



NYSERDA

Evaluation of New York Prize Stage 1 Feasibility Assessments

Final Report

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Evaluation of New York Prize Stage 1 Feasibility Assessments

Final Report

Prepared for:

New York State Energy Research and Development Authority

Albany, New York

Project Manager: John Love
Senior Project Manager

Prepared by:

Brookhaven National Laboratory

Upton, New York

Project Manager: Robert Lofaro
Group Leader

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Abstract

This report documents the results of an independent review conducted by Brookhaven National Laboratory (BNL) of a subset of the microgrid feasibility studies submitted to NYSERDA in response to the Request for Proposals RFP-3044 NY Prize Community Grid Competition [RFP-3044], Stage 1. An important part of the NY Prize Competition involves the opportunity to capture important insights and lessons learned by the applicants and their partners throughout the process of planning, designing, financing, permitting, building, integration, and finally, operation of their microgrids interconnected with the local power system. The observations and insights gleaned from the BNL review will serve as a guideline for the future development of community microgrids in New York State.

Keywords:

Community Microgrid, Feasibility Study, NY Prize Competition

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Acronyms and Abbreviations

BCA	Benefits/Costs Analysis
BNL	Brookhaven National Laboratory
CAIDI	Customer Average Interruption Duration Index
CCHP	Combined Cooling, Heat, and Power tri-generation plant
CHP	Combined Heat and Power cogeneration plant
DBOOT	Design, Build, Own, Operate, Transfer
DBOOM	Design, Build, Own, Operate, Maintain
DER	Distributed Energy Resources
FERC	Federal Energy Regulatory Commission
ITC	Federal Investment Tax Credit
LMP	Locational Marginal Pricing or Location-Based Marginal Pricing
LMP+D	LMP plus the distribution delivery value
MCS	Microgrid Control System
MESCO	Microgrid Energy Services Company
NYISO	New York Independent System Operator
NY REV	New York State Reforming the Energy Vision initiative
NYPA	New York Power Authority
NY SIR	New York State Standard Interconnection Requirements
P3	Public-Private Partnership
PCC	Point of Common Connection
PLC	Programmable Logic Controller
PPA	Purchase Power Agreement
PSC	New York Public Service Commission
PV	Solar Photovoltaic generation
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SPV	Special Purpose Vehicle financing entity
VFD	Variable Frequency Drive

1 Introduction

1.1 Introduction

This report documents the results of an independent review conducted by Brookhaven National Laboratory (BNL) of a subset of the microgrid feasibility studies submitted to NYSERDA in response to the Request for Proposals RFP-3044 NY Prize Community Grid Competition [RFP-3044]. The proposals reviewed were submitted in response to Stage 1 of the NY Prize Competition.

New York State Energy Research and Development Authority (NYSERDA), in partnership with the Governor's Office of Storm Recovery, developed and is conducting the three-stage NY Prize Community Grid Competition (NY Prize) to support the development of community microgrids. The main objective of the NY Prize competition is to promote the design and build of community grids that improve local electrical distribution system performance and resiliency in both a normal operating configuration as well as during times of electrical grid outages. NY Prize objectives include empowering community leaders, encouraging broad private and public sector participation including local distribution utilities, local governments and third parties, protecting vulnerable populations, and providing tools to build a cleaner more reliable energy system. [RFP-3044]

NY Prize awarded funding to 83 competitively selected communities in New York State to conduct a feasibility analysis in Stage 1 of the competition (Feasibility Assessment).

NYSERDA's NY Prize competition offers the ability to significantly advance the understanding of microgrid technology, policy, and business practices. The educational component of the competition has the potential to provide key lessons learned and best practices to help accelerate future community microgrid projects in New York as well as throughout the United States.

1.2 Objective of this Project

This project was sponsored by the U.S. Department of Energy's Grid Modernization initiative, and was performed by BNL in its role as part of the Grid Modernization Laboratory Consortium (GMLC)

under Project 1.3.22, entitled “Technical Support to the New York State REV¹ Initiative.” The objective of this project is to conduct a comprehensive review of a subset of the 83 submitted NY Prize microgrid feasibility assessments, and identify key outcomes, challenges, trends, best practices, essential findings, and commonalities that must be addressed when a community considers the development of a microgrid. NYSERDA provided guidance on the selection of assessments to review.

The primary purpose of this document is to compile key findings based on the outcomes of these NY Prize Stage 1 studies as a means of providing meaningful insights into developing better practices or identifying gaps in technology and other hurdles to microgrid planning, commercialization and operation. Among the key questions to be answered are:

- What are the common barriers to community microgrid formation?
- What are some of the common technical characteristics of the proposed microgrid designs?
- What is the prevalent mix of building/customer types/load shapes, energy efficiency, and distributed generation types that form the basis of the planned community grids?
- What significant weather impacts are the project configurations designed to withstand? How and for how long?
- Are there electrical infrastructure topologies that facilitate microgrid deployment?
- What are the prevalent analytical models/methods being applied in the economic analysis of the community grid?
- What cost and benefit categories have the highest impact on BCA for these projects?
- How do current or pending market rules/regulations (e.g., NYISO behind the meter net generation treatment) impact anticipated revenue streams?

From these reviews, BNL assembled a set of positive attributes and characteristics common to the best of the proposed microgrid projects that enabled the winners of the Stage 1 competition to develop successful, sustainable, and financially viable community microgrid proposals. BNL also noted some of the existing regulatory, policy, and financial challenges and barriers to success identified by the applicants that must be addressed by the State and local governments, the PSC, and the utility industry to inform the REV process going forward and facilitate the future development of community microgrids in New York State.

¹ The New York State Reforming the Energy Vision (REV) is an initiative being undertaken by the PSC, NYSERDA, NYPA, and the Long Island Power Authority to modernize the electric grid in New York State and make it clean, resilient, and more affordable, while improving consumer choice. <https://rev.ny.gov/>

2 Background & Technical Approach

2.1 Background

The NY Prize Competition is a multi-stage competitive process, administered by NYSERDA, with support from the Governor’s Office of Storm Recovery supporting local, community, or neighborhood level energy planning that culminates in the awarding of prize money to implement microgrid development plans. The NY Prize Competition, through each of its stages, will offer awards for feasibility studies, audit-grade engineering design and business plans, and project build-out with post-operational monitoring and evaluation.

The first stage of the NY Prize Community Grid Competition was designed to offer ample opportunity to apply and compete for funding to conduct feasibility studies on the potential benefits of community grids. Statewide promotion of this opportunity by New York State officials and thought leaders with the support of local utility leadership generated unprecedented interest from communities across the State of New York. Over 130 cities, villages, towns, and municipalities applied to the first of this multi-stage competition resulting in 83 awards to conduct assessments of the feasibility of electric grids or microgrids to provide power to essential customers at the neighborhood scale.

By developing innovative market solutions such as microgrids, the State is delivering on Governor Andrew M. Cuomo’s commitment under its REV initiative to transform the energy industry into a more resilient, clean, cost-effective and dynamic system. Working with State citizen and industry-stakeholders, New York’s energy policy is moving to a more market-based, decentralized approach. This means protecting the environment, decreasing energy costs, and creating opportunities for economic growth for current and future generations of New Yorkers. In advancing these new energy systems and solutions, New Yorkers will have improved energy affordability and efficiency without sacrificing their right to live in a cleaner, resilient, and more sustainable environment.

2.2 Capturing Insights and Lessons Learned from NY Prize

An important part of the NY Prize Competition involves the opportunity to capture important insights and lessons learned by the applicants and their partners throughout the process of planning, designing, financing, permitting, building, integration, and finally, operation of their microgrids interconnected with the local power system.

The observations and insights gleaned from the BNL review will serve as a guideline for the future development of community microgrids. The guidelines will help communities and other entities that are considering the development of microgrid projects to realistically evaluate the feasibility of their ideas, understand the characteristics of successful microgrid projects, become aware of the potential challenges that will need to be addressed, and to seek the experienced technical, design, financial, operations and maintenance, legal, and other partners that will be necessary to help achieve a successful and sustainable community microgrid in the State.

2.3 Technical Approach to Conducting the Evaluations

BNL performed preliminary evaluations for a representative sample of feasibility assessments to get a sense of the type of information available and what insights could be extracted. NYSERDA provided technical guidance and documentation to assist BNL in the selection of assessments to review. The initial sample included several studies that were identified by NYSERDA as among the best 10 of the 83 Stage 1 NY Prize Competition winners along with other studies that NYSERDA considered to be well done and thorough, but ranked just below the 10 best submittals. This preliminary sample included studies performed by several larger, more experienced architect/engineer/design partners that had been working with several Stage 1 applicants across the State.

BNL also included multiple feasibility studies in its preliminary sample that were considered to have very little promise of success, poor benefit/cost analysis results, or were lacking in one or more other aspects. BNL felt this sample would provide further observations or insights into those characteristics or attributes of the less promising community microgrid proposals that set them apart from the successful ones.

The preliminary review also provided insights into regulatory, fiscal, legal, and policy barriers that currently exist and challenge prospective community microgrid developers. These are the challenges and barriers that will need to be addressed at local, State, and federal levels to facilitate development and incorporation of community microgrids into the future power grid in New York State per the vision of the NY REV Process. It was noted that utility policies were often among the challenges or barriers to success for a number of the community microgrid proposals; these policies and issues will also need to be addressed by the NYS government, the PSC, and the electric, natural gas, and steam supply utilities.

Based on its observations and assessments during the review of this preliminary sample of feasibility studies, BNL identified six major categories of positive attributes and negative attributes or challenges that characterized various community microgrid proposals:

1. Fundamental Considerations for Microgrid Planning,
2. Benefits/Costs Analysis Issues,
3. Project-Specific Technical Issues,
4. Global Issues Affecting Microgrid Development,
5. Stakeholder Issues,
6. Risk Analysis and Management for Improved Reliability and Resiliency.

Proposal teams that identified and thoroughly addressed various common issues and items within these major categories generally developed the higher quality feasibility studies. BNL observed that the issues and items in these major categories of community microgrid attributes were strong indicators of a proposed project's success and sustainability moving forward to the build-out stage. Hence, these major categories represent a core set of guidelines to success for other New York State communities to seriously consider when planning and developing their own microgrid projects in the future.

BNL then conducted a comprehensive review of 20 feasibility studies selected from the 83 award winners of the NY Prize Stage 1 Competition. The observations, positive and negative attributes and characteristics, and challenges and barriers to development encountered by the applicants were collected, consolidated, and tabulated into a single document. A summary is presented in Appendix A: Community Microgrids—Attributes for Success.

BNL's findings and observations from each of the major categories will be presented and discussed in more detail in the following sections of the report. The final section concludes with the most important challenges that community microgrid developers in the State will face going forward and provides a list of the major findings and observations gleaned from BNL's review of the feasibility studies.

3 Fundamental Considerations for Microgrid Planning

It is understood that most communities have little or no experience regarding technical projects such as the development of a microgrid, nor do they have on staff the engineering, technical, legal, and financial expertise to tackle such an undertaking. Developing the project-specific details of the design of a potential microgrid project is a complex and critical undertaking that will have a significant impact on the overall success and sustainability of the project. It was noted in the BNL review sample that the most successful applicants were those partnered with established design and development engineers with extensive experience in the development of microgrid projects.

When initially contemplating the idea of developing a community microgrid, there are several important fundamental considerations, attributes, and characteristics that should be addressed early in the feasibility planning process. If the communities, developers, or other entities that are beginning to put together a plan for their envisioned microgrids cannot provide realistic solutions to these basic issues, the prospects of developing a successful and sustainable community microgrid are very unlikely.

Several of these fundamental issues identified during the BNL review of the NY Prize Stage 1 feasibility studies are discussed in this section.

3.1 Well-Defined and Focused Mission

Surprisingly, the presentation of a well-defined and focused mission statement was one of the fundamental issues found to be a weakness in many of the Stage 1 feasibility studies, including some of the better-performing proposals. The reason for developing a microgrid in the community should be clearly defined to specify the basic design and performance parameters and establish a realistic preliminary plan. A clear, focused, and bounded basic design is important because it allows the engineers to proceed to the next design steps involving more detailed planning, conducting benefits/costs analyses, performance evaluations, and feasibility studies.

Many of the microgrids were conceived in response to recurring severe weather events that resulted in damage, flooding, extended losses-of-power, and associated threats to the safety and well-being of the community. By developing their own microgrid, these communities hoped to improve the overall reliability of the electric distribution system and resiliency against the effects of severe weather events. The duration of the most severe event expected, i.e., the design basis initiating event, needs to be defined by the mission statement (for many communities in the State this would be a severe storm such as Superstorm Sandy) so that the maximum time frame during which the microgrid is required to operate can be bounded.

Some of the microgrids studied intended to sell energy into peak power markets or even operate continuously to take advantage of the improved efficiency offered by cogeneration and trigeneration units to reduce the costs of electricity, thermal heating, and cooling to the microgrid customers. These communities emphasized electricity cost reduction in addition to the reliability and resiliency improvements as operating objectives that would be realized by developing their own microgrid.

The poorer performing proposals typically did not present a mission statement that articulated their intended objectives for the microgrid. They often failed to identify truly critical customers and essential loads to precisely bound, or limit the service area to be covered by the proposed microgrid. Others had unrealistic expectations about the benefits that could be achieved from a microgrid because they could not focus the purpose/mission of the project for the Stage 1 feasibility study, and consequently could not properly specify the capacity and capabilities required for their proposed design.

3.2 Identify and Characterize Critical and Essential Loads

The microgrid mission statement will typically identify the loads or groups of loads to be served by the microgrid as ‘critical,’ or ‘essential,’ indicating that ideally, they will receive uninterrupted power. Other groups of loads of a less critical nature, designated as “important” loads, may have to be shed in accordance with a hierarchical load shedding schedule to maintain the supply of power to the critical loads, stabilize the grid, and manage voltage and frequency during transitional operations.

During the review of the Stage 1 feasibility studies, it was observed that hospitals, medical centers, medical clinics, emergency treatment facilities, nursing homes, and ambulance services were nearly always considered to be critical facilities. Other critical loads noted during the BNL review included police departments, fire departments, municipal and community government buildings, water treatment/supply companies, waste water treatment plants, sewage treatment facilities, and transportation centers, such as train, bus, ferry, subway, and airport facilities.

Facilities such as pharmacies, grocery stores, banks, department stores, and gasoline stations were frequently designated as important loads. Larger community buildings such as public shelters, school buildings, community centers, and senior centers were designated as either critical or important depending on their roles in the community's emergency plan. For example, these public and government buildings may be established as emergency response organization staging areas, emergency operations and management facilities, or as sheltering centers for people displaced from their homes. Street lighting, area lighting, and traffic signals were frequently identified in the feasibility studies as loads that are important to public safety and the security of the community.

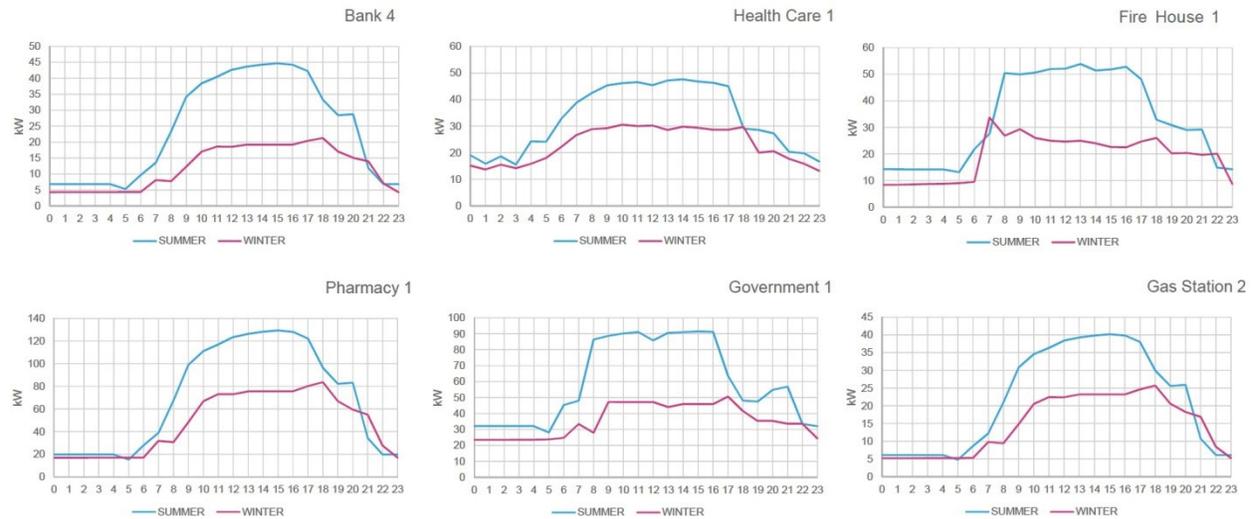
Early in the design and planning process, specific loads designated as critical must be identified and selected, and other loads serviced by the microgrid should be categorized by level of importance. Groups of loads may have to be shed in order of their level of importance during high demand periods, during transitions from grid parallel operation to islanded mode, and from islanded mode back to grid connected operating mode. The microgrid control system's automatic load controller will handle load shedding schedules as described in Section 5.

The selection of facilities to be supplied by the proposed microgrid, and the characterization of their electric power, thermal, and cooling loads, are important fundamental design issues since they will drive and affect all aspects of the microgrid design process. The hourly, daily, weekly, and monthly loading characteristics must be defined for all the facilities included in the microgrid. Historical load data should not be limited to electrical performance alone; thermal heating, steam, and cooling load data are needed for buildings and facilities that will be off-takers of steam and heat by-products from CHP and CCHP generating units, so their output capacities may be sized properly.

Analysis of actual historic data is the preferable method of characterizing facility loads; however, detailed information is not always available, incomplete, or non-existent. Lacking actual data, realistic estimates of facility loads must be developed by experienced and knowledgeable planners and engineers. The necessity of obtaining comprehensive and accurate historic engineering data, such as facility load profiles, to support the microgrid design process further highlights the importance of securing the full cooperation, support, and participation of the local utilities (electric, natural gas, thermal energy supply, and network/communications).

Figure 3-1 shows examples of hourly electric load profiles, in summer and winter, for several typical facilities served by community microgrids. These represent load profiles of facilities during normal operating conditions on ‘blue sky’ days. During islanded mode of operation caused by severe weather events or other catastrophic occurrences, designated critical facilities may have emergency response functions that will significantly alter their load profiles; emergency planners and microgrid design engineers will have to anticipate such changes.

Figure 3-1. Examples of hourly summer and winter load profiles for several typical microgrid customer facilities. (Adapted from Feasibility Study #14)



The fundamental process of load identification and characterization is an important part of the planning and design of the microgrid since it will affect subsequent design activities. It will drive the process of selecting and designing the distributed energy resources (DER) that will make up the microgrid's generation sources and affect the types, quantities, and mix of proposed generation sources, as described in Subsection 3.3. The locations of existing and new DER and the location and demand characteristics of the selected critical and important loads are also a major factor in defining the size and shape of the territory to be served by the proposed microgrid, as discussed in Subsection 3.4.

