely to be interconnecting with:
  - Spot networks: This category of 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.
  - Grid networks: This category of networks use a grid of interconnected secondary conductors. 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.

Microgrid styles include:

- 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.
- Campus style microgrid (multiple generators): This variation on the campus model locations helps improve reliability, but operations and control are more difficult.

- Neighboring loads in a utility microgrid: 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. It shares most of the benefits from the simplicity of a campus design.
- 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*—Because it does not rely on existing utility infrastructure, the microgrid can be arranged and designed to best match critical infrastructure with local generation. This includes system sizing, wiring arrangements, and choice of supply voltages.
    - *Interconnection issues*—Many interconnection issues can be avoided by being completely separate from the utility system.
- Spot network microgrids: A spot network microgrid arrangement is more complicated than a basic radial system as there are multiple connection points to the utility system which 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.
- Grid network microgrids: A grid network microgrid arrangement is more complicated than a typical spot network configuration. 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.

These scenarios are each explored in Sections 5.3 and 5.4 of the full report.

9 How will microgrids operate in emergency conditions?

In order to have continuity of service, reliability, and resilience in a microgrid, several common concerns must be addressed:

- Adequate generating capacity: In order to compensate for the loss of utility service, 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. A common basis of design is called: "N plus One Redundancy (N+1)." This design means providing enough generators to meet peak loads even when the largest generator is out of service.
- Ability to identify 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.
- Maintaining uninterrupted service: 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. The technical requirements to maintain this level of service are described in Section 6.2.3 of the full report.
- Black start capability: 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 or small generator.
- 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 automatic operation of breakers. The technical requirements for load restoration are discussed in Section 6.2.5 of the full report.
- 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.

Some best practices for maintaining high availability and reliability within a microgrid are described in Section 6.5 of the full report. These include:

- Establishing a preventive maintenance program: Equipment manufacturers provide recommendations about periodic maintenance activities to keep equipment in good running order. This maintenance 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.
- Providing 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. Manufacturers should be required to provide at least one paper and one searchable digital copy of Operations and Maintenance manuals.

- Procuring consumable supplies and specialized tools: At least one year of consumable parts should be purchased with all new equipment. Specialized tools should be purchased as required for equipment maintenance performed by operators or in-house maintenance personnel.
- Fully commissioning 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.
- Regularly retesting everything that is not continuously operated: Equipment components can fail even with limited use. 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.
- Procuring multiple fuel options: Fuel supplies can be interrupted for various reasons. Providing multiple fuel options could involve use of separate generators that run on different fuels. 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.
- Providing periodic maintenance to all mechanical equipment: All energy systems require monitoring and maintenance to assure that they will perform as anticipated when they are called on. Good recordkeeping and prompt resolution of problems are at the heart of all proper maintenance programs. Section 6.5.10 of the full report provides best practices for maintenance of photovoltaic systems, battery systems, fuel cells, and flywheel energy storage.

10 What costs, benefits and ownership models of microgrids?

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.

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.

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 will still be created, but it will 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.

Microgrid benefits can be grouped into five main categories:

- **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 will directly accrue to the microgrid users, the utility, or society in general (Table 1).

Table 1. Microgrid Benefit Accrual

Benefits	Users	Utility	Society
Energy benefits	☑	☑	
Reliability benefits	☑	☑	☑
Power quality benefits	☑	☑	
Environmental benefits			☑
Safety health and security benefits	☑		☑

These benefits are discussed in greater detail in Section 7.2 of the full report.

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 2 lists the cost elements of each cost category and ascribes to whom these costs may accrue. These costs are discussed further in Section 7.3 of the full report.

Table 2. Microgrid Cost Accrual

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

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. 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.

Table 3 lists attributes favoring a successful microgrid project. 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. 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.

When delineating the various types of microgrid ownership models, a variety of relevant factors come into consideration. On one hand, an important first-order consideration is ownership of the microgrid's distribution facilities. Are the distribution assets used those of 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 non-utility owns the generation assets it is referred to as the "hybrid" utility ownership model.

