21 - Eighth Avenue Microgrid (Manhattan)

August 2016

Notice

NY Prize Stage 1
Feasibility Study
Eighth Avenue Microgrid
Final Report

prepared for

NYSERDA

energy & resource solutions

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EXECUTIVE SUMMARY

This feasibility study was conducted under an award from the NY Prize initiative and presents an assessment of an electric microgrid between One City Block at 111 Eighth Avenue and the New York City Housing Authority's (NYCHA) Fulton Houses at 421 West 17th St., both in New York, New York. This report has been prepared to document the proposed microgrid capabilities in fulfillment of the NY Prize Stage 1 Feasibility Study requirements.

This project achieves the goals of the NY Prize program to identify projects that incorporate resiliency, emergency power availability, and financial success. The project has the stakeholder support, technical merit, and financial viability to be a strong contender to move on to Stage 2 of the NY Prize program. This project bridges many of the stakeholder gaps that exist in developing successful microgrid projects and is an excellent example of a public-private partnership that is a replicable model throughout and beyond New York to provide resiliency services while reducing greenhouse gas (GHG) emissions.

This Stage 1 project examined the potential installation of a community microgrid (the Eighth Avenue microgrid or, microgrid) encompassing One City Block and the Fulton Houses. Under normal conditions, this microgrid would provide power to One City Block and heat in the form of steam to the Fulton Houses. Under emergency conditions and during grid outages, the microgrid would be islandable, providing all or partial back-up power to the Fulton Houses. These facilities are within a half-mile radius of each other and have New York City (NYC) roads that would need to be crossed. To assess the microgrid's technical and financial feasibility and its ability to meet the New York Reforming the Energy Vision (NY REV) goals, the Stage 1 study completed the following:

- An evaluation of the technical viability of distributed energy resources for One City Block and the Fulton Houses
- Financial feasibility analysis for the development of a microgrid encompassing the facilities
- Identification of the performance and energy savings opportunities in terms of the operation, maintenance, and control of the base building systems
- Documentation of the roadblocks to project success and possible workarounds and/or potential solutions

The Microgrid Vision

Google, owner of One City Block, has a lengthy track record of supporting technology and sustainability throughout its operations. This commitment includes the 2013 acceptance of the NYC Mayor's Carbon Challenge, a voluntary program for universities, hospitals, and commercial offices in NYC to reduce their building-based GHG emissions by 30% or more in 10 years; One City Block has achieved this target and has since accepted a greater challenge of 50% carbon reduction by 2025. This acceptance has been followed by a methodical and sustained effort to implement energy efficiency measures for all systems in the building (which will be highlighted later in this report). One City Block's commitments to environmental sustainability are complemented by its interest in investing in the local neighborhoods that surround its offices to improve resiliency services for local residents. NYCHA's Fulton Houses, located across Ninth Avenue from One City Block, houses over 2,000 residents in 945 apartments across eleven buildings. The Fulton Houses experienced significant outages during Superstorm Sandy; all buildings and apartments, including their elevator services, were without power for 4 days, which caused considerable hardship for this moderate-income population.

This microgrid project leverages the public-private partnership between NYCHA and One City Block that can serve as a replicable model throughout the city. Many housing projects in NYC and in many major metropolitan areas around the country are exposed to the risks of power outages due to weather events and other emergencies. By themselves these facilities lack the means to provide extended back-up power solutions for their tenants. The lack of elevator service for a 4-day outage presents an extreme hardship and safety hazard for many of the tenants. This project showcases the benefits of leveraging the resources of a private sector actor, in this case One City Block with Google as the anchor tenant, to provide increased resiliency and energy security to housing and other services within its local community. These community benefits align with Google's commitment to the NYC Carbon Challenge.