3.3 DER Capacity and Generation Mix

Based upon a well-defined mission statement and the compilation of historical load data (including electric power, thermal, and adsorption cooling demand) for the facilities that will be supplied by the microgrid, the microgrid design engineers will be able to specify the required total capacity of DER necessary to supply the designated critical and important loads during islanded operation. The total capacity of existing DER can be used to determine the quantity of additional new DER that must be built into the proposed microgrid.

However, operating characteristics and limitations of the existing generation must also be considered. For example, diesel-fired units may have emission restrictions that will limit their operating time and the quantity of on-site fuel oil storage capacity will also limit their operation. Hospital back-up diesel generator's will include mandated dedicated emergency units that may be restricted from routinely generating power into an external community microgrid. Solar PV (photovoltaic) and wind turbines are desirable because they support the clean energy objectives of the NY REV. However, renewable energy sources, such as solar and wind, exhibit intermittent and variable output characteristics (unless teamed with energy storage systems), so credit can only be taken for a percentage of the full generating capacity of these sources. (This is 15% of total capacity for PV in New York State).

The majority of the Stage 1 feasibility studies reviewed by BNL proposed natural gas-fired CHP (and CCHP) as the new baseline DER in their community microgrids. The dependability, flexibility, low-emissions, and availability of the low-cost natural gas fuel supply currently make these cogeneration and tri-generation units the DER of choice for microgrid applications. The primary revenue stream for the majority of the Stage 1 proposals is the sale of electric power from their DER.

The capturing of exhaust heat energy from the generating units for thermal steam heating, hot water production, and with absorption chillers for space cooling can boost the overall efficiency of these units

to nearly 90%. Sale of these by-products of the generation process can contribute additional revenue streams for the microgrid to significantly augment their financial viability.

A variety of existing and new DER types were noted during the review of the Stage 1 feasibility studies. These included diesel generators, hydro-electric generators, waste-to-energy facilities, battery energy storage systems, solar PV, wind turbines, and fuels cells. Generally, the renewable energy sources and battery storage systems were too expensive for consideration as new generation unless they were heavily subsidized by grants, utility energy credits, and/or other credits for achieving state and national renewable energy goals.

Several additional considerations must be evaluated when determining the types, sizes, and total capacity of the proposed microgrid's DER. For example, a number of smaller, redundant CHP units may be more reliable and operationally more efficient, but more expensive to maintain than fewer large units. The availability and physical location of property on which to site the new DER may be the overriding consideration in some instances. At least one Stage 1 steam heat and electric power microgrid that BNL reviewed could not go beyond the preliminary design stage because the property proposed for siting the CHP units was no longer available to the microgrid developers.

Many other factors are location-specific. The revenue potential for sale of electricity into the local distribution market will be affected by the locational marginal pricing market for electricity. If the cost of electricity generated by the microgrid is relatively high, there will be fewer opportunities to sell power into the local grid. The reliability and resiliency of the local electric grid will likewise affect how often the community microgrid will need to power critical customers. If the local grid is extremely reliable and the cost of electricity is very low, the pay-back period for the microgrid investors may be unacceptably long.

Another location-specific factor will be the policies of the local utility regarding the sale of electricity potential competitors such as community microgrids and other generating entities within their service territory. The sale of excess electric power, frequency and voltage support, and other ancillary services to the local utility can represent a significant source of revenue to a community microgrid that would make such an enterprise financially sustainable while being a substantial benefit to the utility. BNL reviewed one unsuccessful community microgrid proposal that was too small (e.g., less than 4.5 MW total output) and lacked generation redundancy which kept them from satisfying the minimum guaranteed capacity requirements necessary to qualify as a participant in the power and ancillary services markets in

the local utility grid; loss of these potential revenue streams prevented the proposed microgrid from achieving profitable and sustainable operation.

Currently, the role that community microgrids will play in the State distribution system market is not clearly defined nor completely understood. Long-standing local utility policies are conservative and generally not favorable for developers of small community microgrids. These global challenges to microgrid development are discussed further in Section 6. New York State, the PSC, and the electric utilities will need to continue working together toward implementing the new ideas (such as community microgrids) and other smart grid concepts envisioned by the NY REV initiative.

3.4 Compact Footprint

It was noted that most of the successful microgrid proposals were those that had compact physical size. The critical and designated important loads to be supplied by the microgrid were located within close proximity to each other and the generation sources.

The reasons this factor is important are discussed in more detail in Section 5. It is desirable to maximize the use of existing infrastructure as much as possible due to the high costs of designing, installing, and maintaining new electrical distribution lines to interconnect the critical and important loads to the microgrid generation sources, installing multiple new automatic isolation switches required to separate the microgrid from the local utility distribution system during loss-of-grid power events, and installing a new cybersecure communications and control network for the community microgrid. Physically locating new microgrid DER close to the loads will also help minimize the costs of new interconnection lines needed to link the microgrid generation sources to the microgrid distribution system. If these circuits must be run underground to protect them from extreme weather to improve reliability, the installation costs can be 15 times more expensive than overhead distribution lines.

In addition, if the new DER includes natural gas-fired CHP units, the costs to connect the natural gas supply system and install steam supply piping to connect the thermal output of the CHP units to the steam off-takers in the microgrid must be considered.

Therefore, microgrids with the most compact physical size can minimize the costs of new interconnection infrastructure. This will significantly improve their chances for developing a financially viable and sustainable community microgrid. It can make the difference between success and failure in reducing costs to the microgrid customers while providing a profit for the microgrid's owners and investors.

4 Benefits/Costs Analysis

This section discusses the application of a structured benefits/costs analysis (BCA) approach to the evaluation of the potential merits of a community microgrid project. It will highlight the different levels of benefits that a microgrid can bring at the community, regional, and State levels from the techno-economic and environmental perspective. From the perspective of the projected increases in grid reliability and improved power quality that can be achieved by a successful community microgrid, this section describes the positive effects they have on economic and industrial development, along with more reliable community support (emergency services, health, public safety, etc.).

4.1 Benefits/Costs Analysis of Community Microgrids

In evaluating the economic viability of microgrids, a common understanding of the basic concepts of BCA is essential. Primary elements in BCA are the following:

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

The BCA model must be structured to analyze a project's costs and benefits over the microgrid operating lifetime (generally 20 years). The analysis can apply conventional discounting techniques to calculate the present value of costs and benefits, employing a user specific annual discount rate. For example, it may be reasonable to use a 7% discount rate; this discount rate is consistent with the U.S. Office of Management and Budget's current estimate of the opportunity cost of capital for private investments. One exception to the use of this rate is the calculation of environmental damages. Following the PSC guidance for BCA [NY PSC – 2016], the BCA can rely on temporal projections of the social cost of carbon, which were developed by the U.S. Environmental Protection Agency (EPA) using a 3% discount rate, to value CO₂ emissions. According to the PSC "the social cost of carbon is distinguishable from other measures because it operates over a very long time frame, justifying use of a low discount rate specific to its long-term effects."

The BCA may also use EPA’s temporal projections of social damage values for SO₂, NO_x, and PM_{2.5}, and, therefore, it should again apply a 3% discount rate to the calculation of damages associated with each of those pollutants. The main costs and benefits to be considered for the analysis applied to microgrids are listed in the following Table 4-1.

This section focuses on the different techno-economic and environmental benefits that a microgrid can bring to the local and State levels, from improved grid reliability and power quality support, to economic and industrial development, reliable community support (emergency, healthcare, etc.) and limited carbon emissions with the use of clean energy technologies. The goal of a microgrid is to provide and maintain electricity supply and heat streams, where applicable, to all required facilities during a grid power outage. The choice of the technologies to deploy within the microgrid plays a significant role for assuring the optimal reliability and resiliency of the system. For example, CHP technologies are well-proven, reliable electricity supply systems, and can be used as the main capacity provider for a microgrid. Wherever available, waste-to-energy power plants can also be used as primary energy supply systems. It is, however, practical to consider units that can run on dual fuel options. Additional DER can include fuel cells, wind, solar, energy storage, and diesel back-up generators.

Table 4-1. Main costs and benefits to be considered in the BCA.

Costs	Benefits
Fixed costs (e.g., design and planning, capital costs, fixed operation and maintenance)	Reliability benefits
Variable costs (e.g., cost of natural gas and fuel operation, variable operation and maintenance, emissions and environmental damages)	Power quality benefits (e.g., reduction in the frequency of voltage sags and swells, reduction in the frequency of momentary outages)
Avoided costs (savings from bulk energy supply reduction – microgrid supply base load energy, fuel savings, emissions allowance cost savings, cost savings by avoiding or deferring investments)	

The main challenge is the effective implementation of a load shedding scheme to balance the needs of all facilities connected to the microgrid during more critical islanded situations.

A well-planned microgrid can offer a large range of benefits, including reduced energy costs, lower carbon emissions, energy security, grid hardening, and reliability. Multiple revenue sources can be established around these benefits. Some other benefits include payment for the provision of primary and standby electric and thermal energy, compensation for peaking generation/capacity, compensation for grid infrastructures, and grid reliability improvements.

Dissimilarly, the value of resiliency is not universally defined or quantified. A consistent approach to defining and valuing resilience is going to be very important to the economics of many microgrid projects.

On the other side, uncertainties to the business case may include negotiated exchange electricity rates, incremental capital expenditure for grid resiliency, changing regulations, storage requirements, demand response and capacity market participation, carbon credits, and federal investment tax credit. The largest external risk that can register in some microgrid cases is associated to the uncertainty about project ownership and access to potential subsidies. The largest effort and the highest internal project risks are expected to be related to negotiating contracts with the utility for purchasing ancillary services, and co-location of facilities. Some risk is expected in securing the individual participants.

Generally, for a microgrid case, it is recommended that the BCA achieves a benefit-cost ratio ≥ 1 and a positive internal rate of return (IRR), making the microgrid profitable for potential investments. Two example cases of a good- and poor-performing project from the BCA perspective are shown in Table 4-2.

Implementing a better performing project from the BCA perspective requires impactful benefits that can lead to the clear dominance of the monetization of the benefits in comparison with the costs. From the investigated cases included in this report, a potentially valuable and attractive microgrid system should have a consistent impact in the reduction of the generation capacity and distribution capacity cost savings by avoiding or deferring the need to invest in the expansion of the conventional grid's energy generation or distribution capacity.

Table 4-2. Summary of relevant characteristics pertinent to better-performing and poor-performing projects in the case of no major outages.

Main characteristics	Better-performing project (example case with benefit/cost ratio 2.6 and positive IRR)	Poor-performing projects (example case with benefit/cost ratio 0.5 and negative IRR)
DER	Waste to energy (95%), natural gas CHP (4.8%), PV (0.2%). The microgrid sources are primarily rotating machines. Standby diesel generators are part of the system.	In use: natural gas (78%) and photovoltaic (22 %). Two standby generators are part of the system, using diesel and natural gas.
Identification of cost details	Cost details cover design, planning, capital investment, fixed and variable O&M, fuel, emission control and damages. The capital cost is 19% of the total costs (present value over 20 years).	Cost details limited to design, planning, capital investment and fixed O&M. The capital investment is significantly dominating for 85% of the total costs (present value over 20 years).
Use of the generation capacity during grid-connected operation, fuel costs and availability	The natural gas fuel costs of the microgrid generation resources (for CCHP waste-to-energy does not account for fuel costs) and the cost associated with the corresponding environmental emissions are the highest costs listed. During grid connected operation, the generation capacity, mainly of the CCHP units, will serve to reduce the energy costs of the hosting facilities. Ways for this microgrid to actively participate in the NYISO's energy, capacity, and ancillary services markets are explored.	During normal operating conditions, the project would rely solely on renewable energy sources, and would not account for fuel costs. However, the primary microgrid generation is based on natural gas, which is also considered for grid support, thus likely working also during normal operation.
Emission control, allowances and damages	Emission allowances are not relevant for limited emissions. The emission control and damages account for 144% of the capital investment costs and 27% of the total costs (present value over 20 years).	The emissions damages are considered irrelevant as the power production running during normal operation is solar PV.
Reduction in generating costs	The reduction is about 173% of the capital investment (present value over 20 years).	The reduction is about 8% of the capital investment (present value over 20 years).
Cost savings (fuel, generation and distribution capacity)	The overall value of the cost savings for fuel, generation and distribution capacity amount to about 167% of the capital investment (present value over 20 years).	No fuel saving from CHP is considered, as no CHP is part of the system. The generation and distribution capacity cost savings are about 44% of the capital investment (present value over 20 years).
Power quality support	The power quality improvements are substantial and account for about 683% of the capital investment (present value over 20 years).	Not accounted for, even though it is a considered option for the microgrid operation.
Avoided emissions	The total considered between avoided allowances and avoided damages accounts for about 200% of the capital investment (present value over 20 years).	The total considered between avoided allowances and avoided damages accounts for about 5% of the capital investment (present value over 20 years).

Another relevant and influencing aspect is the microgrid capability to lower the generation costs resulting from a drop in the demand for electricity from bulk energy suppliers; this reduction in bulk energy demand would also avoid emissions of CO₂, SO₂, NO_x, and particulate matter, yielding to avoided emissions allowance costs, and most relevantly, avoided emission damages.

Finally, another important benefit that requires careful consideration is the support offered by the microgrid for power quality improvements. This benefit may depend on the size and inherent capabilities of the power generation units included in the microgrid. However, it may account for large benefits by providing ancillary services, in the form of frequency regulation, reactive power support, and black start support, to the New York Independent System Operator (NYISO). Still, this aspect depends also on whether the NYISO would select the project to provide these services. The market for ancillary services—in particular, black start support—is highly competitive, and it would realistically be a low probability that microgrid projects would be selected to provide support to the grid. In light of this consideration, the potential benefits of providing power quality services are not fully secure.

It is, however, important to design the microgrid with a forward mindset and carefully consider the DER included due to the benefits expected in the near and long-term future of the project, always considering the present policy scenario with the knowledge of ongoing and required changes. The microgrid policy, regulatory, and legal environment is presently in evolution.

4.2 Environmental Benefits

When incorporating energy-efficient and low- or no-emission technologies, the microgrid gets to the root problem of climate change and environmental protection by reducing greenhouse gas emissions and dependence on fossil fuels in two important ways: supporting the viability and deployment of renewables, such as solar power, and reducing energy waste. A positive environmental impact should be among the main microgrid goals.

The analysis of variable costs in the BCA should consider the environmental damages associated with pollutant emissions from the distributed energy resources that serve the microgrid based on the operating scenario and emissions rates provided. The majority of these damages are attributable to the emission of CO₂. However, these damages should be weighted and compared with the emission savings due to the decrease in demand for electricity from bulk energy suppliers that would also reduce air pollutant emissions from such facilities, including CO₂, SO₂, NO_x, and particulate matter.

In addition to increasing reliability, the adoption of diverse DER within the microgrid also supports the achievement of a positive environmental footprint. The near-zero emissions of fuel cells combined with solar PV and energy storage can provide environmental benefits to the community. Moreover, the use of CHP offers a more efficient energy usage. Environmental permitting is one of the variables to be considered for system choice and sizing.

4.3 Local Benefits

A microgrid can provide relief to a vulnerable area. The local community can list the benefits they will enjoy following the establishment of a microgrid; primarily, a more reliable and resilient electricity service. The ability to continuously and reliably operate critical town and community facilities with the availability of electricity and heat stream during emergencies is a benefit to public safety that improves the quality of life for area residents. In island mode during an emergency, reliability, and resiliency must be the primary objectives, and load modulation may be used during the most energy-intensive days. Reliability can be ensured with: use of multiple, diverse, distributed, smaller unit sizes, use of distributed energy storage systems, increased energy dispatch from the grid in grid-connected mode, use of energy storage system and load modulation, greater use of underground cabling and indoor infrastructure.

Aside from the direct benefit of energy supply, there is a sequence of intangible benefits for the community, such as increased life safety, trustworthy healthcare services and home care, reliable emergency response (e.g., fire department, 911 call centers), water and wastewater services, facility attractiveness due to standby power ability, and the potential opportunity for emergency shelter operations. A microgrid would also enable critical facilities to function, such as storm water pumping stations, which could reduce the costs of property damage associated with storm water flooding. In addition, community property value will increase, and the area is likely to experience benefits from local industrial growth due to the presence and support of a reliable energy system. From this perspective, the microgrid can also create local jobs, both through the area development and the opportunities tied to the microgrid installation, operation, and maintenance.

In addition to the previously mentioned benefits, the energy resources contained within a microgrid could provide benefits to the local utility (as well as to the NYISO) during normal operation. Among these benefits the following can be listed:

- Offering capacity to the utility to relieve congestion or defer the costs of transmission and distribution equipment upgrades (benefit to utility and ratepayers).
- Reducing demand behind the meter of sites within the microgrid, thereby reducing the need for the utility grid to provide that capacity.
- Offering ancillary services such as frequency regulation to the NYISO to help maintain grid reliability.

From the financial perspective, a microgrid can bring a value stream where the beneficiaries are the microgrid end-users and the distribution utility. The sum of these total benefits should be greater than the total costs. A standardized methodology for the valuation of the benefits the community microgrid provides to the utility grid and overall society should be adopted; the value of these indirect global benefits can then be better accounted for in the BCA. Presently, the margin of financial sustainability is quite narrow for many proposed community microgrids, requiring grants, tax credits, or other forms of government subsidies to stimulate investments in microgrid structures. The BCA should realistically evaluate the long-term financial viability of the microgrid enterprise to confirm it will remain profitable after the one-time and fixed-term subsidies have expired.

4.4 New York State Benefits

Technically reasonable and financially valuable microgrids can become scalable models and may be replicable elsewhere in the State. The State will benefit by gaining knowledge from the implementation of successful microgrids, as well as helping towards meet the NY REV goals. At present, the microgrid development team is expected to explore market opportunity for the utility and the customers to find competitive solution providers to establish public-private partnerships and develop efficient and resilient microgrids. Nevertheless, the policy, regulatory, and legal issues surrounding the development of microgrids must be properly addressed to benefit from the operation of the microgrid.

However, the situation is expected to evolve in the near future. The best efforts to address technical, regulatory, and contractual challenges to develop a framework that paves the way for future microgrids include aspects that will benefit the REV vision. Additionally, microgrids can promote clean and distributed energy generation, and provide value streams that can be quantified and captured as well as replicated and used to engage additional customers. The goal is to make microgrids attractive financial solutions for different stakeholders, while achieving a series of technical and social benefits.

In addition to what is previously mentioned, a microgrid can play an important role in the support of ancillary or grid-edge services that can have an impact at the State level (involving utilities and the NYISO), thereby enhancing the transmission and distribution systems.

5 Project-Specific Technical Issues

This section discusses the most relevant project-specific technical issues addressed when evaluating the feasibility of a microgrid project and developing the details of its design, interface, and operation. Developing the project-specific design details of a potential microgrid project is a complex and critical undertaking that will have a significant impact on the overall success and sustainability of the project. Coincidentally, the most successful applicants were those who partnered with established design and development engineers that have the following qualities:

1. extensive experience in the development of several comparable microgrid projects including those specifically in NY State
2. knowledge of microgrid technical requirements, communications, and controls
3. experience in the development and performance of BCAs in accordance with PSC guidelines
4. knowledge of NY State, PSC, and utility policies
5. knowledge of federal, state, and local regulations and legal issues
6. experience with the development of the types of financial vehicles that are essential for the success of microgrid projects.