Table 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	Overal 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

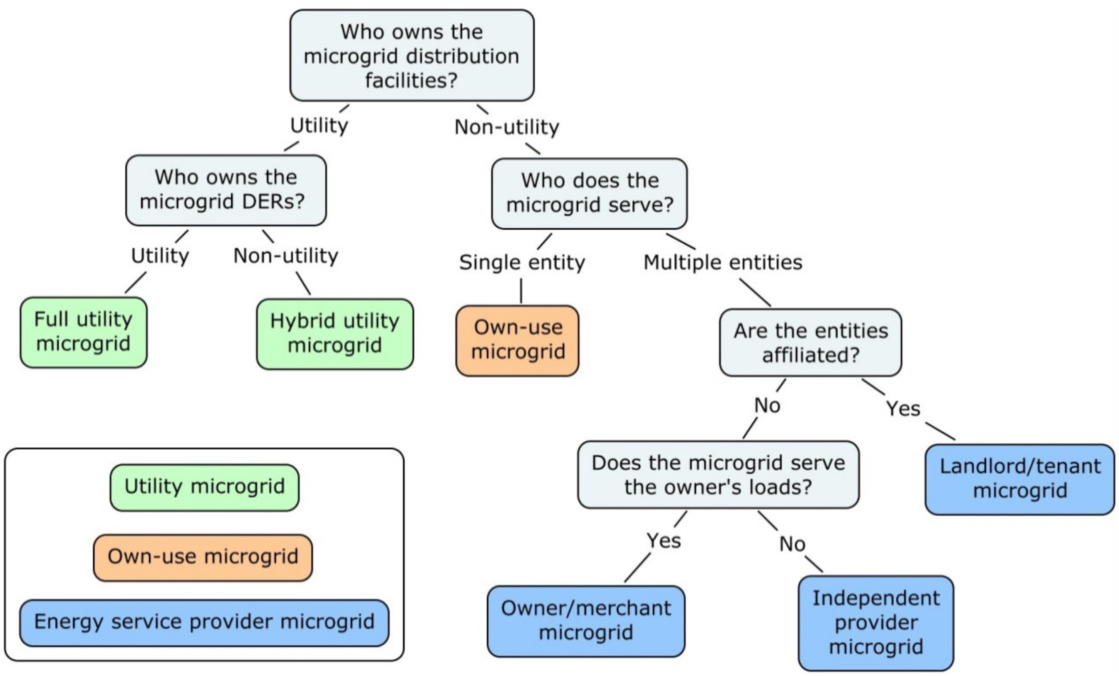
On the other hand, if a nonutility owns the distribution assets then the next set of relevant parameters consider whether one or many entities are served by the microgrid. For microgrids that serve multiple entities, the affiliation of these multiple entities is relevant. For example, microgrid users 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 2 maps the parameters that differentiate these models. These models are each discussed in more detail in Section 7.5 of the full report.

Figure 2. Ownership Model Typology



11 How are costs recovered under different ownership models?

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.

Utility cost recovery mechanisms include:

- General rate base: the utility may 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.
- Alternative tariffs: 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.
- Supplemental delivery charges: 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.

Nonutility cost recovery mechanisms include:

- Net Present Value (NPV) 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.
- Selling energy services: 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). These methods are described in more detail in Section 7.7.2.2 of the full report.
- Macrogrid benefits compensation: Microgrids may be compensated for services that they provide the macrogrid through ancillary services payments, demand response payments, and transmission and distribution investment deferral compensation. These mechanisms are discussed in Section 7.7.2.3 of the full report.

12 What should the benefit-cost analysis for microgrids include?

An exhaustive search of the professional literature revealed that no model currently exists for microgrid benefit-costs analysis including public safety, health, and security. So the project team developed a comprehensive cost benefit analysis model and then applied it to the five case studies to test feasibility in New York City and Broome, Nassau, Rockland and Suffolk Counties.

The benefit cost analysis (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 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 that 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.[11]

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.[12]
- **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.

---

[11] 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.

[12] 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.

- **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.

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 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.[13]

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 safety, health and security benefits, is provided through the case studies included in Appendices C through G of the full report. Brief synopses of the case studies are found in Appendices A through E of this report summary.

[13] 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.

Appendix A: Broome County Case Study

The Broome County Microgrid focused on three sets of facilities:

- **Broome County's Public Safety Facilities (PSF),** 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, which together account for about 35% of SUNY Broome's load.
- **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.

The facilities the microgrid would serve are currently equipped with a variety of emergency generators, which are listed in Table A.1.