The Eighth Avenue microgrid design analyzed during this feasibility study is for a robust and resilient system that would operate 24 hours per day, 365 days per year, leveraging clean energy and power generation sources. The microgrid was designed to allow critical operations at both facilities to remain operational for a period of 7 days or more during extended outages in order to address the Fulton Houses' urgent need for a more reliable grid and better preparedness for future storm events.

This project promotes a wide variety of technologies and puts many of the issues and objectives of NY Prize front and center. On the technology side, this project uses a broad mix of resources blended in a unique way to achieve the islanding duration required by the program. Technologies incorporated into the project in addition to multiple natural gas combined heat and power (CHP) units include photovoltaics (PV) and a back-pressure steam turbine. Further, a modular architecture for the controls provides an optimized solution today that can be easily expanded in the future. The flexibility of the overall architecture allows it to be easily adapted to a wide range of distributed energy resources and future microgrid equipment – essentially future-proofing the installation to the greatest extent possible.

Project Team and Activities

In conducting this microgrid feasibility study, Mr. Kurt Blemel, Ms. Sue Haselhorst, Mr. Ari Michelson, and Mr. Jim Paull of ERS worked with Ms. Emily Kildow of Taconic Management Company on behalf of One City Block and Ms. Bomee Jung of NYCHA to coordinate site visits, develop an understanding of the system operations, and facilitate One City Block and NYCHA staff interviews and assistance with equipment access and data-logging equipment. The ERS team leveraged the expertise of Schneider Electric to develop a control architecture approach to interface with existing Consolidated Edison (Con Edison) electric and steam service to the facilities.

In order to ensure that the proposed microgrid will deliver value to the participants as described in the prior sections, ERS conducted an extensive analysis of building loads for both project sites, as well as an inventory of existing resources that could be leveraged for the microgrid. ERS calculated electric energy, steam, and natural gas consumption for both the Fulton Houses and One City Block, calibrating consumption with weather data to estimate load profiles unique to each facility. A detailed description of the loads and this characterization exercise was presented in the Task 2 report. ERS incorporated planned energy efficiency upgrades into the load estimates to project future electric, steam, and natural gas needs. Through multiple interviews and site visits, an inventory of existing and planned equipment was developed that could be leveraged for the microgrid. One City Block has already engaged Con Edison in discussions regarding other potential CHP and demand management projects. The microgrid will be able to leverage this relationship to guide the three CHP units located at Fulton Houses through the design and permitting process.

The project team explored a variety of generation technologies to serve the necessary loads under normal and emergency generation scenarios. The technologies planned for this microgrid have all been used previously in projects with NYSERDA and the utilities throughout and beyond New York.

Description of the Facilities

The proposed microgrid is intended to include the twelve buildings summarized in Table ES-1. The Fulton Houses encompass eleven buildings spread across three blocks. One City Block is a single structure that covers an entire city block.

Table ES-1. Facility Information

Development Name	Winter/Summer Demand MW	Annual Usage	Emergency Requirements	Sq Ft
One City Block	27/30	218 million kWh, 350,000 therms	1 MW	2,900,000
NYCHA Fulton Houses (eleven buildings)	1.1/1.8	7 million kWh, 1 million therms	1.8 MW	932,450

One City Block

One City Block is a 2.9 million-square-foot property in the Chelsea neighborhood of Manhattan. Originally developed as the headquarters of the Port Authority of New York, the property occupies an entire square block between Eighth and Ninth Avenues and 15th and 16th Streets and sits above the 14th Street/Eighth Avenue subway station. Google bought the property in 2010, and it is managed by the Taconic Management Company.

In its current configuration, the building houses substantial and critical telecommunications infrastructure, and it also contains a cancer center.