Among the relevant project-specific technical issues discussed in the following subsections are design, development, and interconnections with existing local infrastructure; microgrid operation and control systems; operations and interactions with the local electric distribution system; fuel supply and storage; operations and maintenance responsibilities; and energy efficiency improvements and conservations efforts.

5.1 Design, Development, and Interconnections with Existing Local Infrastructure

A typical community microgrid is embedded within the existing local electrical distribution system and serves loads including or more critical buildings or facilities, as well as other designated important loads in the area served and controlled by that microgrid. The microgrid will have one or more distributed generation sources to contribute to the supply of all, or portions of, those loads during normal operation when connected to the local power grid, or in islanded mode, isolated from the local grid, when an emergency condition caused a failure of the bulk power system and/or local distribution system.

5.1.1 Electric Infrastructure

The design of the proposed microgrid must be optimized to maximize the use of existing electrical lines that interconnect the critical and important loads with the microgrid's distributed generation sources.

The addition of new interconnecting electrical lines between distributed generation and loads expensive and can add significant new construction costs to the project. If the lines are routed overhead, they may be vulnerable to the same weather-related conditions that caused failure of the local distribution grid. Routing the interconnection circuits underground can improve the reliability and resiliency of the microgrid circuits but at a cost of at least 15 times more than new overhead lines construction.

Similarly, the automatically controlled electrical distribution system switches needed to isolate the microgrid's circuits from the local distribution system during islanded operating mode are expensive to purchase, install, interconnect with the control and communications network, and maintain.

Consequently, the optimum microgrid design should try to make use of existing automatic distribution system switches wherever possible so fewer new switches need to be installed to achieve isolation for the microgrid.

5.1.2 Natural Gas and Steam Infrastructures

Because of the currently abundant supply of clean-burning, inexpensive natural gas, most of the microgrid applicants proposed one or more natural gas-fired Combined Heat and Power (CHP) units as their distributed generation resources. The new CHP units must be located to minimize the connection costs to the existing natural gas supply system while also minimizing the steam line connection costs to new, as well as existing steam off-takers in the microgrid.

5.2 Microgrid Operational Capabilities and Control System

The community microgrid will be expected to include several functional and operational capabilities to accomplish its intended purpose under normal operating conditions, while connected in parallel with the local grid, and during emergency operation when it automatically separates from the local grid and operates in an islanded mode. This subsection identifies those capabilities and briefly discusses how they are typically accomplished.

5.2.1 Microgrid Operational Capabilities

NYSERDA outlined 15 required and 18 preferred operational capabilities for winners of the NY Stage 1 Competition to incorporate into the microgrid designs for their feasibility assessments. These are summarized in Table 5-1 adapted from one of the microgrid feasibility studies.

Table 5-1. Microgrid Capabilities Matrix (Adapted from Feasibility Study #27)

Required Capability	Preferred Capability
Serves more than one, physically separated critical facilities	Microgrid logic controllers
Primary generation source not totally diesel fueled	Smart grid technologies
Provides on-site power in both grid-connected and islanded mode	Smart meters
Intentional islanding	Distribution automation
Seamless and automatic grid separation/restoration	Energy storage
Meets state and utility interconnection standards	Active network control system
Capable of 24/7 operation	Demand response
Operator capable of two-way communication and control with local utility	Clean power sources integrated
Load following while maintaining the voltage and frequency when running in parallel to grid	Optimal power flow (economic dispatch of generators)
Load following and maintaining system voltage when islanded	Storage optimization
Diverse customer mix (residential, commercial, industrial)	PV observability, controllability, and forecasting
Resiliency to wind, rain, and snow storms	Coordination of protection settings
Provide black-start capability	Selling energy and ancillary services
Energy efficiency (EE) upgrades	Data logging features
Cyber secure and resilient to cyber intrusion/disruption	Leverage private capital
	Accounting for needs and constraints of all stakeholders
	Demonstrate tangible community benefit
	Identify synergies with Reforming the Energy Vision (REV)

As shown in Table 5-1, the required capabilities for NY Prize microgrids emphasize clean and renewable generation sources, seamless automatic interconnection in parallel operation and islanded modes in accordance with interconnection standards, black start capability, supply of critical loads continuously during specified conditions, resiliency and reliability improvements, and energy efficiency improvements.

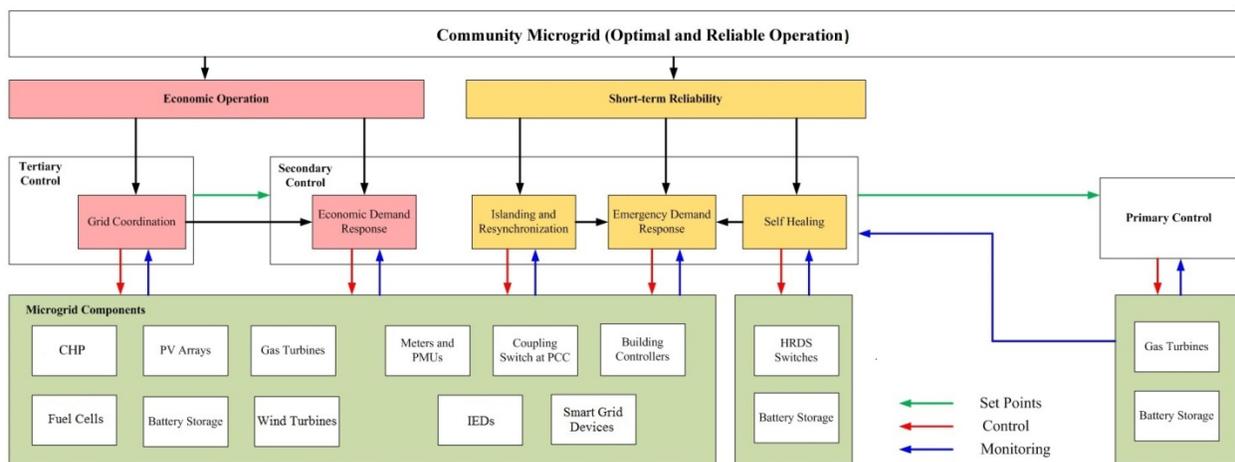
5.2.2 Microgrid Control System

In anticipation of the evolution of the smart grid and the complex requirements for interoperability and connectivity occurring in the State to implement the NY REV Initiative, most of the NY Prize Stage 1 microgrid proposals incorporated a computer-based microgrid control system (MCS) to implement the supervisory control and data acquisition (SCADA) systems, smart grid functions, active generation control and dispatch, load shedding, demand response, and interface with utilities and power markets. The MCS implements hierarchical control via the SCADA system to ensure reliable, economic operation of the microgrid. It will also provide the community microgrid with the flexibility and computing power to interface with local utilities, optimize potential revenue streams by participation in markets for power and ancillary services, and fully utilize advanced smart grid technologies, renewable energy sources, and energy storage systems. The integrated MCS and its associated communications network are the

points-of-application for implementing the latest cybersecurity schemes and technologies necessary to achieve secure operation and delivery of energy to microgrid customers and protection of hardware and data.

Figure 5-1 presents a block diagram indicating the objectives and functions of a typical community microgrid along with common microgrid elements and the control tasks and interactions that must be handled by the MCS.

Figure 5-1. Objectives and functions for control and operation of a community microgrid. (Adapted from Feasibility Studies #56 and #76)



“In order to achieve the optimal economics, microgrids apply coordination with the utility grid and economic demand response in island mode. The short-term reliability at load points would consider microgrid islanding and resynchronization and apply emergency demand response and self-healing in the case of outages. Functionally, three control levels are applied to the community microgrid:

- Primary control which is based on droop control for sharing the microgrid load among DER units.
- Secondary control which performs corrective action to mitigate steady-state errors introduced by droop control and procures the optimal dispatch of DER units in the microgrid.
- Tertiary control that manages the power flow between the microgrid and the utility grid for optimizing the grid-coordinated operation scheme.” [Feasibility Study #76]

“The hierarchical secondary control approach would receive the information from loads and power supply entities as well as the information on the status of the distribution network and procure the optimal solution via an hourly unit commitment and real-time economic dispatch for serving the load in the normal operation mode and contingent modes.” “...the monitoring signals provided to the master controller indicate the status of DER and distribution components, while the master controller signals provide set points for DER units and building controllers. Building controllers will communicate with sub-building controllers and monitoring systems to achieve a device level rapid load management.” [Feasibility Study #56]

5.2.3 Communications and Control Network

“Any modern utility or system operator relies heavily on communication infrastructure to monitor and control grid assets. For a microgrid master controller and microgrid operators, this architecture enables real-time control, rapid digestion of critical grid information, and historical data for analysis and reporting.” [Feasibility Study #56]

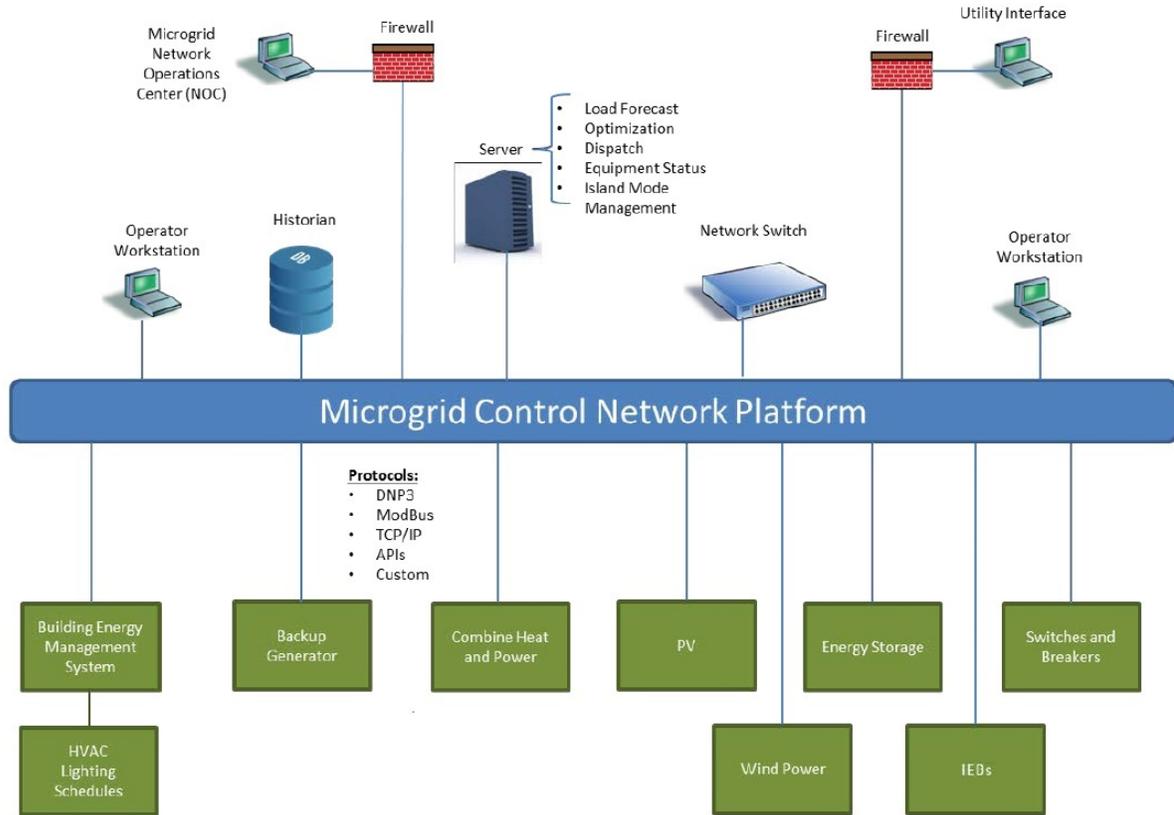
“A microgrid controller design needs to be reliable and have redundancy comparable to the other microgrid resources. A standard controller approach such as central controller or PLC design will, therefore, not be sufficient. The architecture must support the capability to interface with field devices, provide a platform for communications and data management, provide for both local and remote operator access, have a data historian, and provide for applications to meet the microgrid...” specified design functions and capabilities. [Feasibility Study #49] A conceptual microgrid control system architecture is shown in Figure 5-2.

The master control station would be a hardened server hosting monitoring, optimization, and control services. Communications with the utility-wide area network may be accomplished over secure 3G/4G, Worldwide Interoperability for Microwave Access, wireless radio, fiber optic networks or other communications links. Each microgrid facility is linked to the control system via a local control node, which is a hardened computer hosting local applications.

A typical community microgrid communications network “...will provide at least 100 Mbit/s Ethernet which is expected to be sufficient for all monitoring and control applications... The application-layer protocols will be selected among Distributed Network Protocol 3, Modbus TCP/IP, Modbus Serial, IEC61850, and Ethernet depending on microgrid deployed devices (e.g., intelligent electronic device (IED), PLC, switchgear, relay, sensors, meters, etc.)” [Feasibility Study #5]

A successful microgrid will take advantage of existing utility protection and control communications networks and infrastructure, within the local utility and the area served by the microgrid, to leverage these resources to reduce the costs of developing a new IT/communications network. A new dedicated communications network will be the most secure system, but it will also be the most expensive option.

Figure 5-2. Conceptual microgrid control system architecture. (Adapted from Feasibility Study #49)



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

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

“Maximum weather resilience and performance is achieved when underground fiber optic networks are deployed. Additional surety can be obtained by creating redundant fiber rings and including two-way communications. The use of fiber, redundant networks, and underground deployment makes this the most reliable and resilient method, but it is also the most expensive option. The generation portfolio for the microgrid and potential use cases during connected and islanded modes would go a long way [Study #64]

5.2.4 Cybersecurity

The microgrid control system network data must be fully encrypted when stored, accessed, and transmitted. Network segmentation by function, network firewalls, continuous monitoring of data activity will detect malicious activity and protect the microgrid from cyber intrusion and disruption. Access to the microgrid management and control center will be limited to authorized personnel with specified levels of access. Active analysis of security and access logs can help to provide an added measure of protection. The microgrid’s operating system and firewalls can be configured to monitor, record, and flag suspicious activities, intrusion attempts and other activities.

Smart grid devices and sensors, IEDs, hardware, and distributed logic controllers used within the microgrid system and at interface points with the local utility may be located at or nearby load points. This brings the microgrid SCADA network out to the edges of the microgrid’s service area where it may be more vulnerable to malicious activity. Tools to protect these distributed logic points must be implemented to maintain cybersecurity.

“Cybersecurity addresses protection against hacking and malicious intent. The microgrid design team will consider security options such as: modern hardware platforms and network nodes that incorporate device level authentication and authorization; adding security services to the microgrid control nodes and control center to address encryption of data at rest and data in motion; and adding a security architecture that applies defense in depth design principles, which includes segmenting of data and system components across different levels of security zones to offer a hierarchy of authorization constraints and system access barriers. Note that cyber security services can be added as a security

layer on top of existing communications when reusing networks but cannot change the existing physical security, resilience or performance limitations of the existing networks or device nodes.” [Feasibility Study #64]

5.3 Operational Interaction with Local Utility

At this time, we are in the initial stages of the evolution of the grid to incorporate the concept of community microgrids embedded within the local utility’s distribution control area. Stage 1 proposals typically involve a single microgrid residing within the distribution grid of a utility, requiring that contractual interconnection agreements and interface arrangements must be worked out between the microgrid stakeholders and the local utility. The microgrid developers need to work with the utility to understand the relevant features of local distribution systems, identify the current distribution network challenges in terms of parsing out a microgrid within the existing distribution grid, and ensuring that the overall larger grid will not be adversely impacted by the presence of one or more microgrids. These include issues such as ownership and control of system components, co-location of microgrid components on utility property, sale of energy to the grid, scheduling and forecasting demand, providing ancillary services to the utility and grid, and ensuring equitable compensation among the parties.

It was noted during the review of Stage 1 proposals, microgrids that were to be developed within the service areas of municipal utilities or co-ops, where the municipal or co-op already owned and controlled the infrastructure, controls, communications networks, and interfacing elements, had an easier pathway to success compared to the proposals that were being carved out of the existing service territory of the local investor-owned utility (IOU). In the case of municipals and co-ops, the points of common connection (PCCs) with the utility remain the same and the interaction agreements and contracts are already in place. New community microgrids developed within the service territory of the local IOU must work out these agreements from scratch with an IOU that is uncertain of the role of the microgrid, concerned about encroachment upon their service territory and customer base, and is working with existing policies that predate the concept of the community microgrid and its potential benefits to the power grid.

Major issues regarding operational interaction with the utility include control of generation resources, control of switching at the PCCs, and configuration of the protection system.

5.3.1 Control of Generation Resources

Under normal operation in grid parallel mode, the utility will develop load forecasts for the following 24 to 48 hours and may call upon the community microgrid to provide energy, ancillary services, configuration changes, and reschedule equipment outages to optimize the operation of the local distribution grid. In the case of unintentional islanding, the microgrid control system will operate in an automatic sequence to open the PCCs with the utility and stabilize the microgrid generators, inverters, energy storage devices, and load shedding schedules to pick up the microgrid's critical loads following a loss of the local grid.

5.3.2 Control of Switching

When intentional islanding is required, the utility operator will work with the microgrid operator to initiate the semi-automatic control of the PCC switches between the utility and the microgrid. "The utility operator will provide the appropriate permissives for opening the PCC(s). The local microgrid controller for each microgrid node will be responsible for setting the voltage source and load following resource." [Feasibility Study #49]

The transition from islanded mode back to grid-connected parallel load will be under the control of the local utility operator, who will provide the appropriate permission to close the PCC switches. The microgrid control system will monitor and support the reconfiguration of affected dispatchable resources and equipment.

5.3.3 Protection System

The microgrid protection system is designed to protect equipment and personnel. "The microgrid controller will ensure two primary conditions. The first is that each protection device is properly configured for the current state of the microgrid, either islanded or grid-connected. The second condition is that after a transition, the microgrid controller will switch settings or test that the settings have changed appropriately. If the test is false in either condition, the controller will initiate a shutdown of each resource and give the appropriate alarm." [Feasibility Study #49]

5.4 Fuel Resources and Storage

The majority of the Stage 1 microgrids proposed the addition of new natural gas-fired CHP units to cover the critical and important loads. Most of these indicated the availability of highly reliable sources of natural gas supplied by the local gas supply utility. It is important in the final design stages of the microgrid design process that the reliability performance and delivered volume of natural gas necessary for the CHP units to supply the design loads be verified.

Many microgrid proposals depend on existing or upgraded diesel generators to pick up the critical loads during peak demand or other emergencies requiring extended periods of operation. The length of time for operation of the diesel generators is determined by the specified design basis mission for the microgrid. Sufficient fuel oil storage must be provided on-site for the duration of the design basis emergency to keep the diesel generators operating. Some microgrids had delivery contracts in place with local fuel suppliers to bring in fuel oil by truck to assure adequate supply beyond the on-site storage capacity.

The initiating events requiring emergency operation of the microgrid, often involve severe weather events, floods, or other catastrophes, as discussed in Section 7. These large-scale regional initiating events may also affect vulnerabilities in the natural gas supply system and the diesel fuel supply chain. The microgrid designers must assess the risk to the fuel supply resources depended upon by the microgrid DERs during emergency conditions brought about by these initiating events.