Table A.1. Existing Generation Resources at Broome Site

Plant	Capacity
PSF Main	1,500 kW
PSF Secondary	123 kW
SUNY Main	100 kW
UNMH gen-1	375 kW
UMNH gen-2	375 kW
Total	2,473 kW

The Broome Site is special because it appears to have no need for any new generation resources. The microgrid design for the Broome County site incorporates the five diesel generators noted in Table A.1, providing sufficient generating capacity to meet estimated peak demand during a major power outage. Load estimates, incorporating a 20% emergency premium, are given in Table A.2.

Table A.2. Broome Site Load

Load Name	Scaled Average (kWh/Day)	Hourly Peak (kW)
PSF	11,584	927
SUNY Broome + UMNH	20,623	1366
Total	32,207	2,293

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 focused 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.

Figure A.1 shows existing generation and overlays all new control and communications infrastructure in the modeled microgrid. Cost estimates for this microgrid were given low, average and high values, and are summarized in Table A.3.

Figure A.1. Broome County One-line Interconnection Diagram

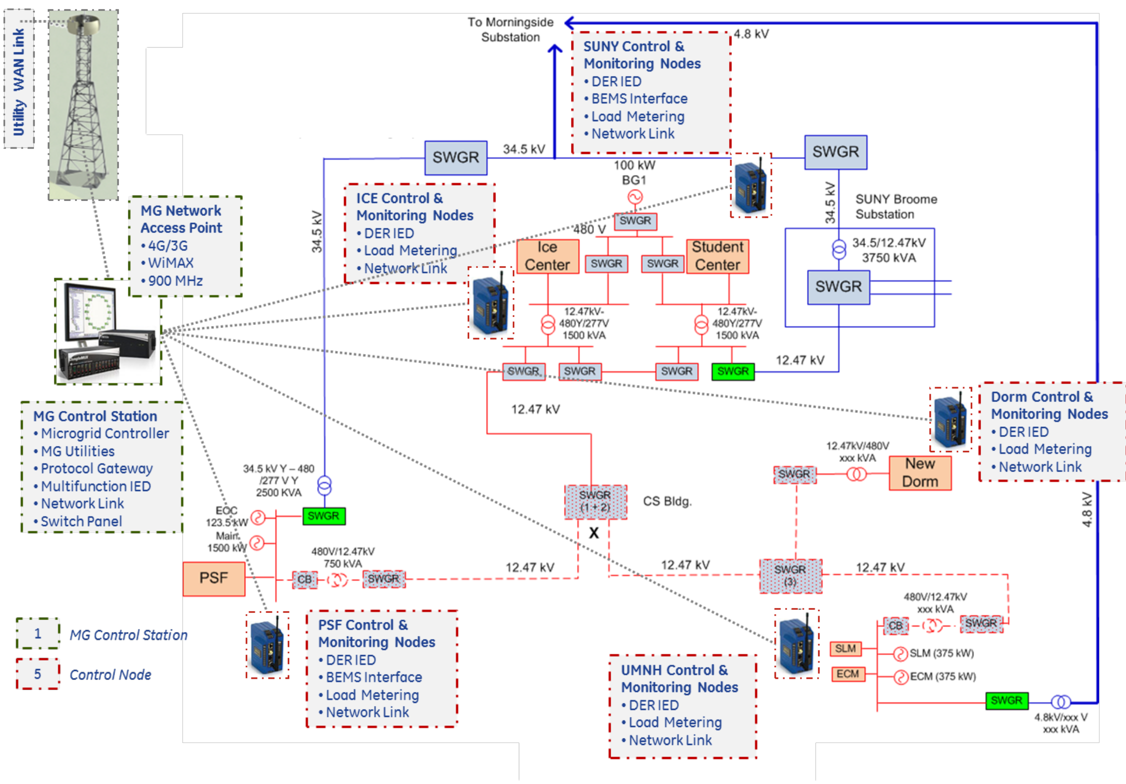


Table A.3. Cost Estimates for Broome County Microgrid

Microgrid Cost Estimates	Low Estimate	Medium Estimate	High Estimate
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

Cost benefit analysis took into account the following variables:

- Initial design and planning costs, approximately $2.7 million.
- Capital costs, approximately $1.3 million.
- Fixed O&M costs, approximately $45,000 per year.
- Variable O&M costs at $19.75 per MWh, plus fuel costs at approximately $286 per megawatt-hour (MWh).
- Reliability benefits of $37,000 per year.
- Demand response payments of $143,000 per year.