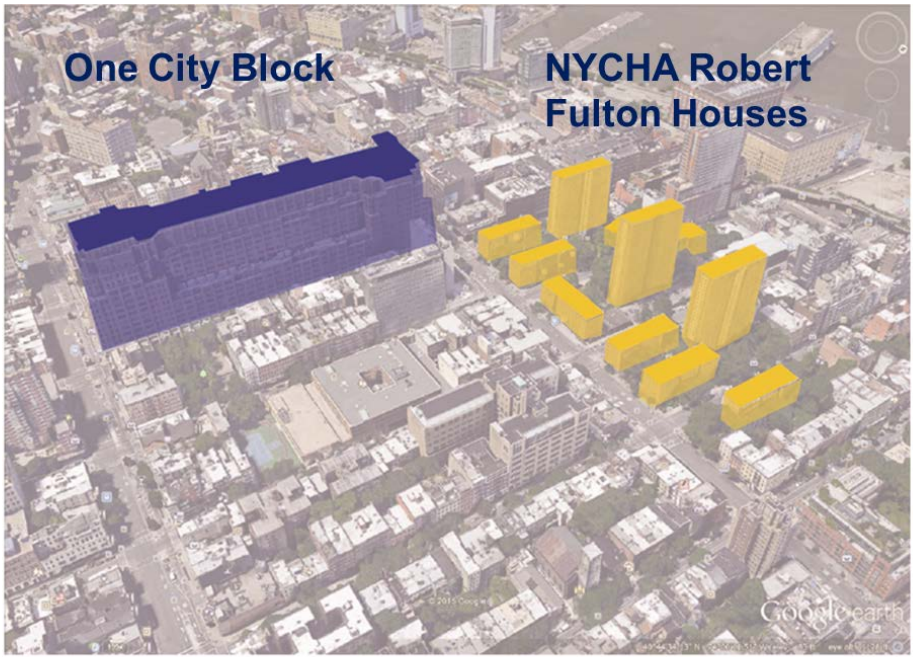
The Fulton Houses

The Fulton Houses cover three blocks, with eleven total buildings and a garage. There are three high-rise buildings of twenty-five stories each and eight low-rise buildings of seven stories each. In total, the Fulton Houses contain 945 apartments with more than 2,000 residents. All of the buildings are separately master-metered, and there is no tenant metering.

Summary of Proposed Microgrid Capabilities

Figure ES-1 presents the facilities included within the microgrid. This image demonstrates the proximity of the sites, the enormity of One City Block, and the layout of the Fulton Houses across three city blocks.

Figure ES-1. Overview Map of the Facilities Included in the Microgrid



The proposed microgrid generation plant will include three new CHP natural gas-fired microturbines next to each of the Fulton Houses high-rises, as well as a PV array and a back-pressure turbine. These will be the main microgrid generation units providing power during normal and emergency operations. An additional CHP plant is under consideration at One City

Block that could potentially supply electricity to the Fulton Houses during an islanding event. Additional existing resources will be used to provide normal and emergency back-up generation, depending on need. The microgrid will run parallel with the grid during normal operation and will be able to run islanded from the grid during an emergency event. All of the new generation sources targeted for the microgrid's normal operation will be located on the Fulton Houses campus. The planned locations for the Eighth Avenue Microgrid generation resources are shown in Figure ES-2.