5.5 Energy Efficiency and Conservation Improvement Efforts

Successful stage 1 NY Prize microgrids are those that are financially sustainable and can operate profitably for their owners and investors. The revenue stream of the enterprise can be maximized by implementing energy efficiency and conservation improvements to the critical facilities and important loads served within the service area of the microgrid so that more excess energy is available for export sale to the power grid.

The majority of the Stage 1 microgrids proposed the addition of new natural gas-fired CHP units to supply electric power to the critical and important loads. In some cases CCHP units are also included. Microgrids powered by these cogeneration and trigeneration units make very efficient use of the natural gas that they consume. The primary revenue stream for community microgrids comes from the sale of electric power. Provided that there are off-takers for steam, heat, and absorption cooling, the sale of

energy captured from the exhaust heat of these units can greatly supplement the total revenue produced by the microgrid and improve its overall financial viability.

Other energy efficiency measures noted during the review of Stage 1 feasibility assessments include: upgrading buildings, offices, residences, and street lighting to LEDs; implementation of building energy management systems; installing variable frequency drives (VFDs) on pumps in facilities such as waste water treatment plants, sewage plants, and water supply facilities; exploring demand response options with facility operators and local utilities; and including renewable generation with energy storage and load management systems to increase energy efficiency and reduce peak demand.

5.6 Operation and Maintenance Responsibilities

This subsection discusses the breakout of operations and maintenance responsibilities for various community microgrid configurations noted during the reviews of Stage 1 feasibility assessments.

5.6.1 Microgrids in Municipal and Cooperative Utilities

Proposed community microgrids that were to be owned by, and located entirely within the service area of, municipal utilities or co-ops generally did not have to significantly alter their interface agreements with the local utility. These organizations have their own operations and maintenance personnel to operate the generating plants and distribution system and to perform routine periodic maintenance on generation plants, electric distribution systems, steam and gas pipelines and equipment, storage tanks and fuel pumps, metering systems, and control and protection systems. Municipals and co-ops normally contract out larger, non-routine maintenance tasks and more extensive construction and modification projects. This practice would hold true for microgrid equipment and the more complex maintenance and testing requirements for microgrid control systems, energy management systems, and building energy management systems served by the microgrid and its controller.

Likewise, routine operational activities within the service territory of the municipal or co-op utility and associated with the microgrid will be handled by their own operations personnel. Most of the operational optimization tasks within the microgrid are handled automatically by the master microgrid control system, various distributed control systems in buildings and facilities served by the microgrid, and distributed logic controllers in IEDs on the microgrid distribution system.

If it is intended to export power to the local utility and provide demand response and other ancillary services to them, purchase power agreement (PPA) or other agreements are necessary to contract for these services. This will also require transferring a measure of microgrid O&M control to the local utility over scheduling of routine maintenance outages within the microgrid to ensure that power generation, demand response, and other ancillary services will be available to meet the forecast long- and short-term requirements of the utility transmission and distribution grid.

5.6.2 Single Community Microgrids within an Investor Owned Utility Service Territory

Proposals for single community microgrids embedded within the territory of a local distribution utility are dependent on the local utility for performance operations and maintenance tasks. These microgrids all incorporate the local utility's existing distribution circuits and equipment to interconnect the facilities served by the microgrid; additional circuits and automatic switches must be installed at PCCs at the interconnection boundaries with the local utility. Likewise, they depend heavily upon the existing communications and control infrastructure of the utility to design the microgrid control and communications network.

These types of microgrids are totally dependent on the utility for operating personnel, experienced maintenance crews and equipment, load forecasting and scheduling, and delivery of power from the grid during normal operating conditions. The agreements between these proposed microgrids and their interfacing utilities will, therefore, be much more complex, and will cover many issues that cannot be fully addressed at the Stage 1 level of the NY Prize Competition. Issues such as utility policy on microgrids, New York State utility regulations, PSC rules and regulations, ownership of microgrid equipment and controls, compensation to the utility for operations, maintenance and other support services to the microgrid, compensation to the utility for use of power system circuits and equipment, PPAs for microgrid-generated power, demand response services, and ancillary services, and legal and financial questions surrounding multi-party owned microgrids are not yet well-understood and fully developed.

Consequently, the most successful Stage 1 community microgrid proposals had the full support and cooperation from their local utilities. These utilities understood the potential benefits of microgrids in the future the State distribution grid and expressed a willingness to work with the NY Prize applicants to identify and address these issues to their mutual benefit.

In contrast, the Stage 1 applicants reviewed by BNL that did not have the full commitment of their utilities were not successful in developing feasible community microgrid proposals.

5.6.3 Dedicated Urban Microgrid Serving One or More Contiguous Campuses

Another unique configuration BNL reviewed was a dedicated microgrid serving multiple contiguous, similarly purposed campuses, in an urban setting. This microgrid is designed to have sufficient capacity to supply 100% of the electric load and the thermal needs of all four of its mission critical customers in both a grid parallel mode as well as in an islanded mode. Thus, this proposed dedicated microgrid shall act as a single controllable entity with respect to the grid, essentially a “virtual power generating plant,” and will be able to function in both a connected and disconnected or “island” mode during cases of the loss of the main power grid. [Feasibility Study #16]

The DER that provides power to this microgrid are proposed as a combination of multiple units to afford maximum flexibility of operation. This provides optimum matching of the DER capacity to the microgrid electric demand as well as the thermal needs of the customers. The DERs of the proposed microgrid will predominately use natural gas-fired cogeneration units, which will enable it to recover the waste heat produced during the generation of electricity. This will save energy and improve the system’s efficiency during normal operations as well as essential thermal energy during a loss-of-grid emergency. For further flexibility of operation, the CHP units will be backed up by solar PV generation as well as several diesel generator units, with on-site fuel storage tanks, to provide black-start capability. [Feasibility Study #16]

In this unique configuration, it is intended that the local utility “...provide control of the microgrid via SCADA automation, such that the transition from grid power to microgrid islanded operation will be fully automated and take effect immediately upon a loss-of-grid incident. It is proposed that all communications to the separating switches as well as the microgrid power distribution monitoring and control utilize fiber optic communication that will be routed in the same trench ways as the electrical distribution network. This would provide capability for complete isolation and grid independent operation to include isolation from [the utility’s] existing grid SCADA, hardening the [microgrid] from any cyber threat (potentially why a loss of grid incident might have occurred).” [Feasibility Study #16] “This would allow the utility to manage voltage and frequency regulation, and force the microgrid into island mode if necessary.” [Feasibility Study #16]

The design of this proposed microgrid configuration is for the local utility to own and maintain the lines used to distribute microgrid power. Each of the microgrid customers would have to develop contractual agreements with the utility to grant easements to the utility to perform installation of new facilities and for distribution system maintenance and repairs as needed. [Feasibility Study #16]

“Further discussions would be required to fully outline the contractual arrangements between the microgrid owner and the utility. Regulatory specifications would also be required as an outcome of NY Prize to facilitate this arrangement.” [Feasibility Study #16]

6 Global Issues Affecting Microgrid Development

This section highlights several important global issues noted during the BNL review of the NY Prize Stage 1 feasibility studies that have a general impact on the development of community microgrids in New York State. These include the legal, regulatory, and policy requirements associated with interconnecting community microgrids to the local utility power grid, the emerging role of microgrids in the future smart grid, and the structuring of financial and business models to support and sustain microgrid development.

The global issues will have an impact on the ways in which microgrids and microgrid stakeholders will interact with utilities and the electric power grid. The roles and interactions among the various participants are still evolving as we transition from the traditional power grid toward the future smart grid. Consequently, these global issues must be viewed as challenges to community microgrid development while the State, utilities, and PSC continue working together to identify and resolve problem areas to realize the goals of the NY REV initiative. Programs such as the NY Prize competition are very important because the observations, lessons learned, challenges, and solutions identified during the design, build, and operation of integrated community microgrids help to inform the NY REV process.

6.1 Interconnection Requirements

Community microgrids must comply with the PCS interconnection standards for new distributed generators connected in parallel with utility distribution systems. [NY SIR - 2016]

6.1.1 New York State Regulations & Requirements

Table 6-1 below outlines the most significant interconnection standards that apply to a typical community microgrid project in the State. [Adapted from Feasibility Study #27] The interconnection standards are grouped by category (common, synchronous generators, induction generators, inverters, and metering) in the table along with a brief description summarizing the highlights of the standard.

Individual "...customers connecting to the grid via DER projects must also follow the New York State Standard Interconnection Requirements (SIR) identified in [Table 6-1]." [Feasibility Study #27] The PSC has recently approved and published Standardized Interconnection Requirements for distributed generators with less than 5MW of capacity. [NY SIR – 2016]

Although typical single community microgrid CHP generators are normally smaller than 5MW, DER generators that are somewhat larger than the 5MW capacity limit still usually follow normal SIR. Most of the proposed community microgrid DERs will likely need to follow the normal State SIR.

In addition, the DEC and New York State Environmental Conservation Law have established limits on the emissions from DERs such as gas turbines and diesel generators. Existing fossil-fired generating units comprised a not insignificant part of the generation mix of many of the Stage 1 community microgrid proposals review by BNL. Diesel generators are subject to annual operating time limits, based on size of the unit, and are also restricted to operation only during designated emergency situations affecting the power system. In urban areas, such as New York City, emissions and operating time limits are more restrictive than those that apply throughout most of the state. Periodic testing is required to verify compliance.

Table 6-1. New York State Interconnection Standards [NY SIR - 2016]

Standard Category	Description
Common	Generator-owner shall provide appropriate protection and control equipment, including a protective device that utilizes an automatic disconnect device to disconnect the generation in the event that the portion of the utility system that serves the generator is de-energized for any reason or for a fault in the generator-owner’s system
	<p>The generator-owner’s protection and control scheme shall be designed to ensure that the generation remains in operation when the frequency and voltage of the utility system is within the limits specified by the required operating ranges</p> <p>The specific design of the protection, control, and grounding schemes will depend on the size and characteristics of the generator-owner’s generation, as well as the generator-owner’s load level, in addition to the characteristics of the particular portion of the utility’s system where the generator-owner is interconnecting</p> <p>The generator-owner shall have, as a minimum, an automatic disconnect device(s) sized to meet all applicable local, state, and federal codes and operated by over and under voltage and over and under frequency protection</p> <p>The required operating range for the generators shall be from 88% to 110% of nominal voltage magnitude</p> <p>The required operating range for the generators shall be from 59.3 Hz to 60.5 Hz</p>
Synchronous Generators	<p>Requires synchronizing facilities, including automatic synchronizing equipment or manual synchronizing with relay supervision, voltage regulator, and power factor control</p> <p>Sufficient reactive power capability shall be provided by the generator-owner to withstand normal voltage changes on the utility’s system</p> <p>Voltage regulator must be provided and be capable of maintaining the generator voltage under steady state conditions within plus or minus 1.5% of any set point and within an operating range of plus or minus 5% of the rated voltage of the generator</p> <p>Adopt one of the following grounding methods: Solid grounding High- or low-resistance grounding High- or low-reactance grounding Ground fault neutralizer grounding</p>
Induction Generators	May be connected and brought up to synchronous speed if it can be demonstrated that the initial voltage drop measured at the PCC is acceptable based on current inrush limits
Sources: [NY SIR - 2016] and [Feasibility Study #27]	

6.1.2 Utility Policy

In addition to the State requirements previously discussed, the individual policies of the local utilities with regard to the interconnection of DERs and microgrids may vary from company to company, but they will be based on similar concerns and considerations. Utilities must ensure the safety of personnel, customers, and system components against malfunctions, overloads, and protection system failures caused by the connection with and operation of community microgrids. The utility must be assured that the

presence of the microgrid and any switching operations involving the microgrid do not adversely affect the reliability and power quality of the local electrical distribution system and service to their customers.

Finally, they must be assured of fair compensation for their efforts supporting and contributing to the operation, control, maintenance, monitoring, and testing of microgrids operating within their service territory. The utility should be compensated for use of existing distribution lines, components, communications and control networks, and other hardware that will be shared with or leased to the microgrid, as well as new equipment and controls added to support the operation of the microgrid.

During the Stage 1 feasibility studies review it was observed that local utility policies were generally conservative and not yet receptive to the concepts of DER and community microgrids.

Examples noted included: restriction of certain generation facilities to the supply of power behind the meter only; minimum capacity restrictions for participation in ancillary services markets; and interconnection restrictions due to reliability and power quality concerns.

6.1.3 Federal Regulations and Requirements

In addition to the NY SIR requirements "...there is a possibility that interconnection will need to follow the Federal Energy Regulatory Commission (FERC) guidelines for small generators (2-20MW)." [Feasibility Study #27] Applicable FERC guidelines affecting DER and microgrids can be found at: <http://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp>. [FERC - 2016] Beyond the New York State environmental considerations, Federal environmental law such as the Clean Water Act and EPA regulations and emissions standards may apply to microgrids and in particular, fossil-fired DER.

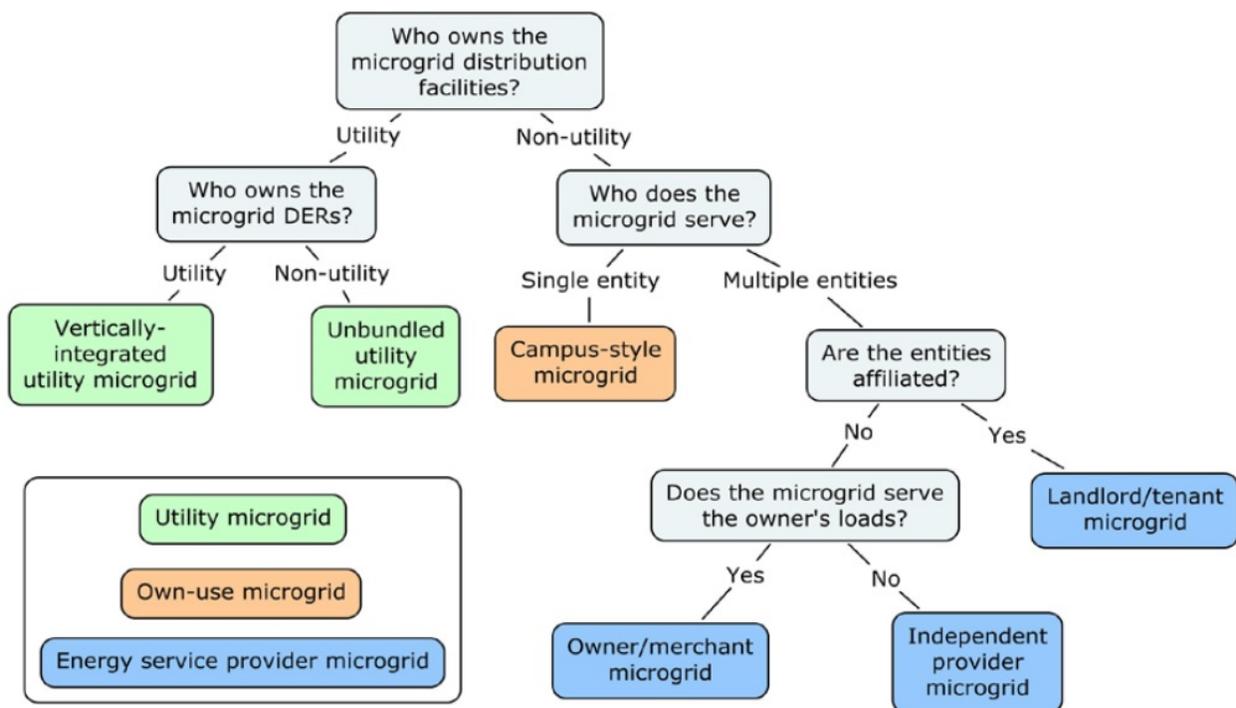
6.2 Business and Financial Considerations

The structure of the business agreements needed to implement community microgrids will be driven by the proposed partnerships, ownership rights, operating and maintenance responsibilities, and financing arrangements for the various possible microgrid configurations. The agreements among the various participants will most likely be quite complex and will need to address a variety of legal issues, some of which are anticipated and others have not yet been identified.

The roles of single-campus microgrids, institutional microgrids, and commercial generating facilities with respect to their interfacing utilities are well understood from the standpoint of business and financial considerations, purchase power agreements, and various rates for power and ancillary services. Community microgrids, on the other hand, will involve multiple party ownership of microgrid facilities, partnerships among private investors and local communities, and complex interactions with their local utilities. As discussed in Subsections 5.3 and 5.6, the interactions among the various parties and the local utilities may be quite complex and not yet fully defined. Consequently, the scope and detail of the agreements structuring these interactions, responsibilities, rate structures, and liabilities will mostly likely require extensive negotiations among the various stakeholders. The purpose of the NY Prize Stage 1 feasibility studies is to provide the applicants with the opportunity to explore the various business and financial arrangements that may be needed to develop their proposed community microgrid projects, which will in turn inform the NY REV process.

One of the Stage 1 Feasibility Studies reviewed by BNL used the decision tree illustrated in Figure 6-1 to represent the typology of the various potential microgrid ownership business models. [Feasibility Study #74]

Figure 6-1. Microgrid business ownership model typology. [Feasibility Study #74]



For example, in a vertically integrated utility microgrid financed through a public capital vehicle based on the most mature revenue streams currently available for microgrid, the local distribution utility would continue to be the owner of the microgrid's transmission and distribution assets. The vertically integrated utility microgrid "...ownership structure significantly reduces the complexity of establishing and managing the microgrid, and places operation responsibility mainly on the utility company, not including the design of generation facilities and any behind-the-meter modifications for load management. The microgrid owner is also responsible for design, construction, operation, and maintenance of the electrical distribution system that connects the generating assets to the facilities, as well as all points of interconnection with its own distribution system. The microgrid operating participants would be organized as a special purpose vehicle (the Microgrid SPV) for designing, building, owning, operating and transferring the microgrid assets for microgrid customers. The Microgrid SPV would be a Master Limited Partnership to secure the debt and equity financing needed to finance the microgrid." [Feasibility Study #74]

"A vertically integrated microgrid could raise capital through public markets by pooling the microgrid's assets and payment streams under a single investment umbrella. Public capital vehicles can secure funds on more favorable terms than would otherwise be available from private investors. The result is that investments in energy projects funded with capital raised on public markets has the potential to provide greater cost savings to customers than would otherwise be possible. The potential public capital vehicles available for financing the microgrid include asset-backed securities, master limited partnerships (MLPs) and real estate investment trusts." [Feasibility Study #74]

"In a second business model example, the ownership arrangements would fall into the "unbundled utility microgrid" category. This ownership arrangement "...envisions the microgrid owner serving as a "network coordinator" or "microgrid coordinator" that incentivizes customers to provide the highest value energy supply, load management, or ancillary services to the microgrid system by providing differentiated price signals. The Microgrid Coordinator's role would be more like that of a wholesale grid operator and provide highly differentiated price signals to direct investments by other service providers. The Microgrid Coordinator would focus on operating the grid, interconnecting customers, and managing complex transactions among growing number of actors. In particular, the local distribution utility would own a majority stake in the SPV created to own and operate the microgrid system. The SPV would be used to ring fence the microgrid assets to insulate ratepayers not served by the microgrid from potential operating risks." [Feasibility Study #74]

Another business model encountered during the BNL reviews of a community microgrid and a municipal utility microgrid was the Microgrid Energy Services Company, or MESCO (Microgrid Energy Services Company). “The MESCO is a modified version of an ESCO that will provide 100% of the energy needs of the microgrid customers both when the main grid is functioning and when it is out of service. The MESCO will own and operate the DERs and purchase energy from the NYISO, and/or other suppliers. When the main grid is functioning, the MESCO will utilize the DERs and energy purchased from the NYISO to supply energy for the microgrid customers. When the main grid is out of service, the DERs would supply 100% of the energy for all microgrid customers, including the peak electric loads. The MESCO will include both “behind-the-meter” DERs, and utilize the existing PSEG-LI distribution system to distribute energy from DERs to customers that do not have adequate behind-the-meter supply.”