The analysis of the Broome County site indicate 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, i.e., a 100% probability of an outage between 8 and 27 days, depending on the cost and peak load support scenario.

Appendix B: NYC Case Study

The NYC Microgrid focused on three sets of facilities:

- **MHC**: Metro Hospital Center.
- **NYCHA**: New York City Housing Authority's Lexington and Washington complexes.
- **VZ**: Verizon Central Office.

Table B.1 matches existing generation at the NYC site (three generators at Metro Hospital and one the Verizon compound) with six new diesel generators proposed to make up the gap to meet critical load. This generation scenario was used to perform cost-benefit assessment (CBA).

Table B.1. NYC Site Generation Performance

Generation	Capacity (kW)	Capital Costs	Production (kWh/Month)	Capacity Factor	Fuel Consumption (Gallons/Month)	O&M Costs ($/Month)	Fuel Costs ($/Month)	Total Variable Costs ($/Month)
Verizon	750	N/A	547,500	100.0%	39,297	9,308	119,521	128,829
Metro-1	600	N/A	299,900	68.5%	21,526	5,098	65,477	70,575
Metro-2	675	N/A	296,156	60.1%	21,257	5,035	64,655	69,689
Metro-3	750	N/A	515,428	94.1%	36,995	8,764	112,521	121,285
New Diesel 1	750	637,500	381,208	69.6%	27,362	6,487	83,225	89,712
New Diesel 2	750	637,500	214,057	39.1%	15,364	3,643	46,735	50,378
New Diesel 3	500	425,000	323,346	88.6%	23,208	5,517	70,589	76,106
New Diesel 4	500	425,000	249,743	68.4%	17,925	4,290	54,521	58,811
New Diesel 5	500	425,000	133,483	36.6%	9,581	2,315	29,142	31,456
New Diesel 6	375	318,750	144,845	52.9%	10,396	2,750	31,622	34,372
Total	6150	2,868,750	3,105,666	69.2%	222,912	53,205	678,008	731,213

Another diesel generation scenario, which assumed replacing older existing generators, was also explored by the team, but was not used as the basis of cost-benefit analysis, due to there being no plan to replace these existing units at present.

Further additional scenarios also included solar installations and CHP. Table B.2 describes the solar potential for the NYC site, as determined by Sungevity.

Table B.2. 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
Total PV Potential (kW DC)	1,096.3

Metro Hospital would likely be a poor candidate for CHP, given its ability to purchase power at low NYPA rates (leading to a 15+-year payback period), the inflexibility of natural gas start-up time preventing it from replacing diesel backups, lack of available space, and tight facilities budgets and staffing levels.

Figure B.1 shows new and existing diesel generation from the chosen scenario and overlays the control and communications infrastructure in the modeled microgrid.