Figure ES-2. Fulton Houses with CHP Locations

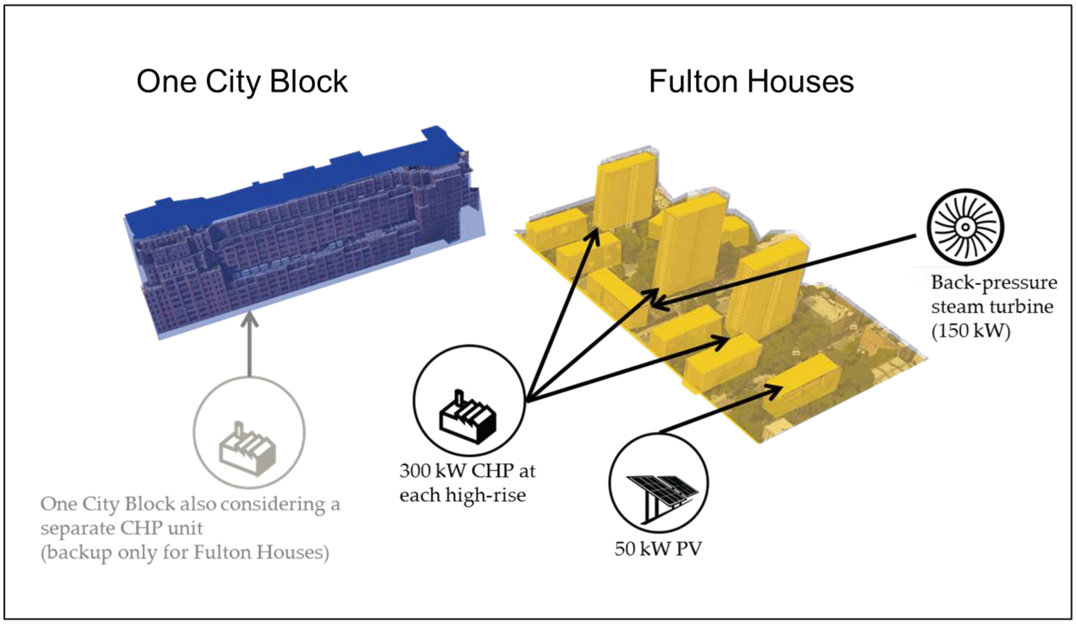


Table ES-2 shows all of the power generation capabilities that are under consideration for the facilities included within the microgrid, their fuel source, and whether they will be available for emergency power operation. The units designated as new will be designed and installed under this project. The existing and in-planning units will be incorporated into the microgrid to supplement emergency operations.

Table ES-2. Current and Planned Power Generation Resources

Location	Generation Resource	Generation Capacity (kW)	Normal Operations	Emergency Operations	Emergency Operation Duration	Back-Up Generation
Fulton Houses	New natural gas CHP unit(s)	900	X	X	7 days	
	New solar PV generation	50	X		N/A	
	New back-pressure turbine	150	X	X	7 days	
One City Block	In-planning natural gas CHP unit	4,800		X	7 days	
	Existing back-up diesel/natural gas generators	25,000		X	7 days	X
Total generation capacity for microgrid		**1,100[a]**				

N/A = Not applicable
[a]Total generation capacity does not include One City Block resources, which would only be available during grid outages.

Microgrid Operation

The microgrid is designed to operate 24 hours per day, 365 days per year. The generation plant will be located at Fulton Houses, where it will provide steam for the high-rises to offset steam purchases. All of the electricity generated by the plant will be directed to One City Block, providing lower cost power. One City Block will lease space from Fulton Houses to house the plant, providing a mechanism for balancing the distribution of value between Fulton Houses and One City Block. The following sections outline the normal and emergency operations for the microgrid.

During normal operations, all of the electricity from the CHP units at the Fulton Houses plant will be directed to serve One City Block and will operate in parallel with the grid. The power will be used exclusively by One City Block, offsetting its current load; no power will be exported to the grid. On the steam side, the three microturbines will produce low-pressure steam, which will be distributed to the three high-rises through a new dedicated steam distribution system. The balance of the campus steam usage will continue to be supplied by Con Edison high-pressure steam. Additionally, a back-pressure steam turbine will replace the existing pressure-reducing valves, generating additional electricity.

During emergency operation, which includes all grid outages, the electrical output from the Fulton Houses plant will be switched from serving One City Block to meeting the needs of the Fulton Houses campus, with any shortage in capacity made up by output from additional generation existing or planned at One City Block. One City Block will use its existing back-up generation units to serve its emergency power loads.

Resiliency

The proposed microgrid will increase resiliency for Fulton Houses. Connections between the facilities will be underground below Ninth Avenue, and redundant generation will be available from One City Block as described in the previous sections. The Fulton Houses plant includes diverse and multiple sources of power with three independent gas-fired microturbines, a steam-power back-pressure turbine, and PV. The microturbines will be installed on elevated platforms, above possible flood zones and away from potential damage from vehicles.