A design and engineering partner of one of the NY Prize Stage 1 applicants nicely summarized the evolving research and challenges that must be explored toward defining the concept of the small community microgrids and their role in achieving the goals of the NY REV initiative:

Research “...considerations in microgrid development may center around three areas. First, research into relatively small grid systems with multiple generators (some spinning, some inverter-based), temporally and spatially variable loads, and multidirectional power flows may inform better designs and more efficient placement of generation and controls relative to loads. The second is optimizing financial structures for collections of distributed energy resources and control infrastructure. To-date, most microgrids in the United States have been campus-style developments in which the grid serves a single institution and can be easily segregated from the macrogrid. Community microgrids consisting of multi-party owned facilities and generation are a new concept, and literature on how best to own and operate such developments is not yet robust. Lastly, and related to financial structures, is the idea of how a “grid of grids” would be managed and structured to provide optimal operational support and the right mix of incentives to encourage customer and utility buy-in.”
[Feasibility Study #27]

6.3 Stakeholder Issues

Each of the actors that play a significant role in the planning, financing, design, operation and final use of a microgrid has unique interests in the success of a microgrid and can benefit from it various ways. This sub-section will focus on the role played by each stakeholder and the opportunities that a microgrid can offer them.

6.3.1 Support and Ownership Scenarios

Different ownership scenarios can occur for the microgrid and its generation assets, while in the majority of cases, the utility will continue to own and operate the distribution network. The ownership configurations can be multiple from the most common public-private partnerships, including the public-private-partnership (P3) design-build-own-operate-maintain (DBOOM) structure, to multi-stakeholder ownership, public-purpose funding (town, public office, or county ownership), cooperative ownership, microgrid-as-a-service, and a team forming a special-purpose limited liability company to own the microgrid assets (including both independent investors and end-users who have chosen to invest in the project). Owners, partners, and stakeholders can list, among others, citizens, businesses, technical service providers, utility companies, communities and government entities. Distributing costs between and delivering benefits to all parties is an approach that makes the business case of a microgrid possible. Depending on future regulatory and market developments in the State, microgrid owners may have opportunities to create new revenue streams similar to those pursued by Community Choice Aggregation entities.

As previously mentioned, the P3 is the most common ownership form for a microgrid and it is central for commercial viability. In the case that the community may lack financial resources to design, plan, and construct the microgrid, the P3 approach could help overcome two issues: project financing and microgrid design, construction, operation, and maintenance. Members of the microgrid project should be prepared to provide cost-sharing capacity, but external financing support is often required in order to develop the project. Investors should be considered and need to be engaged in the microgrid.

6.3.2 Developer Roles and Opportunities

The microgrid developer is expected to consider different technical, political, legal, and social aspects of the project to make it the optimal platform to achieve financial and end-use benefits. With respect to the developer, the owner can maintain control of the project or, as in the case of the P3 DBOOM structure, it can shift construction, technical, financial, and operational risk to a qualified, financially strong entity with a proven track record. An added benefit of the P3-DBOOM approach is that it allows the private entities to monetize the tax related benefits associated with the deployment of certain distributed generation technologies including PV, fuel cells, and cogeneration.

The microgrid developer should primarily focus on certain issues:

- Combine multiple generation technologies among the resources (including CHP, natural gas, renewables and storage) to achieve the purpose of resiliency and reliability of the electricity and heat distribution.
- Investigate the possibilities for generation interconnected on the utility side of the meter to avoid damaging rates. PPAs with end-users should also be considered, which improve their energy costs over the term of the agreement. In exchange, end-users should agree to host power generation equipment and balance of plant at no cost, interface BMS with the microgrid controller, curtail in the event the load exceeds capacity, and be under variable pricing formulas to mitigate the risk of the load exceeding capacity. Depending on the microgrid size, anticipated peak demand and load size, the energy produced by the microgrid assets can be consumed directly by the microgrid without planning to sell energy back to the grid.
- Define the proper contractual form for the customers. The financial feasibility of the project may be sensitive also to the negotiated price of excess power produced, for example by the fuel cells, during off peak periods as well as the price of natural gas. The goal is to obtain a positive net present value without external funding, but investors may be needed. The financial feasibility of the microgrid ensures that the project can be of interest to financiers and investors also in the future.
- Leverage existing utility infrastructures.
- Appropriately locate the generation capabilities to support high-penetration levels, reliable configurations of the system, and provide targeted support to the grid.

6.3.3 Utilities Support and Responsibilities

The support from the local utility is a fundamental aspect to consider in the planning process of a microgrid. The microgrid stakeholders will likely have legal and tariff issues to be arranged, which will add time and costs. A good relation and negotiation process with the utility in advance of the microgrid construction needs to be maintained and it can help facilitate the solution of the issues that are faced. It is important to consider that the installation of the microgrid interconnection lines and switches will be subject to the negotiation of an acceptable agreement with the utility for co-locating facilities within its right-of-way. The microgrid generation units suitable for paralleled interconnection are subject to IEEE-1547 requirements as well as Northeast Power Coordinating Council, Inc.-A03 low frequency ride through standards. It would be more beneficial to both parties if there was an additional incentive for the utility to encourage and drive the behind-the-meter development of DERs as an offset to capital projects, which would occur in the absence of DERs and microgrids.

In addition, among other potential features to contemplate with the development of a microgrid there is the design of rates that guarantee that the involved utility is compensated for the operating costs—e.g., Active Network Management—similarly to capital costs. Furthermore, the utility and the microgrid team should work together to develop an understanding of the significant aspects of the electric distribution

system and identify the current distribution network challenges to ensure that the existing distribution grid will not be harmfully impacted by the new microgrid participation. In this context, the discussion with the utility should be also driven to consider the opportunity of the ancillary services that the microgrid could sell to the utility and support the local power quality.

6.3.4 Community Involvement and Support

Community participants in a microgrid project may include a mix of town-owned facilities, hospitals, community infrastructure operators, senior centers, schools, and so on. Community support of a local microgrid project can have different reasons, from the need of improving the reliability of its electricity supply to understanding local geographic area vulnerability to annual natural disaster risks. In addition to improved grid reliability and resiliency benefits, the community could experience benefits including an increase in overall property values, opening the door to an improved economic activity and businesses desire in the area. Most end-users do not place value on the incremental reliability that a microgrid can bring unless they currently face issues or place a high value on reliability, such is the case of a high-tier datacenter. Having end-users who are concerned about reliability based on frequent outages and the impact they could have on their large-served populations of patients, worshippers, students, etc. may be an important input from and to the community to support a local microgrid project. Otherwise, without strong support and valuable reasons, microgrids are currently difficult to develop without significant, if not 100%, funding by outside parties or developers.

6.3.5 Microgrid Access by Non-Critical Customers

“Engaged communities are important, but so are realistic expectations of what a microgrid might include. Many communities expected dozens of facilities, or entire towns, to be included in the microgrid without understanding the limitations of the electrical and gas systems, the utility’s operation requirements, or simple cost feasibility. While the Project Team worked with each community to scope out and incrementally refine the facilities for inclusion, there is still much work to be done communicating the infrastructural realities of microgrid development. Setting expectations ahead of future microgrid initiatives will help communities begin with more concise and actionable goals for their community microgrids.” [Feasibility Study #27]

7 Risk Analysis and Management for Improved Reliability and Resiliency

A microgrid, as an energy system, can be affected by different types of hazards: technical, natural, and politico-economic. These hazards can be diverse in nature, mainly distinguished into accidental (hurricane, flood, transformer failure, outages) or voluntary (cyberattack) events leading to different degrees of risk. The voluntary man-made risk associated with cybersecurity and the preventive actions that can be enacted to protect the grid from an unwanted cyberattack is discussed in section 5.

The discussion in this section focuses on technical and mainly natural hazards that may affect a microgrid. At present, the role of a microgrid is to improve reliability, resiliency, and stability of the electricity distribution in selected areas involving specific sensitive customers; however, we may expect that in the near future and with the proper policy support in place, regular deployment of microgrids in areas sensitive to the unpredictability of adverse weather conditions, covering a large range of customers, with a widespread residential inclusion.

Understanding and managing the extent of possible hazardous impacts and their time span of duration can help avoid major failures and plan the necessary technical improvements to include in the microgrid design. It is not easy to identify and quantify the proper parameters capable to express the level of safety and security of a microgrid; some parameters need a qualitative categorization. However, being able to quantify or qualitatively categorize relevant aspects could help the definition of the necessary approach to support the final goal of improved reliability, resiliency, and stability of the electric distribution in the identified area. The approach can vary from redundancy of components to better equipment protection and so on. Some important aspects and solutions are discussed in the next paragraphs.

7.1 Natural Disasters and Approaches for Potential Mitigation Strategies

New York State can be vulnerable to natural events such as hurricanes, tropical storms, tornadoes, extreme cold, snowstorms, and blizzards. Nevertheless, major storm-related events are more likely during certain seasons or months of the year than others; thus, some preventive actions can be taken, such as avoiding scheduled equipment maintenance and ensuring necessary fuel storage is in place.

All equipment and construction involved in a State microgrid should be designed to be resilient to the forces of nature. A good rule should be that they can withstand category 4 hurricanes (Staffer-Simpson scale), category F2 wind speeds for most areas of the U.S. and F3 for some historical high-risk areas, and seismic event magnitude 6.9 (Richter scale) or 100-year local seismic event, whichever is less.

To protect in case of a flood, the height of the base foundation for outdoor units should be designed to ensure the equipment is at least one to 1.5 feet above the 100-year flood plain level. This may mean that existing planned installations need to be relocated. Overhead risks from buildings and other structures located above the microgrid equipment should have due consideration, including the presence of trees and vegetation on the path of aerial cables or near the outdoor facilities. Other preventive approaches may involve using existing indoor locations, adopting outdoor enclosures, identifying locations above flood plains, and using natural gas as a main source of fuel (CHP/CCHP plants). Once strategically positioned, it is expected that natural gas power generation should be able to run for days in case of emergency without an on-site operator. If the natural gas distribution pipelines are in areas prone to flooding, then the delivery should be converted into high pressure distribution, resistant to flooding to avoid shutdown for risk of water infiltration.

Aside from the general need to locate CHP installations, solar PV, and energy storage outside or above of the flood plain, there are additional specifications to consider for some DER installations; for example, CHP and solar PV plants should be designed to resist seismic and wind loads. The CHP units and energy storage equipment can be housed in structures compliant with the State Building Code to withstand all anticipated weather events. In addition, snowstorms and snow removal should have high priority for technologies located outside, such as solar panels participating in the microgrid assets.

It is very important the portions of the grid distribution system that will become part of the microgrid should be storm hardened, with possible relocation underground to reduce vulnerability. However, despite underground positioning, it must be taken into account that major storm events have shown negative consequences even when most of the electrical distribution is underground. When evaluating a risk mitigation strategy, extreme events may be considered to the limit allowed by their financial impact on the microgrid design, construction and operation, as well as depending on the importance and sensitivity of the connected loads.

7.2 Approaches and Parameters for a Safe and Secure Microgrid

Technical, economic, and financial risk assessment must be performed during the microgrid design phase. Risk management along with emergency planning, including risk zoning categories, especially when relevant fuel storage or outdoor equipment with explosion/fire risk are involved must also be considered.

For example, the approach may evaluate possible flood scenarios and pumping in place to mitigate the risk. It may look into the economics and the financial risks for potential investors and customers. It should account for the amount of thermal customers expecting the microgrid to provide them with full peak demand and consider carefully investigating customers' building envelopes and heating systems ahead of time. It should also contemplate a minimum threshold of electricity consumption is something customers will likely feel comfortable committing to, especially if cooling loads are not included into that minimum threshold. However, there are several points of risk that the microgrid risk assessment, as well as business plan, must carefully consider.

This exercise is a fundamental part of achieving a safe and secure microgrid, capable to provide the expected services and at the same time being a good investment platform for stakeholders.

The availability and capability of rating specific parameters to evaluate the level of risk/benefits that a microgrid can add to the local and regional community could be a valuable way to understand if the system complies with its purpose. However, it is not always straightforward to rate and qualify parameters. One example is given by resiliency—the majority of the microgrid projects may state that the microgrid will enhance the resiliency of the electricity delivery to the involved community, but there is not a commonly agreed and clear way to quantify resiliency.

The National Infrastructure Advisory Council (NIAC) defines infrastructure resilience as "...the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event." [NIAC – 2009]

One important variable of resiliency is time, identified as the time of a system to react and recover after a disaster (technical, natural, or cyberattack). A system reacting better with a shorter recovery time after a disaster is more resilient than a system that falls into a more critical situation with a longer recovery time. In such a vision, resiliency is an important characteristic of a reliable system, and both aspects are interconnected. For this reason, the technical choices made for the microgrid are determinant. For example, it may be possible to limit the risk from losing parts of the existing utility feeders involved in the microgrid by allowing the microgrid to function in smaller independent sub-microgrids, increasing resiliency and reliability, partly reducing the system functionality, and possibly requiring load shedding.

Furthermore, using technologies with very long, reliable track records can help reduce technical risk, and at the same time support the technical viability of the microgrid. It is also important that the project team work with the local utility to understand current distribution network challenges and how the microgrid can mitigate the correlated risks. This not only includes looking at current issues, but also accounting for possible future microgrid expansion and load growth in the area as well. Urban environments with a mature physical infrastructure and established gas and electric tariffs more easily support the microgrid team working with end-users and utility partners to coordinate efforts with REV and the PSC and look for ways to mitigate the impact that regulations may have on microgrid implementation and a solution for containing risk.

The previously mentioned reliability is another parameter of relevance to consider in the feasibility and design phase of a microgrid. Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. In estimating the reliability benefits of a microgrid, the BCA employs metrics that separately evaluate outages caused by major storms or other events beyond a utility's control (classified as "major power outages"). The New York State Department of Public Service requires utilities delivering electricity to collect and regularly submit information regarding electric service interruptions. The reporting system specifies 10 cause categories: major storms, tree contacts, overloads, operating errors, equipment failures, accidents, prearranged interruptions, customers equipment, lightning, and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). A reliable microgrid would reduce customers' susceptibility to such power interruptions by enabling a smooth transition from grid-connected mode to islanded mode. The reliability benefits of such a microgrid can be quantified in monetary terms over the operating lifetime. They can also be quantified in term of likelihood and average duration of outages in the service area using the U.S. Department of

Energy's Interruption Cost Estimate Calculator; the System Average Interruption Frequency Index (SAIFI) and the Customer Average Interruption Duration Index (CAIDI) can be calculated for the specific microgrid project and represent two valuable reliability parameters. The estimate of the two parameters incorporates the number of large commercial or industrial customers the project would serve; the distribution of these customers by economic sector; average annual electricity usage per customer; and the prevalence of backup generation among these customers. It also considers the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15% failure rate for backup generators. It assumes that establishing a microgrid would reduce the rate of failure to near zero.

It is important to note that the analysis of reliability benefits assumes development of a microgrid will protect the facilities the project would serve from outages of the type captured in SAIFI and CAIDI values. The distribution network within the microgrid is unlikely to be wholly invulnerable to such interruptions in service, though extreme scenarios should be always kept in mind, not to overstate the reliability benefits a project would provide.

Importance may be also given to the quantification of the power quality benefits of a microgrid. They 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, which are not captured in the reliability indices). Despite the quantification of the avoided power quality issues relies mainly on the microgrid team's best estimate, avoiding five power quality events per year may be already considered a positive achievement.

7.3 Effective Solutions for Better Microgrid Reliability and Resiliency

Aside from important feasibility design evaluation parameters, reliability and resiliency are critical to the microgrid community and statewide grid infrastructure. From a reliability perspective, the weakest sections in a microgrid infrastructure are the overhead portion of the feeders. Overhead lines are impacted by vegetation (mainly trees), lightning, and animal activity correlated with trees. Whenever possible and economically feasible, all electrical cables should be installed in underground concrete encased ducts, which will provide full resiliency against major weather phenomenon. If a severe weather event was to impact the area, a minimum of one week of full microgrid operation should be the target.

The microgrid should improve the local grid resiliency for the connected customers. It may also seek to negotiate a cost of “additional resiliency” and provide the financing of this into the microgrid contract with the customers. Under such a scenario, any additional operating expense that would be incurred by the microgrid to provide a “premium” resiliency service, on the demand of one site, would be an additional cost charged to that site.

To provide a resilient network design, the microgrid team should work with the utility and the stakeholders to develop hardening strategies commonly practiced by systems engineers in areas exposed to storms and outage events. This includes fault-tolerant and self-healing network designs, redundant or reconfigurable supply, remote monitoring and diagnostic equipment, robust construction, use of submersible equipment in underground construction, and a number of other time-tested measures.

A multi-zone microgrid system can be developed, combining several separately islanding systems. With an eye on the future development of the grid, it can be envisioned that the likely widespread presence of microgrids within the electricity system may allow portion of adjacent microgrids to rapidly reconfigure and connect between each other for a sustainable dynamic resiliency of the grid.

Nevertheless, the microgrid should be designed to allow a minimum of N+1 redundancy to meet the only critical loads. Redundancy is a common effective solution in technical systems. The microgrid controller design will utilize redundancy in the server, data collection server, and in the communication system design. This could include redundant fiber rings with redundant Ethernet switches at each key site/facility in the microgrid. Intelligent devices, such as UR relays, eight series relays and controllers, offer redundant communication ports and reduce failover time to zero through IEC 62439-3 Parallel Redundancy Protocol. This feature helps minimize cost by using a single, high-reliability IED/controller instead of two devices. Maximum weather resilience and performance is achieved when underground fiber optic networks are deployed. Additional security can be obtained by creating redundant fiber rings and including two-way communications. The use of fiber, redundant networks, and underground deployment is the most reliable and resilient method, but it is also the most expensive option and its impact should be evaluated in the BCA.

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

The precise benefits of Smart Grid/Distribution Automation (SG-DA) to storm resiliency and recovery are harder to quantify (due to the lack of available methodologies and metrics), but anecdotal evidence suggests they are real and potentially substantial. Smart Grid/Distribution Automation (SG-DA) solutions should be explored to ensure reliability in both connected and islanded mode and to enable rapid, continuous transfer when the grid is down. Strategic placement of field devices can enhance the flexibility and innate reliability of the microgrid area, whether it is in grid-connected or islanded mode. Reclosers, sectionalizers, and fuses are the mainstays of conventional utility overcurrent protection schemes. Digital sensors and measurement devices, such as transformer monitors, remote fault sensors, and Advanced Metering Infrastructure Smart Meters all help to provide additional situational awareness to both the utility operations center and the microgrid control system, allowing faster detection of fault conditions and operators to respond more rapidly. During the entire process, collaboration with the utility is fundamental. The interaction with the utility can help to solve issues such as metering, rights of way, how to “share” the use of distribution lines, and how to interface with and sell/buy power with the grid.