Figure B.1. NYC One-line Interconnection Diagram

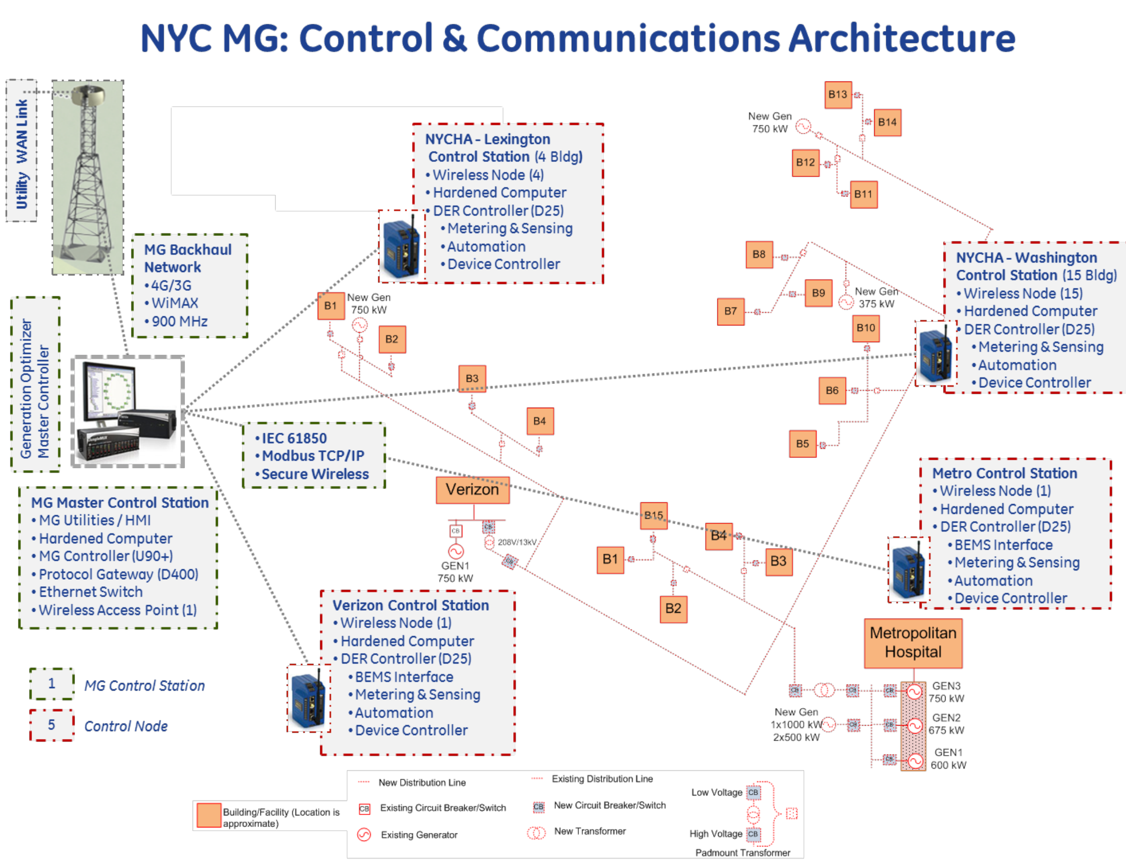


Table B.3 gives low, medium and high cost estimates were prepared for the NYC microgrid, including costs for maintenance and support, new electrical infrastructure, generation, control and communications, engineering and construction, management, certification, communications and management systems.

Table B.3. Cost Estimates for NYC County Microgrid

Microgrid Cost Estimates	Low Estimate	Medium Estimate	High Estimate
Total MG One-Time Cost	8,736,000	10,622,000	12,507,000
Annual MG O&M Cost	41,000	45,000	50,000

The CBA 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. That is, 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.

Appendix C: Rockland Case Study

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. Table C.1 lists the facilities to be incorporated in the microgrid and the existing generation resources at each facility.

Table C.1. Rockland Site Facilities and 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 – 8,000 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 – 2,000 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 Natural Gas Generator
Verizon Building	200 kW, Diesel Generator, 4,000 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.

For load analysis purposes, these facilities were placed into two groups. Table C.2 measured the peak critical demand for the Rockland site, with and without an emergency 20% premium.

Table C.2. Peak Critical Demand for the 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
Total	1,815	2,178

Figure C.1 shows new and existing generation from the proposed microgrid design and overlays the control and communications infrastructure.