NY Prize Microgrid Criteria

The ERS team assessed many desired features for integration into the Eighth Avenue microgrid, including three CHP plants powered by natural gas, a back-pressure turbine, and one solar array. The microgrid will be kept relatively separated from the grid during normal operation, even though some utility power will be used and it will be able to run islanded from the grid during an emergency event. The incorporated control systems will be able to automatically separate from the grid during the event and restore the facilities to the grid after the event. The electrical infrastructure will be buried underground to protect the lines in case of emergencies, allowing the best level of protection to ensure reliability of the microgrid during a storm or grid-level outage.

Microgrid Controls, Isolation, and Islanding

The controls, communications, islanding capabilities, and seamless operation of the microgrid will provide One City Block and Fulton Houses with the added resiliency and emergency operations they will need to provide NYCHA with emergency services. The project will incorporate data collection and storage for multiple parameters to monitor the building loading, power provided from the microgrid, and power provided from the utility. The data collection will also incorporate points to develop efficiency profiles for the microgrid.

The microgrid will go into isolation automatically if power is lost during grid-connected mode. The control system will manage the generation to ensure optimum voltage and frequency control. Communication and interoperability with the local utility and the primary operator of the Eighth Avenue microgrid will be incorporated into the final project design.

Commitment to Energy Efficiency Projects

Behind-the-meter efficiency will play a large role in the reduction of peak demand needs and annual energy usage to maximize the electricity and steam produced by the microgrid. One City Block is currently implementing many energy efficiency upgrades, including extensive lighting projects, an ice storage cooling system, and a full window replacement project and plans to upgrade its diesel generators to natural gas. NYCHA’s Fulton Houses property is planning an energy performance contract to upgrade all of its facility lighting. The impacts of the planned energy measures along with any newly developed energy measures ascertained through this study will be used in the final power requirement assessment for the microgrid.

Utility Engagement

The project team has held extensive conversations with the Con Edison electric and steam groups throughout the microgrid feasibility study. The microgrid’s location is of particular interest to both the electric and steam grid operators. As the fourth-largest building in New York, One City Block offers the electric grid operators a unique scale and density together with high visibility and long-term needs. The ERS team has had multiple discussions with the Con Edison electric team responsible for the Manhattan territory encompassing One City Block and Fulton Houses to present configuration options under consideration, evaluate the capacity of the existing grid to accommodate the additional generation, and discuss potential options for underground cabling and microgrid operation.

The steam distribution system surrounding the Eighth Avenue microgrid is constrained, and the microgrid could in part alleviate this stress by the systems proposed or alternate configurations under consideration. This project is unique in that due to the size of the CHP plant proposed for Fulton Houses, there is likely excess steam that can be fed back into the Con Edison grid. The ERS team has held multiple meetings with the Con Edison steam group to discuss participation in a pilot buyback program to receive compensation for providing steam back to the grid, increasing its resiliency. Con Edison has been engaged in meetings with the ERS team and discussions are planned as the team prepares its submission for Stage 2 of the NY Prize program.

Financial Feasibility

The Eighth Avenue microgrid between One City Block and NYCHA has been developed to be mutually beneficial under normal operation and during emergencies. Table ES-3 shows the simplified economics as viewed by the owner of the microgrid behind the project; the value, not only in lifetime financial feasibility, but in emergency system redundancy. The revenue for One City Block comes from a reduction in electric utility costs and from the sale of power and heat to the Fulton Houses. As a NYCHA property, the Fulton Houses development is unable to realize the full financial benefit of reducing their energy costs. Thus, in the structure presented below, Fulton Houses will purchase the heat produced by the microgrid from One City Block and its revenue will come from lease agreements for the space to locate the CHP units being situated on their property. The revenue streams will be relatively fixed on an annual basis over the life of the equipment and contracts.