8 Conclusions and Findings

This section summarizes the highlights of BNL's independent review of the selected sample of NY Prize Stage 1 Feasibility Assessments.

8.1 Conclusions

Based on the results of the independent review conducted by BNL, some of the major conclusions are as follows:

- A well-defined and focused mission statement; i.e., the reason for developing a microgrid in the community should be clearly defined to specify basic design and performance parameters, and establish a realistic preliminary design.
- Early in the design and planning process the microgrid designers must identify and characterize the critical and essential loads to be supplied by the microgrid. Other non-critical loads must be categorized and prioritized by level of importance; these groups of loads may have to be shed in order of their level of importance during high demand periods, during transitions from grid parallel operation to islanded mode and back. Historic load profile data will be used to size and schedule DER required by the proposed community microgrid.
- Hospitals, medical centers and clinics, and emergency medical care services and facilities were identified as critical loads in all the feasibility studies that BNL reviewed. These were the core loads in most microgrids and ensuring a continuous supply of power to these facilities was a primary mission objective.
- The majority of the Stage 1 feasibility studies reviewed by BNL proposed natural gas-fired CHP (and CCHP) as the new baseline DER in their community microgrids. The dependability, flexibility, low-emissions, and availability of the low-cost natural gas fuel supply currently make these cogeneration and tri-generation units the DER-of-choice for microgrid applications. The primary revenue stream for most of the Stage 1 proposals is the sale of electric power from their DER. The capturing of exhaust heat energy from the generating units for thermal steam heating, hot water production, and with absorption chillers for space cooling can boost the overall efficiency of these units to nearly 90%. Sale of these by-products of the generation process can contribute additional revenue streams for the microgrid to significantly augment their financial viability.
- Most of the successful microgrid proposals were those that had compact physical size: the critical loads and designated important loads that were to be supplied by the microgrid were located within close proximity to each other and to the generation sources. This allowed maximum use of existing infrastructure and helped microgrid developers to minimize the high costs involved with building new interconnecting infrastructure. This includes new electrical distribution circuits as well as natural gas and fuel pipelines, steam lines for thermal energy off-takers, and communications and control networks.

- Developing the project-specific details of the design of a new microgrid project is a complex and critical undertaking that will have a significant impact on the overall success and financial sustainability of the project. Most communities have little or no experience regarding technical projects such as the development of a microgrid nor do they have on staff the engineering, technical, legal, and financial expertise to tackle such an undertaking. Consequently, the most successful applicants were those that partnered with established design and development engineers that had extensive experience in the development of microgrid projects in NY State.
- “The highest uncertainty facing [a community microgrid] project is its financial viability. It is important to recognize that the financial viability of the proposed project depends on access to external funding or additional revenue streams to offset approximately half of the expected investment costs. The valuation and monetization of major power outage benefits potentially play key roles in achieving financial viability, and providing a model for future microgrid investments.” [Feasibility Study #1]
- “The most significant issue facing microgrid development in New York and elsewhere is the lack of a consistent legal and regulatory framework. This must be addressed for the emergence of a stable microgrid business environment. For specific projects...these issues can be addressed on a case-by-case basis, and help develop policy models and experience for more systematic implementation of future projects. However, a case-by-case approach will limit the growth of microgrids.” “... there are common issues that require legal and regulatory solutions for the development of a consistent framework:
- “Definition of microgrid and utility franchise: The NY PRIZE Stage 1 awards used a definition of a microgrid that would violate utility franchises is put into general practice. Except for campus facilities, the traditional definition of utility franchise areas would prevent the development of non-utility owned microgrids serving multiple utility customers. Re-definition of a utility franchise will be needed at the state level. In particular, it should not be a violation of the utility franchise when a non-utility microgrid is installed, subject to reasonable limitations. Limitations might be based on geography, purpose, number and/or types of customers, and other factors.
- “Cost recovery: This is also related to the ownership of the microgrid infrastructure. Utilities may be able to recover microgrid costs under conventional rate-based regulation. Non-utility microgrid owners may require standard tariffs and/or other types of contracts with utilities to insure reasonable cost recovery and recognition of benefits, such as capacity, energy, and renewable energy benefits.
- “Infrastructure and interconnection: Technical issues are likely to arise related to the interconnection of multiple microgrid systems within a utility-owned distribution system. The means to quickly identify and analyze potential problems and opportunities will help to greatly accelerate siting.
- “Value of resiliency: A key benefit of microgrids is increased system resiliency, however, the value resiliency is not universally defined or quantified. A consistent approach to defining and valuing resilience is going to be very important to the economics of many microgrid projects.” [Feasibility Study #1]

- The roles of single-campus microgrids, institutional microgrids, and commercial generating facilities with respect to their interfacing utilities are fairly well understood from the standpoint of business and financial considerations, purchase power agreements, and various rates for power and ancillary services. Community microgrids, on the other hand, will involve multiple party-ownership of microgrid facilities, partnerships among private investors and local communities, and complex interactions with their local utilities. The interactions among the various parties and the local utilities may be quite complex and not yet fully defined. Consequently, the scope and detail of the agreements structuring these interactions, responsibilities, rate structures, and liabilities will mostly likely require extensive negotiations among the various stakeholders. The NY Prize Stage 1 feasibility studies provide the applicants with the opportunity to explore the various business and financial arrangements that may be needed to develop their proposed community microgrid projects. However, the full details of the business models in multi-party owned microgrids involving private-public partnerships will be developed and finalized in the New York Prize Stage 2 audit-grade engineering design and business plans.

8.2 Findings and Observations

Based on the results of the independent review conducted by BNL, some of the important findings and observations are noted as follows:

- “New York State policy does not currently address microgrids in a cohesive or holistic manner, nor have utility programs adequately recognized microgrid operations in their policies. Demand response is a potentially lucrative revenue stream in New York; however, current policies do not address microgrid demand response participation.” [Feasibility Study #1]
- Some gas utility policies create barriers to microgrids: a [natural gas] utility’s “...gas tariff for electric generation includes a Value-Added Charge (VAC) that could result in prohibitive delivery charges for gas for the electric only generating plant. In addition, the VAC charge can impose a year-end True Up charge for generators that cannot be predicted or passed on to customers. These policies could effectively preclude use of pipeline gas for the electric only generating plant, even if pipeline gas proves to be available on an interruptible basis.” [Feasibility Study #18]
- Full cooperation and participation by the local utility is critical to project success. Project teams often experienced problems with information flow. Reportedly, utilities were guarded about fully providing data in response to design team requests for engineering information about feeders, switches, and other infrastructure from the utilities to inform the best possible microgrid design. Gathering data required significantly more time and dialogue than expected and the utilities may have been unprepared for the volume and detail of data requests from design teams. [Feasibility Study #27]

- “Investor-owned-utilities in the Project Team’s portfolio...” “...were uniformly against allowing a third party operational control of utility-owned infrastructure. This view is understandable; however, it engenders a particularly difficult situation if the utility does not support the microgrid development. In such situations, the microgrid will generally be forced to construct duplicate infrastructure, with is both prohibitively expensive and against the spirit of the NY Prize. In general, utilities which support the integration of their infrastructure to the extent technically possible allow for more expansive microgrid possibilities.” [Feasibility Study #27]
- “The NY Prize program provides highly valuable funding for early stage design. However, early stage funding is also needed for other microgrid projects to expand deployment of microgrids. The costs to obtain, compile and analyze data from multiple facilities, and design the DERs and controls, and develop a microgrid project, are high in relation to the project size and risk. Government funding is critical for providing early stage capital to perform these tasks, and develop projects to the point where they can attract permanent private project financing.” [Feasibility Study #5]
- The existing tariff structures of many NY utilities do not permit net metering from CHP resources. “Net metering of microgrid assets allows assets in beneficial locations such as locations where waste heat use can be maximized, to be sized to generate more power than that location can use. It also allows for microgrids to share generation assets in such a way that keeps the overall efficiency of the generation maximized. Without such a mechanism for sharing generation, community microgrids would be forced to either build separate distribution systems or scale back generation.” [Feasibility Study #2] Modifying tariffs and policies to enable net metering of CHP resources in any microgrid, in multiple utility service territories that serve the community at large, would further stimulate microgrid development as envisioned by the New York REV and remove restrictions that oppose the progress that the REV is trying to achieve.
- “The ability to sell capacity, energy and ancillary services into the NYISO market would make any new generation financially more attractive. To enable the engine-generators to sell power back to the market when the [municipality or community] does not require the energy, the engine generators would have to be connected directly to the transmission system. Alternatively, “behind the meter/net generation” regulations are currently being discussed in the NYISO committee(s) to recognize resources installed “behind the meter.” If promulgated, the regulations could permit partial or full recognition of the capacity, energy and ancillary services of the behind-the-meter resources in the market.” In one feasibility studies reviewed, installation of a new engine generator “in front of-the-meter” would increase the installation cost by an estimated \$0.5 M compared to behind the meter installation of those assets. Behind-the-meter recognition would also possibly recognize the planned solar generation. [Feasibility Study #12]
- The creation of an “M” Solar Program for government/municipal facilities by NYSERDA, NYPA, or other state agencies, similar in concept to the “K” Solar Program for schools in New York State, would “...would help reduce costs and help achieve economies of scale and accelerate installation [of solar PV generation] across the State. A similar program for battery storage sponsored by NYSERDA and/or NYPA would also help lower costs and speed implementation as well.” [Feasibility Study #12]

- “Battery storage systems were investigated in this phase but excluded from the [proposed] Microgrid because of their very high capital costs which resulted in payback periods well beyond the replacement life of the batteries. Battery storage could be a valuable resource to (a) store off-peak power for use during on-peak periods; (b) reduce [the municipality/community] need to run their generator fleet, resulting in reduced emissions; (c) avoid power purchases during peak pricing (which may not be coincidental with [the municipality/community] peak needs); (d) solar energy storage during off-peak periods (holidays, off hours) (e) load shifting, and (f) provide additional voltage regulation during islanded operation. Battery storage systems have gained a lot of interest over the recent years as they continue to be implemented into commercial systems. The price of battery storage systems is predicted to drop significantly over the coming years with improving technology and economies of scale. RRT is currently involved in a battery storage system design in NYISO Zone J which could reveal application synergies.” [Feasibility Study #12] Establishment of a Municipal and School (“M & K”) Storage Program, sponsored by NYSERDA, NYPA, or other state agencies, would help “...lower the soft costs of storage and realize purchasing discounts for equipment and installation service by aggregating installations across multiple entities. This would help [municipalities/communities] and other government agencies across NY State conform further to the Governor’s Reformed Energy Vision and his mandate of meeting 50% of energy needs with renewable resources by 2030.” [Feasibility Study #12]
- Local utilities or NYSERDA “...should consider providing microgrid energy credits and/or capacity payments (“MECs” or “MCAPs”), similar to renewable energy credits for renewable energy sources, to provide financial incentives for DERs that support microgrids and are not eligible under the Renewable Portfolio Standard. The MECs or MCAPs would be justified in light of the financial, societal and environmental benefits provided by microgrids.” [Feasibility Studies #4 and # 5]
- Zonal capacity prices sometimes do not reflect the need for local peaking power. The proposed electric generation facility would reduce the need to dispatch the [local] liquid-fueled peaking plant...” “... and help reduce transmission constraints. However, the value of these benefits is not reflected in zonal capacity prices. As a result, the project would not be economically viable without a subsidy, or a PPA with PSEG-LI [in NYISO Zone K] with a fixed capacity payment that is more than the zonal capacity price.” [Feasibility Study #5] NYISO capacity payments for Zone K (Long Island) are far below the Net Cost of New Entry, [and] thus do not provide sufficient fixed cost recovery to render new projects financially viable based on market revenues alone.” [Feasibility Study #14]
- “As part of REV development, the Transmission Service Charges (TSCs) paid by wholesale buyers, and stand-by and demand charges paid by retail customers, may need to be reconsidered and modified in the REV DER pricing. The REV framework includes a pricing mechanism to be applied to DER, called LMP+D. LMP component is based on the NYISO Locational Marginal Pricing. The “D” part of “LMP+D” should reflect the true impact and cost of DER (include those in the microgrid) on the distribution systems. Hence, it is expected that the “D” component is expected to cover all other costs or values not covered by the LMP, such as TSCs and stand-by and demand charges.” [Feasibility Study #5]

- “Engaged communities are important, but so too are realistic expectations of what a microgrid might include. Many communities expected dozens of facilities, or entire towns, to be included in the microgrid without understanding the limitations of the electrical and gas systems, the utility’s operation requirements, or simple cost feasibility. While the Project Team worked with each community to scope out and incrementally refine the facilities for inclusion, there is still much work to be done communicating the infrastructural realities of microgrid development. Setting expectations ahead of future microgrid initiatives will help communities begin with more concise and actionable goals for their community microgrids.” [Feasibility Study #27]
- One applicant’s microgrid development team expressed the opinion that the Industrial Economics, Inc. (IEc) BCA methodology/IECModel “...in the case of larger microgrids, may overstate the costs of power quality disturbances. This is based on our understanding that the model assumes that electrically all the customers on the microgrid are powered from a common circuit. In larger microgrid projects that have multiple circuits...” “... a power quality disturbance on one circuit will not necessarily impact the customers on adjacent circuits. Also, as stated on page 7 of the IEC report, “the analysis of reliability benefits assumes that development of a microgrid would insulate the facilities the project would serve from outages of the type captured in SAIFI and CAIDI values¹¹. The distribution network within the microgrid is unlikely to be completely invulnerable to such interruptions in service. This assumption will lead the BCA to overstate the reliability benefits the project would provide.” [Feasibility Study #12]
- One applicant’s microgrid development team expressed the opinion that “...the IEC model does not measure or assess the impacts of outages during major storms (e.g., hurricane Gloria, Bob and Superstorm Sandy) or major system emergencies (e.g., Northeast blackout, Aug 2003). Per IEC BCA footnote No 2, in Appendix C, “the BCA employs metrics that exclude outages caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility’s control as ‘major power outages,’ and evaluates the benefits of avoiding such outages separately”. These major events will have different impacts based on the type of event, type of stakeholder and that stakeholder’s relationship to the microgrid project. In preparation for, during and after an event there [are] a multitude of costs that require an extensive amount of time to prepare for and restore to original, functional conditions. Long Island and other Tri-State utilities experienced the following issues during recent major storms (Hurricanes Gloria and Bob and Superstorm Sandy):
 - Duration of pre-outage preparation, outage, and post outage restoration of up to 1-3 weeks (not 1-3 days);
 - Additional staff required to fix and operate the grid during outages;
 - Hotel and travel costs associated with utility staff from outside contractors, utilities etc.;
 - Post storm construction activities to either rebuild the systems in locations with significant damage or “return the system to normal” work such as replacing damaged poles and other damaged facilities that did not result in outages.” [Feasibility Study #12]

- “Scalability is governed by three factors. The structure of the electrical infrastructure...”
“...is a key factor to expansion of the microgrid. At some point of expansion, it becomes necessary to link multiple feeders, and having proximate feeders of the same voltage and connected to desirable facilities is an important criterion. Second, widespread advanced metering infrastructure makes expansion far less complicated and allows for the selective disconnect of facilities that are not microgrid participants.” “Lastly, the larger the microgrid grows, the more switches and controls are needed to be installed, connected, and maintained for smooth islanding and grid-reconnect processes. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are also likely to push back if the microgrid grows to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the local utilities to find acceptable footprints that meet NYSERDA’s goals and respect the operational concerns of the utilities.”
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Appendix A: Community Microgrids-Attributes for Success

Community Microgrids - Attributes for Success

Fundamental Considerations for Microgrid Planning

Criteria	Keywords	Positive Attributes	Challenges
Mission/Purpose	Mission, Objective, Purpose, Goal	The mission statement of the microgrid should be clearly defined and well-focused; e.g., provide reliable power supply to specified critical and important loads during loss of local grid or weather-related emergencies. The time frame that the microgrid is expected to operate should be specified. If continuous operation is intended or generation during grid peaking periods is the goal then the microgrid must achieve reduced energy cost, improved reliability, and improved resiliency to the customers of the microgrid.	Identifying critical, essential, and important loads to be supplied by microgrid. Identify design basis weather-related or other emergency initiating event. Define mission time frame. Provide accurate historical electricity cost, reliability, resiliency, and catastrophic event grid outage data that the proposed microgrid performance must exceed. Minimize inclusion of non-critical loads onto microgrid.
Physical Size	Miles, square miles	Compact physical size was seen as a desirable characteristic with minimal length radial feeders connecting any outlying loads and generation sources. Microgrids reviewed ranged in size from 75 acres and less than .5 miles across to service territories of 2 miles X 2.5 miles or more.	Compact size minimizes the length (and high linear costs) of any new distribution lines needed to isolate the the microgrid from the local distribution grid during islanded mode and interconnect microgrid DER with critical and important loads. Similarly, linear costs of new IT/communication & control network interconnects that may be required are minimized in a compact microgrid. Linear costs for new natural gas and fuel oil supply pipelines minimized in compact microgrid. Linear costs for new steam lines supplying thermal energy off-takers minimized in a compact microgrid.
Capacity	MW	Examples considered ranged from 1.5 MW to more than 41 MW of DERs. The total microgrid emergency generation depended on size and characteristics of microgrid customers' loads; other microgrids designed and sized for continuous operation and sale of energy and ancillary services to local grid as additional revenue streams to achieve financial sustainability.	Smaller microgrids lack total capacity and DER redundancy needed to meet minimum guaranteed output for participation in electric energy and ancillary services markets. Utility policy may prohibit small microgrids and DERs from sale of excess energy onto local distribution grid.
DER Mix	Fuel cells, CHP natural gas, diesel generator, solar PV, geothermal, wind, hydro, energy storage, battery	CHP (and CCHP) fueled by natural gas/biogas are the primary sources considered due to high efficiency that enables sale of steam, heat, and absorption cooling in addition to electric power generation. Other DERs proposed included solar PV, wind turbines, hydro, fuel cells, energy storage systems and batteries, gas turbines, and diesel generators. Existing DER typically included older DGs with restricted use due to emissions limits. Dedicated emergency DGs not normally credited toward total microgrid capacity.	Renewable energy sources teamed with energy storage systems are encouraged by NY REV initiatives but they are generally not cost effective in community microgrids unless they are supported by grants, tax and energy credits, and other subsidies. Improvement of building efficiency can somewhat offset the total generation required by a microgrid by reducing energy losses.
Nature of Loads	hospital, public buildings, fire, emergency centers, police, water, transportation, school, shelters, pharmacy, grocery, safety.	The critical and essential loads generally included hospitals, medical clinics, psychiatric facilities, emergency medical services, pharmacies, town/city halls, government buildings, senior centers, community centers (e.g. YMCA), schools, colleges, universities, water supply and waste water treatment plants, emergency response units, fire departments, police departments, grocery stores, banks, department stores, transportation terminals (airports, railways, subways, ferry services), radio/TV transmitting facilities, public work departments, street lighting and traffic signals.	Characterizing the loads is an important fundamental step in design of the community microgrid. Loads must be identified as critical, essential, important, or non-essential. Accurate historical data are required to define the energy use profiles of the microgrid loads; the data must include electrical load, heating load, and cooling load. Such detailed data are often incomplete or not available requiring estimating of load profiles. More effort is required to include residential and commercial/industrial loads in the microgrids. These loads are mostly considered of secondary importance.