Figure C.1. Rockland One-line Interconnection Diagram

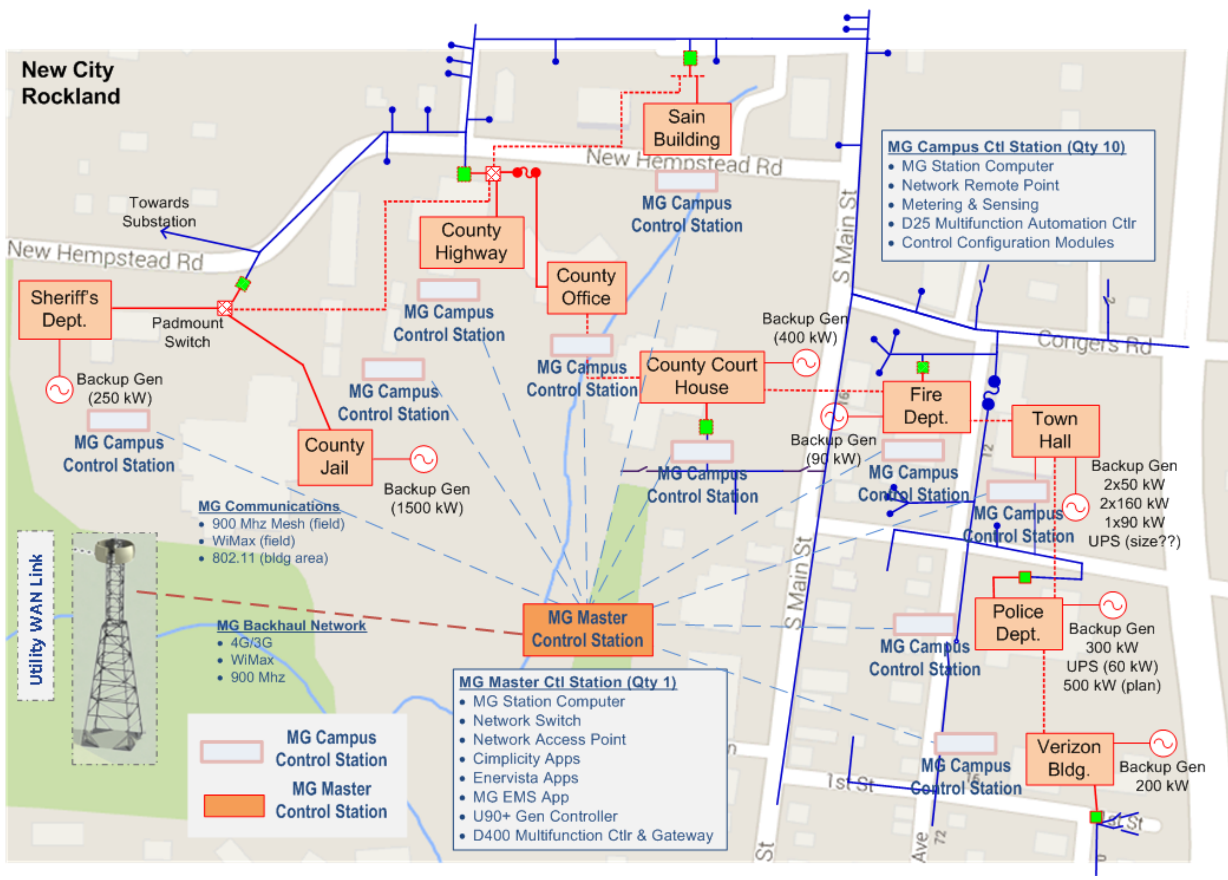


Table C.3 provides one-time and continuous cost estimates measurements for the microgrid, based on low, medium and high estimates.

Table C.3. Cost Estimates for Rockland Microgrid

Microgrid Cost Estimates	Low	Medium	High
Total MG One-Time Cost	3,149,000	4,014,000	4,879,000
Annual MG O&M Cost	38,000	43,000	47,000

BCA analysis indicates that without participation in some type of demand response program, the benefits of the Rockland 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. That is, 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.

Appendix D: Suffolk County Case Study

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. Table D.1 lists the facilities to be incorporated in the microgrid, the proposed generation to be sited at each, and its performance metrics over a one-month period.

Table D.1. 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
Total	12,095	2,304,136	26.1%	165,432

For load analysis purposes, these facilities were placed into two groups. Table D.2 measured the peak critical demand for the Suffolk site, with and without an emergency 20% premium.

Table D.2. Total Demand for Suffolk 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
Total	6,004	7,205

Figure D.1 shows new and existing generation from the proposed microgrid design and overlays the control and communications infrastructure. Table D.3 shows low, medium and high microgrid cost estimates.