Benefits/Costs Analysis Issues

Criteria	Keywords	Positive Attributes	Challenges
Environmental Benefits	Emissions	When incorporating energy-efficient and low or no-emission technologies, the microgrid gets to the root problem of climate change by reducing greenhouse gas emissions and dependence on fossil fuels in two important ways – by making renewables, such as solar power, more feasible; and reducing energy waste. A positive environmental impact should be among the main microgrid goals. The reduction in demand for electricity from bulk energy suppliers would also reduce the emissions of air pollutants from such facilities, including CO ₂ , SO ₂ , NO _x and particulate matter. The near zero emissions of the fuel cell combined with solar PV and energy storage could provide environmental benefits to the community. In addition, the use of CHP could provide a more efficient energy usage. Environmental permitting is one of the variables to be considered for system sizing.	The analysis of variable costs should consider the environmental damages associated with pollutant emissions from the distributed energy resources that serve the microgrid, based on the operating scenario and emissions rates provided by the project team and the understanding that none of the system's generators would be subject to emissions allowance requirements. The majority of these damages are attributable to the emission of CO ₂ .
Community Benefits	Economic, healthcare, electricity availability, steam, safety, industrial development	The community will benefit primarily from a more reliable electricity service, which is correlated with more reliable health infrastructures and community services. The ability to maintain critical town and community facilities during emergencies is a benefit to public safety and improves the quality of life for area residents. Intangible benefits for the community can also be described such as increased life safety, facility attractiveness due to standby power ability, and the potential opportunity for emergency shelter operation. The community property value will increase. The industrial growth of the area will improve due to a reliable energy system. The microgrid could also create local jobs.	

Local Regional Benefits	Economic, healthcare, electricity availability, steam, safety, Industrial development	The resources contained within the microgrid could provide benefit to the local utility and/or NYISO during normal operation. These benefits could include: offering capacity to the utility to relieve congestion or defer the costs of transmission and distribution equipment upgrades; reducing demand behind the meter of sites within the microgrid, thereby reducing the need for the utility grid to provide that capacity; or offering ancillary services such as frequency regulation to the NYISO to help maintain grid reliability. A microgrid can provide benefits to a broad region in a vulnerable area. It would also enable critical facilities to function, such as stormwater pumping stations, which in turn could reduce the costs of property damages associated with stormwater flooding. Ratepayers can also benefit because the microgrid may significantly reduce loads on local substations and thus help defer rate increases related to the substation expansion. Reasonable microgrids can become scalable models and may be replicable elsewhere in New York State.	The microgrid can bring a value stream where the beneficiary are the microgrid users, the distribution utility and the society. The sum of total benefits (to the end-user, the utility, and society) are greater than the total costs. However, due to the fact that end-users aren't compensated for the utility benefits and societal benefits that they create, meritorious projects have a hard time to materialize. The owner will not invest unless the benefits that they receive outweigh the costs that they incur. At the current time, some form of government support is likely to be necessary, in order to stimulate such an investment.
NY State Benefits	Industrial development, economic growth, grid reliability and resiliency	NY State will benefit from gaining knowledge of implementing successful microgrids as well as moving towards meeting the REV goals. Microgrids can be expected to advance innovative energy solutions, including market-based technologies, products, services, and new business models, in the State of New York. The microgrid team should explore the market opportunity for the utility, its customers, and competitive solutions providers to establish public-private partnerships and develop efficient and resilient microgrids. A microgrid can test the demand for enhanced reliability/resiliency services, promote clean and distributed generation, and determine value streams that can be quantified and captured by the parties as well as commercial structures that may be replicated and used to engage additional customers. The best efforts to address technical, regulatory, and contractual challenges and develop a framework that paves the way for future microgrids are all aspects that will benefit NY State and the REV vision. In addition, ancillary or grid-edge services could be an important feature of a microgrid and could impact at state level, enhancing transmission and distribution systems. Improving resiliency of service is a goal. In island mode, reliability and resiliency are the primary objectives, and load modulation may be used in times of the most energy-intensive days. Reliability will be ensured with: use of multiple, distributed, smaller unit sizes, use of distributed energy storage systems, increased energy dispatch from the grid in grid-connected mode, use of ESS and load modulation, greater use of underground cabling and indoor infrastructure.	
Summary/Challenges	Power quality, resiliency and reliability quantification	The goal of a microgrid is to provide and maintain power and heat in the form of steam to all required facilities during a power outage. CHP technologies are well proven as a reliable electricity supply system, and can be used as the main capacity provider for a microgrid. Improving resiliency can provide backup electrical power to the microgrid customers allowing for continuity of services during extended grid outages. Multiple revenue sources are presented around benefits of the microgrid including reduced energy costs, declining GHG emissions, energy security, grid hardening, and reliability. Revenue streams could be established including payment for the provision of primary and standby electric and thermal energy, compensation for peaking generation/capacity, compensation for grid infrastructures and grid reliability improvements.	The value of resiliency is not universally defined or quantified. A consistent approach to defining and valuing resilience is going to be very important to the economics of many microgrid projects. The challenges of employing the CHP technology are to ensure that adequate electricity and steam can be supplied to all users during loss of the utility electrical supply. Load shedding can be required to ensure that the microgrid capacity is not exceeded during high load periods. The challenge will be to effectively implement the load shedding in order to balance the needs of all facilities connected to the microgrid.

Project-Specific Technical Issues

Criteria	Keywords	Positive Attributes	Challenges
Infrastructure	Utility, new distribution lines, natural gas lines, steam lines	The presence of existing distribution infrastructures and rights-of-way is always maximized in the routing of the microgrid interconnection. However, new infrastructures, such as medium voltage class underground cable systems interconnecting generation and loads, may be needed. Accompanying such medium voltage cable there are requisite step up and step down transformers and switchgear to connect and disconnect the circuits and interconnections as needed. If existing distribution feeders can be used for the microgrid when in islanded mode, then new automatic switches would need to be installed to allow for this separation. The microgrid operator will be able to coordinate with the utility through integrated controls and protocols to ensure proper switching of the local grid to support islanding of the microgrid. Waste heat use is also maximized, including existing and new infrastructures.	Microgrids are predominantly an electric commodity, thus the waste heat use is often considered as a secondary option, and in some case not at all. Utilization of the waste heat from the generation process use would greatly increase the overall efficiency of the community microgrid. The use of the utility distribution lines may imply in the most of the cases that the area is served exclusively with overhead, mostly radial, lines and service drops, introducing possible reliability issues. New lines may be required and in this case is suggested to consider a looped distribution system for future microgrid phases to reduce single points of failure. Costs impacting on the microgrids budget should be evaluated. Uninterruptible gas supply availability and contracts should be investigated, while onsite diesel fuel storage should be assumed for emergency purposes.

Maintenance	Schedule, routine, emergency	<p>Using reliability-centered maintenance (RCM) strategies would help focus on critical pieces of equipment (such as rotating machines, transfer switches, breakers) and on periods during the day, week, and year when routine maintenance would be less likely to coincide with an outage event. This is a data-driven task that is likely to become more effective given a longer operating history. At least a 5-year maintenance agreement (with the equipment providers) should be planned, not only as an opportunity to fix costs but to honor warranties with proper servicing.</p> <p>Natural gas engine-based CHP with operation above 8,500 hours per year typically requires a quarterly routine maintenance session (< 6 hours) plus an annual routine maintenance session (< 1 week). The shutdown periods should be planned when natural disasters are less likely to happen along the year. The maintenance for the PV is mainly annual cleaning, with inspection of modules and electrical components. The scheduled maintenance for the energy storage systems is a quarterly routine inspection of the units. Fuel cells do not have a defined maintenance schedule per year; they are designed to operate 24 hours a day, 7 days a week. The fuel cell manufacturer may provide remote monitoring to alert the microgrid sites of any potential issues.</p> <p>A waste-to-energy plant normally has fulltime operations and maintenance staff, and procedures dedicated to keep the plant running 365 days. Maintenance is typically done by unit, with turbine takedown every 5-7 years.</p> <p>Maintenance of the transmission and distribution assets is a responsibility of the utility.</p>	<p>Maintenance of equipment should comply with the manufacturer's requirements. Despite the importance of maintenance, primary microgrid design criteria, such as stability and resiliency, should have priority.</p>
Fuels	Natural gas, diesel, supply, storage	<p>Natural gas is the main fuel for nearly all of the new DER proposed in NY Prize Stage 1 microgrids. Existing and backup diesel generators are found in many of the proposals to supplement the natural gas fired units and as replacements when the natural gas supply is interrupted; onsite fuel oil storage capacity should be considered for emergency purposes. Dual fuel generation units are preferred. A waste-to-energy facility can serve as microgrid support DER, waste being the main fuel, but capable of running also on natural gas. Solar PV is considered a secondary power generation, coupled with storage and diesel generation.</p>	<p>Although natural gas may be considered an uninterrupted energy source, possible risks and common vulnerabilities must be considered (seismic event, sabotage, technical failure, supply constraints) and delivery contracts investigated.</p> <p>Low pressure natural gas systems are susceptible to water infiltration, thus they can be interrupted in areas prone to flooding. In this case, upgrading the supply system to high pressure distribution will prevent water infiltration and improve the resiliency of the natural gas supply to initiating events involving flooding. Natural gas prices are expected to be fairly stable at their current low levels for many years. It is however wise to consider the risk of inflation occurring sooner than expected and the impact on the microgrid's business model. End-users must understand they are exposed to this risk should they remain with the status quo. The microgrid owner should hedge commodity pricing and have electric/thermal pricing adjustment mechanisms in the power purchase agreement to account for changes in fuel price.</p>
Control Systems	Microgrid controller, load shedding, cybersecurity	<p>The microgrid controller supports: frequency control, voltage control, intentional islanding, unintentional islanding, islanding to grid-connected transition, energy management, micro-grid protection, ancillary services, black start, user interface and data management. The controller will operate the microgrid to maximize economic benefits, minimize emissions, and maximize reliability of service.</p> <p>Besides dispatching optimal levels of generation and managing load in the microgrid facilities, the main task of the control system will be to coordinate the switching devices at the interconnection points with the surrounding distribution network in the transition mode from grid-connection to island and back. Additional analysis must be performed and compliant with IEEE 1547.4. The microgrid controller will assign the load-generation mix based on what is needed to satisfy the primary control objectives; in case of need, loads would be dropped according to the prearranged load shedding priority.</p> <p>Loads are classified into critical, discretionary, and deferrable. At a minimum, the generation and storage mix must be sufficient to meet critical load at all times.</p> <p>The controllers shall adhere to the NERC CIP standards to provide secure controls and communication. Security features shall also include password protection, as well as a historian.</p> <p>Cyber security addresses protection against hacking and malicious intent. The microgrid design team will consider options such as: modern hardware platforms and network nodes that incorporate device level authentication and authorization; adding security services to the microgrid control nodes and control center to address encryption of data at rest and data in motion; and adding a security architecture that applies defense in depth design principles which includes segmenting of data and system components across different levels of security zones to offer a hierarchy of authorization constraints and system access barriers. Note that cyber security services can be added as a security layer on top of existing communications when reusing networks but cannot change the existing physical security, resilience or performance limitations of the existing networks or device nodes.</p>	<p>Cyber security services can be added as a security layer on top of existing communications when reusing networks but cannot change the existing physical security, resilience or performance limitations of the existing networks or device nodes.</p>
Grid support	Ancillary services, demand response, energy storage, CHP, fuel cells	<p>The microgrid is expected to help the utility in: grid stability; relieve T&D constraints; frequency response; regulation reserve; spinning & non-spinning reserves; peak shaving; dispatch able capacity and generation for energy arbitrage. All these functions are incorporated in available microgrid control systems. The types of ancillary services that a microgrid can provide will depend on the types of resources included in the microgrid that can meet the required qualifications and also have the technical capability of providing the requisite service. Another incidental ancillary service that a microgrid provides to the grid is a decrease in risk of total grid failure as a result of special circumstances, e.g., a lapse in system security.</p> <p>Ancillary services can be sold to the utility under an Ancillary Services Contract.</p> <p>Work is ongoing to implement the controllers with Energy Management System (EMS) space. The microgrid EMS is the envisioned next generation of the existing microgrid management tools. Current IEEE 1547 and P2030 standards working groups are addressing requirements and data models for microgrid controller interfaces and grid support functions for the evolving microgrid controller unit and the microgrid EMS.</p>	<p>The microgrid participation in ancillary services and the benefits in reducing load on local substations are expected to be significant and should be discussed with the utility. Services to benefit the utility operation will in the end depend on how the final REV framework is structured. Assuming a more open market with less stringent size requirements for DER market participation, it is expected that behind the meter distributed generation, and in fact all types of DER, including both supply side and demand resources in microgrids, will participate in utility and also NYISO energy, capacity and ancillary services markets.</p> <p>Commercial Microgrid EMS are not available at this time; however, a vendor that provides a microgrid controller and demonstrates that they have a microgrid EMS solution in development for their specific controller platform may offer a highly desirable platform with growth potential.</p>

Interconnections/ Interfaces	Switches, substation	<p>The microgrid interconnection system includes switchgears, distribution line transfer switches, and controls. Interconnection/interface points should be discussed and agreed with the local utility, including the possible co-location on the utility poles and rights-of-way.</p> <p>The microgrid has to be configured to utilize required sets of automatic transfer switches in the distribution network in order to be able to operate in grid connected and islanded mode. The transfer switch subsystem is the primary integration point between the switching and protection components in the power delivery system and the microgrid controller unit. Key performance aspects that should be analyzed are: ability to facilitate seamless disconnect/reconnect, switching transition, transfer speed, cost, availability, fault-current contribution, and maintenance requirements. Other performance aspects include coordination with the microgrid controller unit to provide voltage and frequency support at the point of connection, transfer of critical load, and fast shedding of non-critical load during disconnect.</p> <p>A redundant transfer trip system can also be provided.</p> <p>The interconnection switch system should be able to communicate via dedicated telephone lines. A remote operating synchronizing system can be provided that will enable synchronizing of local generation with the incoming utility circuits specially when total utility system gets isolated and reappears as a result of a serious fault in the utility network. A SCADA system should be installed to provide the status information of selected distribution circuit breakers and metering data to the utility substation via a dedicated telephone line. The design of all equipment, installation, and functioning will be strictly based on the utility standard specifications (e.g. EO-2022, EO-4133 and EO-2115 for Con Edison).</p>	<p>Negotiations and acceptable agreements with the local utility are necessary when co-locating facilities within its right-of-way. Existing equipment may need to be upgraded to meet the control, communication and electrical demand requirements. For example, ConEd currently communicates with their remote switches via cellular technology. Thus, if the microgrid intends to use ConEd's overhead system for power distribution, it may also make sense to use cellular technology for the microgrid's communications network. Ethernet may be used locally at each facility where it makes sense to do so.</p> <p>A significant issue involves the ownership of the Medium Voltage (MV) switches and step down transformers at the microgrid facility's substations. Introducing privately owned facility substations may be a too impactful economic burden. Also, there may be significant space constraints to install an additional station service in parallel. The solution could be in the definition of a structured procedure to buy, rent, or lease the facility substations from the local utility.</p> <p>As microgrids may have distributed sources including both rotating machines and inverter based generation, the traditional protection schemes based on high fault currents will likely not be applicable when in islanded mode. Coordination of the protection schemes between grid-connected and islanded mode will require relays capable of being remotely switched between multiple modes or set-points. The microgrid protection scheme should employ some combination of the following: instantaneous/timed overcurrent; over/under voltage; over/under frequency; reverse power; transfer trip; anti-islanding.</p>
Energy efficiency Improvements	Energy efficiency, conservation, advanced metering infrastructure (AMI), data	<p>Increasing energy efficiency while reducing the use of fossil fuels and the overall environmental footprint should be one of the principal goals for a microgrid. The planned use of proven energy efficient design such as combined heat and power systems, renewable resources, energy storage and load management systems will increase energy efficiency and reduce peak loads at facilities. The microgrid can be able to maximize the use of renewable energy by selectively dispatching energy to meet the load demand by using the logic controllers. The controllers may also input real-time weather data to forecast renewable energy availability. It may also be possible to minimize distribution losses and maximize energy efficiency through Volt/VAR controls. Energy efficiency does not imply any change in operations or consumption behavior. Energy efficiency is driven by equipment choice. The energy efficiency of the system is based on the choice of new equipment and devices that will be included in the microgrid.</p> <p>Demand response, on the other hand, implies a change in operations and consumption behavior, and potential options can be considered. Among others, the adoption of the capability to treat electric and thermal loads differently according to their classification as critical, discretionary, and curtailable, constitutes demand response functionality of the microgrid.</p> <p>The implementation of advanced metering will enable microgrid customers to better manage their energy use and costs by virtue of having precise time of day information on their energy use. This will allow them to save money. Meters will also measure a number of electricity variables beyond consumption: demand, voltage level, voltage frequency, and reactive power. Behind energy efficiency, technical control and administration protocols will likely necessitate real time, or near to real time, monitoring. Participation in future ISO (wholesale) or utility (distribution / retail) markets for services, will require sophisticated and fast response communications, controls, and metering.</p> <p>An additional intervention can include building structure upgrade to better efficiency.</p>	<p>Considerable questions related to the existing regulatory policy and the operation of the microgrid are expected, but subtle changes to the remote net metering laws could alleviate a significant amount of regulatory hurdles. The main hurdle being the qualified DER resources approved for remote net metering in NY and the capacity limits on those systems. There is a current remote net metering cap of 2MW. However, possible projects could propose a remote net metering scenario well above that threshold.</p> <p>Metering and control points should be integrated to allow a better energy use and efficiency. Some plants reject waste heat to the atmosphere and makes no use of the heat used to spin the turbine. Those cases are potential opportunities for a high-energy-use business such as an inland ports, green houses, bottling plants, or sterilization facilities, as a business development concept, to set up shop and purchase the waste thermal energy at a discount.</p>
Operations	Utility operation, grid operation and management	<p>During normal conditions, the microgrids will operate in parallel with the utility infrastructure to provide voltage support, satisfy electrical demand during peak consumption periods, or to support the growth of the community. The microgrid generation units can help reduce electricity demand from the utility system. With such electric reduction on the distribution system, the utility will have more capacity for other customers on the their system.</p> <p>The overall energy strategy should focus on both load management, and new distributed generation and energy storage resources to support the microgrid's strategic and operational objectives. The microgrid controller will provide active load management. Demand-side management tools will include automation to support peak-load shifting, dynamic demand response, resource scheduling, and system balancing.</p> <p>In addition, community microgrids generally are designed to provide black-start capability.</p> <p>During emergency operation, transfer switches will isolate the microgrid, including its critical loads from the broader distribution network; load balancing will occur through the controller in cooperation with the operation of the generation units.</p>	<p>Although many inverter-based systems are better able to meet interconnection standards per IEEE 1547, they are are not always capable of handling the types of inrush currents that are associated with motor starting. For this reason, frequency regulation may be required from backup generators. In islanded mode, the microgrid resources will need to provide for power balance/frequency control and reactive power balance/voltage control.</p> <p>While a microgrid project would potentially eliminate some revenue streams from the utility in terms of lost electrical customers, there may be an additional revenue stream in supplying natural gas to the CHP/natural gas plants. This can support and benefit natural gas supply utilities. Revenue balancing implications between the two utility services (electrical vs. natural gas) should be evaluated to show the real financial impact.</p>