Figure D.1. Suffolk County One-line Interconnection Diagram

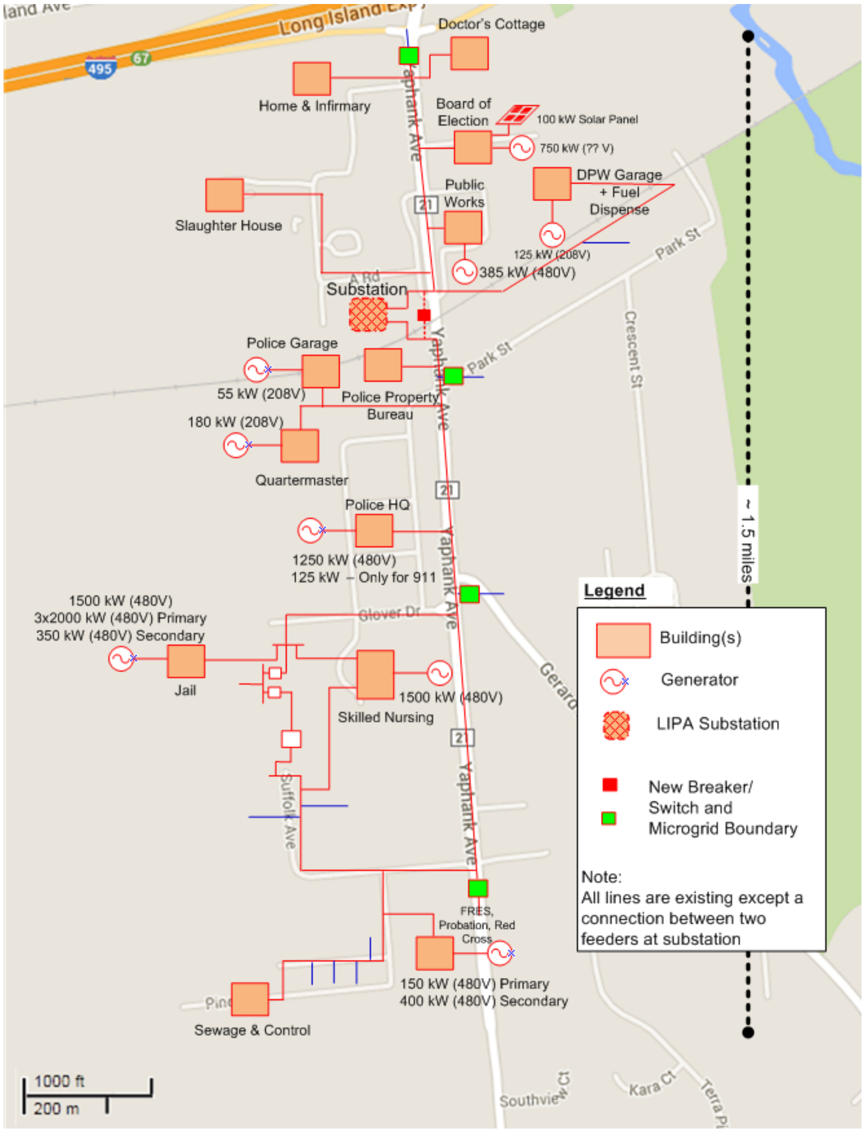


Table D.3. Cost Estimates for Suffolk County Microgrid

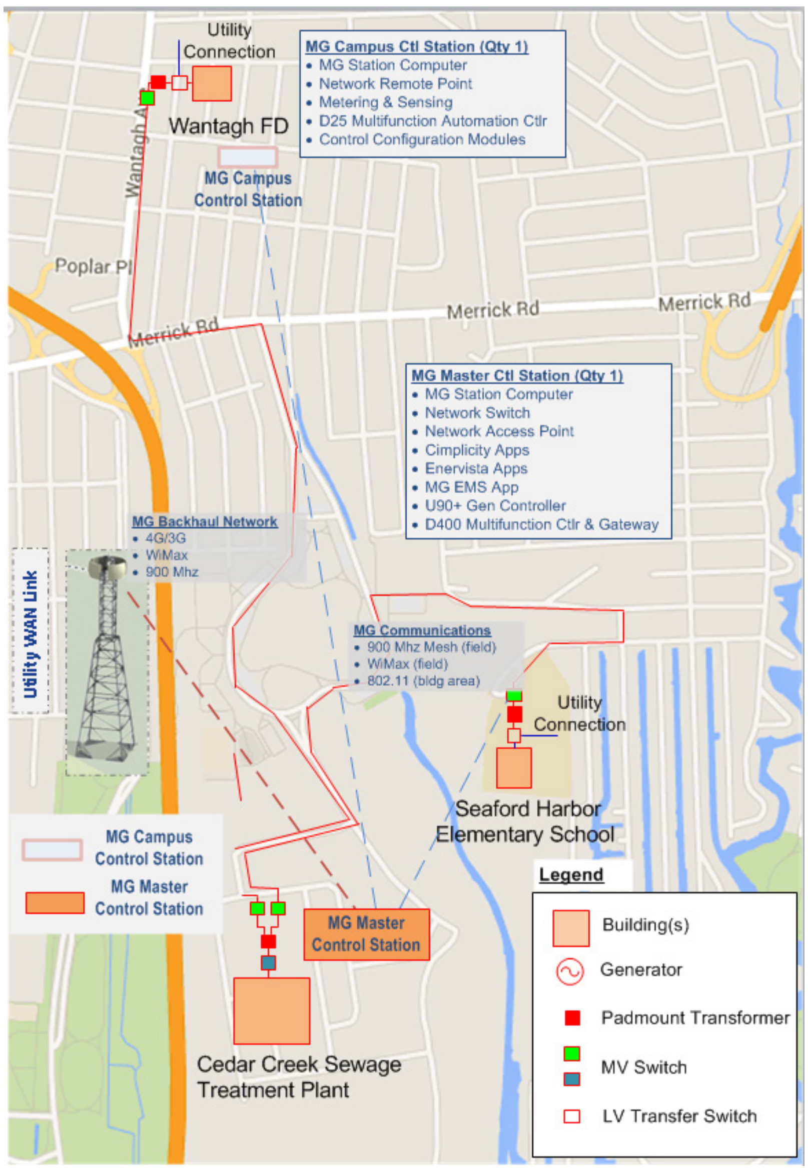
Microgrid Cost Estimates	Low	Medium	High
Total MG One-Time Cost	$2,747,000	$3,566,000	$4,389,000
Annual MG O&M Cost	$91,000	$101,000	$113,000

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, 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.

Appendix E: Nassau County Case Study

The Nassau County site consists of three facilities within the adjacent communities of Wantagh and Seaford—the Cedar Creek Wastewater Treatment Plant, the Wantagh Fire Department Administration building, and the Seaford Harbor elementary school. The wastewater treatment plant is a self-powering facility that uses a utility connection for backup only. The plant holds five on-site generators totaling 15 MW with three used in normal operation (N+2 redundancy). The daily peak is approximately 6 MW leaving ample excess capacity. The fire department administration building also contains a 130 kW back-up generator. Figure E.1 shows the site configuration.

Figure E.1. Site Configuration for Nassau County



The feasibility analysis considered two microgrid scenarios. Scenario 1 is a "high" estimate where dedicated distribution lines and equipment connect the treatment plant to the administration building and school. Scenario 2 is a "low" estimate that includes only connecting the elementary school to the treatment plant's excess generation. Table E.1 presents the cost estimates for each scenario.

Table E.1. Two Microgrid Scenarios for Nassau County

Scenario 1 (High)	
EI Cost	$426,000
C&C Cost	$493,000
Total Fixed Cost	$919,000
Total Variable Cost/Month	$8,000

Scenario 2 (Low)	
EI Cost	$221,000
C&C Cost	$218,000
Total Fixed Cost	$439,000
Total Variable Cost/Month	$5,000

The BCA analysis indicates that the breakeven conditions for the project site are less extreme than other sites analyzed due in large part to the system's lower capital costs since no new generation is needed. The cost effectiveness also relies on the large benefit created by maintaining electric service to the elementary school during a major power outage. 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 for Scenario 1; this figure declines to 0.35 for Scenario 2. Finally, 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.

Appendix F: 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

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and funding to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

To learn more about NYSERDA's programs and funding opportunities, visit nyserda.ny.gov or follow us on Twitter, Facebook, YouTube, or Instagram.

New York State Energy Research and Development Authority

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov

New York State Department of Public Service

3 Empire State Plaza
Albany, NY 12223-1350

telephone: 518-474-7080

dps.ny.gov

New York State Division of Homeland Security and Emergency Services

1220 Washington Avenue
State Office Campus, Building 7A Suite 710
Albany, NY 12242

telephone: 518-242-5000

dhses.ny.gov

Microgrids for Critical Facility Resiliency in New York State

Final Report Summary
December 2014

Report Number 14-36s

State of New York
Andrew M. Cuomo, Governor

New York State Energy Research and Development Authority
Richard L. Kauffman, Chair | John B. Rhodes, President and CEO

New York State Department of Public Service
Audrey Zibelman, Chair

New York State Division of Homeland Security and Emergency Services
Jerome M. Hauer, Ph.D., MHS, Commissioner