Policy/Regulatory	Regulations, net-metering, public service commission, utility service law	A microgrid project should follow regulations, including IEEE 1547 Interconnection Standards, National Grid Interconnection standards, conditions of NYS SIR (Standard Interconnection Requirements), and the requirements of ANSI C84-1 in islanded mode. Any federal regulations governing security and protection mechanisms for the microgrid should be followed.	There are numerous outstanding regulatory issues. Some outstanding issues include: 1) Types of payments for the services to be provided by the microgrid to the utility and those to be provided by the Distributed System Platform Provider (DSPP) to the microgrid. 2) Type of payment for utilizing existing distribution wires both in normal and islanded modes. 3) Control of the communications and control system when in normal operating and in islanded modes. 4) Existing tariffs such as electric and steam standby rates, gas-delivery rates and others to ensure that the microgrid is not economically disadvantaged because of existing approaches. 5) Interconnection processes. 6) Variable pricing, crossing rights of way, off-taking to residential customers and grid buy-back rates will require exception and approval by the PSC. Regulations for net metering of the micro-grid are currently not in place. Net metering policies in New York present a substantial problem for community microgrids. Removal of artificial regulatory barriers and a consistent planning horizon for microgrids for the next decade is also critical.
Scalability	Technical model, modular components, expandability	Scalability of the microgrid includes: (i) The electric and thermal distribution network can then be easily routed and tapped to the load centers for scaling up the size of the microgrid. (ii) The microgrid will include additional capacity and space for future DER units as well as an extension of the proposed switchgear. (iii) For renewable generation, solar rooftop PV panels can be added to any building roof with the required square footage and be easily connected to the building's electric system. (iv) The fuel cell generation is modular and could be expanded. They also minimize permitting and construction costs.	
Summary and Challenges	Multi-party ownership, utility interface model	It is assumed that the microgrid's assets will be owned and operated by a private entity in order to take advantage of tax credits and other tax benefits. The Microgrid Asset Owner would be responsible for financing, installing, operating and maintaining the generation equipment and PV arrays. The utility should coordinate protection and switching schemes for the PCC and the distribution system. The adopted PCC solution may simplify the interconnection agreement and interconnection study by using a straightforward approach to isolate the microgrid from the distribution grid with control by the utility in accordance with the IEEE 1547 interconnection standard. This gives the utility control of the interconnected system and makes the interconnection agreement easier to execute.	If the utility is part of a special purpose entity that owns and operates the microgrid, certain regulatory concerns regarding franchise limitations are diminished while others that restrict utility ownership of generation become problematic. If a new line is built without utility's involvement, the microgrid would need regulatory approval to cross public rights of way. If the utility is part of the microgrid, the following issues arise: restrictions on utility ownership of generation; ability of microgrid ownership entity to recover fixed costs for infrastructure from direct and indirect beneficiaries; ability of microgrid ownership entity to act as DR aggregator for wholesale markets; valuation of locational benefit of microgrid DERs. Additional challenges may include the evaluation and legal exploration of the possible special purpose vehicle (SPV) ownership, clearing of regulatory hurdles with the utility, the NYS PSC and the NYS DEC, and new service class rate structures.

Stakeholder Issues

Criteria	Keywords	Positive Attributes	Challenges
Developers	Ownership, financial investors	Different ownership scenarios can happen for the generation assets, while in most cases the utility will own and operate the distribution. Scenarios may go from the most common third party ownership, to town, public office or county ownership, to the team forming a special-purpose limited liability company to own the microgrid assets (both independent investors and end users who have also chosen to invest in the project). PPAs with end-users should be considered, which improve their energy costs over the term of the agreement. In exchange, end-users should agree to host power generation equipment and balance of plant at no-cost, interface BMS with the microgrid controller, curtail in the event load exceeds capacity, and be under variable pricing formulas to mitigate the risk of load exceeding capacity. Ownership can be also in the form of a public-private-partnership or "P3" design-build-down-operate-maintain (DBOOM) structure that shifts construction, technical, financial and operational risk to a qualified, financially strong entity with a proven track record. An added benefit of the P3-DBOOM approach is that it allows the private entities to monetize the tax related benefits associated with the deployment of certain distributed generation technologies including PV, fuel cells, and cogeneration. Financial feasibility of the microgrid ensures that the project can be of interest to financiers and investors. Depending on future regulatory and market developments in New York State, the microgrid owner may have opportunities to create new revenue streams similar to those being pursued by Community Choice Aggregation entities.	A public-private-partnership (P3) is central for commercial viability. The P3 approach could help overcome two issues: project financing and microgrid design, construction, operation and maintenance. The community may lack financial resources to get to the audit-grade engineering and economic study of the microgrid, and construction. Members of the microgrid project should be prepared to provide some cost-sharing capacity, but external financing support is required in order to perform advanced development. Investors should be considered and need to be engaged in the microgrid. The financial feasibility of the project may be sensitive also to the negotiated price of excess power produced, for example by the fuel cells, during off peak periods as well as the price of natural gas. The goal is to obtain a positive NPV without external funding, but investors may be needed.

<p>Technical Issues</p>	<p>Islanding or grid parallel operation</p>	<p>Under normal condition the microgrid facilities can be served by the local utility and the electricity generation can come from microgrid units as well as conventional grid-connected plants.</p> <p>When connected to the utility, the microgrid's voltage and frequency will be controlled by the grid.</p> <p>Unintentional islanding can be detected by the 81R function on the primary isolation switches, which will detect a high rate of frequency change and cause the isolation switch to open.</p> <p>When in islanded mode, generator AVR and frequency control system will regulate the voltage and frequency and will be able to ride through voltage and frequency deviations. It is assumed 10 min to transfer from grid sync to island mode, depending on the needs of specific loads.</p> <p>In emergency situation the microgrid controller will sense the loss of voltage or frequency and the DERs protection relays will shut down the system (in accordance with anti-islanding protection procedures). Existing diesel backup generators can start up to supply facility emergency life safety loads. Once the facilities are isolated from the utility system and the generation is stabilized, load at all locations can be sequentially transferred from the backup generators to the microgrid DER units. Once the island is stable and active, PV would reconnect and begin generating. When islanded, the generators will follow the system load and maintain voltage within the limits of ANSI C84-1 standards. The microgrid's voltage and frequency are not expected to vary greatly from nominal if the loads are not large enough to introduce a perturbation. Non-essential load will be shed to ensure that the islanded system load does not exceed the capacity of the generators. Diesel generators will then be safely shut down and load will be transferred back to the microgrid system.</p> <p>The CHP systems designed to be part of a microgrid should have black start, load following, part-load operation, ability to maintain voltage, ability to maintain frequency, the capability to ride-through voltage and frequency events in islanded mode, and the capability to meet interconnection standards in grid-connected mode. Where the project must use emerging technology (microgrid controls, energy storage), each product should be proved before entering the microgrid.</p>	<p>Many utilities have been historically resistant to intentional islanding, however, the correct IEEE 1547 settings in the protective relays, and the potential to incorporate utility direct transfer tripping, are approaches that are expected to overcome the issue.</p> <p>The operational control of the microgrid isolation switches will need to be agreed on for parallel operation, islanded operation, and for parallel operation when the communication between the microgrid and the utility control centers has been lost.</p> <p>Updated utility interconnection requirements were issued by the New York State Public Service Commission in July, 2015. These requirements are applicable to new distributed generation (DG) facilities connected in parallel with utility distribution systems. The maximum nameplate rating of 2 MW or less is required on the customer side of the point of common coupling (PCC). As of November, 2015, the Public Service Commission is reviewing proposed utility interconnection requirements which would raise the maximum nameplate rating of DG facilities to 5 MW. However, for microgrids with total aggregate capacity exceeding 5 MW, this PSC requirement will need to be explored further.</p> <p>This is the case when, for example, a large waste-to-energy plant that is normally connected to the main grid enters the microgrid to serve a group of critical facilities. This exposes several technical, economic, and regulatory issues that go the heart of REV.</p> <p>Also a potential customer that will enter or is into a remote metering PPA with a solar farm, will be problematic as the micro-grid cannot rely on this power generation in the event of a grid outage.</p>
<p>Financial Issues</p>	<p>Business plan, financial terms, electricity price, local marginal pricing, revenue stream</p>	<p>Different business models can be envisioned. It is important that the business model is achievable and has a net positive return, while ensuring that the capital costs of the T&D infrastructure investment required to construct the microgrid are allocated fairly between microgrid customers and operators. Reducing costs to energy users is one of the operational objectives. Energy cost saving around 10% should be estimated, based on proper energy savings, project financing costs, and a 25-year contract term. There should be a mechanism in place for the microgrid to ensure long-term commitments that allow multi-year revenue projections from the sale of electricity and thermal energy to customers.</p> <p>Customers should be allowed to engage in "energy services trading" amongst themselves provided it doesn't mean a reduction in minimum billing thresholds or other negative impact on the microgrids required cash-flow.</p> <p>Business models may include: (i) A vertically-integrated utility microgrid financed through a public capital vehicle based on the most mature revenue streams currently available for microgrid; the local distribution utility would continue to be the owner of the microgrid's T&D assets. (ii) The microgrid project is scalable and creates a platform where the owner could become a "network coordinator" or "microgrid coordinator" that incentivizes customers to provide the highest value energy supply, load management, and ancillary services to the microgrid system by providing differentiated price signals. The Microgrid Coordinator's role would be more like that of a wholesale grid operator and would provide highly differentiated price signals to direct investments by other service providers; the Microgrid Coordinator would focus on operating the grid, interconnecting customers and managing complex transactions among growing number of actors. The ownership arrangements would fall into the "unbundled utility microgrid" category.</p> <p>Strengths to consider are:</p> <ul style="list-style-type: none"> • Microgrid customers pay no capital costs for developing the microgrid. • The microgrid special purpose vehicle (SPV) ownership can earn significant tax credits not available to public sector entities with no tax liability. • Energy service agreement (ESA) contracts could be structured to ensure that microgrid customers paid lower rates than they would have paid if they had not become a microgrid customer. • Any additional savings that may arise during the tenure of the ESA could be shared between the microgrid SPV and the microgrid customers to augment the customers' cash flow savings or accelerate transfer of the microgrid assets to customers. 	<p>The enactment of new policies to allow "behind the meter net generation" or "BTM: NG" may allow the microgrid to sell ancillary services to the grid and receive new ongoing revenue as a result. The magnitude of these potential revenues is difficult to predict given the emerging nature of these grid services and markets.</p> <p>The availability of external subsidies and credit guarantees may be very important in the financial viability of a microgrid project.</p> <p>Business model weaknesses may include:</p> <ul style="list-style-type: none"> • General Partner may not be as effective as energy service companies at developing DERs on the customer's side of the meter. • Centralizing ownership of DER assets may limit flexibility of financing options. • The business plan does not identify the export of electricity to the grid as a source of revenue for the microgrid. • Procurement requirements may have a chilling effect on community microgrids. State and local taxes and prevailing-wage standards may increase project costs in some U.S. jurisdictions compared to others. There is the need to develop appropriate structures to capture tax benefits. • The utility may be available in a stand-by role to pick up the electrical load if the microgrid needs to be shutdown or local generation is reduced for any reason. A known potential regulatory hurdle is the stand-by charge. This is a significant charge which would negatively impact the economic and financial feasibility of the microgrid and reduce the potential economic savings generated by the microgrid. Reduction of the stand-by rate would create value to the microgrid partners.

Local/regional government	Legislations, financial support, ownership	Depending on the facilities involved in the microgrid and its location, additional support may come from local authorities and government related institutions, such as the case of the New York City's Department of Homeless Services, and the Mayor's Office of Sustainability.	Financial support is mostly needed for the microgrid. It may be required from funding, town/state, and potential investors.
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Risk/Reliability/Resiliency Analysis Issues

Criteria	Keywords	Positive Attributes	Challenges
Initiating Event	Hurricane, storm, tornado, flood, earthquake	New York State can be vulnerable to hurricanes, tropical storms, tornadoes, extreme cold, snowstorms and blizzards. Major storm-related events (hurricanes, ice, snow, tornadoes, etc.) are more likely during certain seasons or months of the year than others. All systems should be designed to be resilient to forces of nature and existing installations should be relocated if needed. This includes, but is not limited to, using existing indoor locations, outdoor enclosures, location above flood plains, and using natural gas as a main source of fuel (CHP). Natural gas distribution should be high pressure to be resistant to flooding. Snowstorms and snow removal should also be addressed for technology located outside (solar PV). CHP installations, solar PV and energy storage should be outside or above of the flood plain. CHP and solar PV plants should be designed to resist seismic and wind loads. The CHP units and energy storage equipment can be housed in structures compliant with the NY building code to withstand all weather events anticipated for the NY area. The portions of the distribution system that will be sectionalized to become the microgrid distribution system should be storm hardened and/or relocated underground to reduce vulnerability.	Major storm events have shown to have negative consequences even in the case where most of the electrical distribution is underground.
Time Frame	Normal and emergency operation support	There is the expectation that natural gas power generation should be able to run for days without an operator being on-site. It must be taken into account that clearing of snow to solar panels providing access to microgrid assets has high priority.	
Quantifying Parameters	Risk ranking, FMEA, risk assessment	A risk assessment (technical, economical and financial risks) has to be performed before the microgrid can be developed; it may consider, for example, possible flood scenarios (natural or from building pipes) and pumping in place to mitigate risks. Using technologies with a very long, reliable track records, can help reducing technical risk, along with the technical viability of the microgrid. Urban environments with a mature physical infrastructure and established gas and electric tariffs can support the microgrid team to work with the end-users and utility partners to coordinate efforts with REV and the PSC and look for ways to mitigate the impact that regulations may have on microgrid implementation. It is also important that the project team will work with the local utility to understand current distribution network challenges and how the microgrid can mitigate risks. This not only includes current issues but accounting for load growth in the area as well. Risk management has to be considered as well. For example, it may be possible to limit the risk from losing parts of the existing utility feeders involved in the microgrid by allowing the microgrid to function in smaller independent microgrid, increasing resiliency and reliability, but with reduced functionality. There are several points of risk that the microgrid business plan must thoroughly take account of: thermal customers expect that the microgrid will be able to provide their full peak demand; the business plan for the microgrid should thoroughly investigate the building envelopes and heating systems of their customers ahead of time; a minimum threshold of electricity consumption is something customers will likely feel comfortable committing to, especially if cooling loads don't figure highly into that minimum threshold.	Uncertainties to the business case may include negotiated exchange electricity rates, incremental CAPEX which improves grid resiliency, changing regulations, storage requirements, demand response and capacity market participation, GHG credits, federal ITC. The largest external risk is uncertainty about project ownership and access to potential subsidies. The largest effort and the highest internal project risk is expected to be in negotiating contracts with the utility for purchasing ancillary services, and co-location of facilities. Some risk is expected in securing the individual participants.
Synergies	Component redundancy, infrastructure support	The microgrid should be designed to allow a minimum of N+1 redundancy to meet the only critical loads. A multi-zone system can be developed, combining several separately islanding systems. The microgrid team should work with the utility and the stakeholders to develop a resilient network design that incorporates hardening strategies commonly practiced by systems engineers in areas exposed to storms and outage events. This includes fault-tolerant and self-healing network designs, redundant supply or reconfigurable supply where it makes sense, remote monitoring and diagnostic equipment, robust construction, use of submersible equipment in underground construction, and a number of other time-tested measures. The controller design will utilize redundancy in the server, data collection server, and in the communication system design. This could include redundant fiber rings with redundant Ethernet switches at each key site/facility in the microgrid. Intelligent devices, such as UR relays, 8 series relays and controllers, offer redundant communication ports and reduce failover time to zero through IEC 62439-3 Parallel Redundancy Protocol. This feature helps to minimize cost by use of a single, high reliability IED/controller instead of using two devices.	The use of fiber optic cables, redundant networks, and underground deployment makes this the most reliable and resilient method, but it is also the most costly option.

Grid Technical Benefits	Stability, reliability, resiliency, cost-effective solutions	<p>Reliability and resiliency are critical to the microgrid community and state. All of the electrical cables should be installed underground, in concrete encased duct bank which will provide full resiliency against any weather phenomenon. If a severe weather event was to impact the area, a minimum of one week of full microgrid operation should be the target.</p> <p>The New York State Department of Public Service (DPS) requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions. The reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. The microgrid may seek to negotiate a cost of "additional resiliency" and provide the financing of this into the microgrid contract. Furthermore, any additional operating expense that would be incurred by the microgrid to provide a "premium" resiliency service, on the demand of one site, would be an additional cost charged to that site.</p> <p>The team would expect that metering, rights of way, how to "share" use of distribution lines, and how to interface with and sell/buy power with the grid are all problems they need to solve. Collaboration with the utility is fundamental.</p> <p>Smart Grid/Distribution Automation (SG-DA) solutions will be explored for the community microgrid to ensure reliability in both connected and islanded mode and to enable rapid, seamless transfer when the grid is down. Strategic placement of field devices can enhance the flexibility and innate reliability of the microgrid area, whether it is in grid-connected or islanded mode. Reclosers, sectionalizers, and fuses are the mainstays of conventional utility overcurrent protection schemes. Digital sensors and measurement devices, such as transformer monitors, remote fault sensors, and Advanced Metering Infrastructure (AMI) Smart Meters all help to provide additional situational awareness to both the utility operations center and the microgrid control system, allowing faster detection of fault conditions and operators to respond more rapidly.</p>	<p>From a reliability perspective, the weakest sections in a microgrid infrastructure are the overhead portion of the feeders. Overhead lines are impacted by vegetation (trees), lightning and animal activity correlated with trees.</p> <p>In estimating the reliability benefits of a microgrid, it may be that the BCA employs metrics that exclude outages caused by major storms. The benefits of avoiding major power outages should be then considered separately.</p> <p>There is a trade-off between cost savings acquired via reuse of existing communications systems and the reduced security and resilience attributes in older communications technology and design approaches. This trade-off should be analyzed, and cost and security considerations balanced to accommodate the site-specific functional requirements.</p> <p>The precise benefits of Smart Grid/Distribution Automation (SG-DA) to storm resiliency and recovery are harder to quantify (due to the lack of available methodologies and metrics), but anecdotal evidence suggests they are real and potentially substantial.</p>
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**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@nyserdera.ny.gov
nyserdera.ny.gov



NYSERDA

State of New York

Andrew M. Cuomo, Governor

New York State Energy Research and Development Authority

Richard L. Kauffman, Chair | Alicia Barton, President and CEO