Table ES-3. Summary of Benefits

Parameter	Fulton Houses	One City Block
Existing Operation – No Microgrid		
Electric energy load	7,603 MWh/year	190,000 MWh/year
Peak demand, monthly average	1.27 MW	23.7 MW
Thermal energy load	74,799 MMBtu/year	N/A
Electric energy (kWh) cost	$684,270/year	$17,100,000/year
Electric energy (demand) cost	$608,240/year	$15,200,000/year
Natural gas cost (excluding appliance fuel)	$0/year	N/A
Steam costs	$1,920,090/year	N/A
Total energy cost	$3,212,600/year	$32,300,000/year
Proposed Operation – with Microgrid		
Electric energy supplied by the microgrid	0 MWh/year	9,125 MWh/year
Demand supplied by the microgrid, monthly average	0 MW	1.05 MW
Electric energy supplied by the utility	7,603 MWh/year	180,875 MWh/year
Demand supplied by the utility, monthly average	1.27 MW	22.65 MW
Thermal energy supplied by the microgrid	31,487 MMBtu/year	0 MMBtu/year
Net natural gas used by the microgrid	0 MMBtu/year	86,979 MMBtu/year
Electric energy (kWh) cost from utility	$684,270/year	$16,278,759/year
Electric energy (demand) cost	$608,240/year	$14,954,561/year
System maintenance costs	N/A	$194,000/year
Steam costs	$1,920,090/year	($758,761)/year
Net cost of natural gas used by the microgrid	N/A	$669,738/year
Energy facility lease payment	TBD	TBD
Total energy cost	$3,212,600/year	$31,337,961/year
Net energy savings	$0/year	$962,039/year

N/A = Not applicable
TBD = To be determined

Based on the project pricing and annual fees associated with the project, the simple payback for the project is 14 years, using a total project cost of $13,529,000, annual savings of $1,155,702, and annual maintenance fees of $194,000. Maintenance costs include maintenance of the CHP units at NYCHA Fulton Houses, the distribution equipment, and control hardware. Further financial details are included in the Task 4 report and the societal benefits and costs are documented in the Industrial Economics, Inc. (IEC) analysis located in Appendix B.

Please note: The IEc model and analysis was designed to characterize the societal impacts of the proposed microgrid on the electric grid and on the community, while the ERS analysis reflects the costs and benefits to the individual microgrid customers. Thus, the economic feasibility shown in the results of the IEc model does not reflect the actual value to One City Block and the Fulton Houses.

Microgrid Configuration Options and Alternative Solutions

Multiple options were reviewed for the Eighth Avenue microgrid. ERS developed energy models for a wide range of energy generation sizing and technologies. The project configuration presented in this report is the best economic and emergency load configuration for servicing the two buildings and their emergency requirements under normal and emergency operation.

Of the many options reviewed, the project team identified an attractive alternate microgrid configuration, replacing the three smaller microturbine units at Fulton Houses with a single, larger generation unit. However, this project would face additional regulatory hurdles under the NYC building code. The code requires a licensed steam operator to be within eyesight of the generator 24 hours per day, 7 days per week for any generation system producing steam at a pressure above 15 psi. This requirement adds a significant annual cost to the project, which makes it financially unfeasible. This alternative design will be reviewed in further detail during Stage 2 of NY Prize since it would potentially be more valuable to all parties. The project team has held initial conversations with the Con Edison steam program regarding potential participation in a pilot buyback program to offset a portion of this additional cost, as well as an alternate business model Con Edison is considering in which it would own and operate a plant under contract to an end user.

Microgrid Roadblocks and Potential Solutions

While the potential for microgrids to increase resiliency and provide complementary services to One City Block and Fulton Houses is great, the ERS team identified several roadblocks throughout the course of the feasibility study. Many of these roadblocks are likely faced by many of the NY Prize projects currently under analysis. Table ES-4 highlights the primary roadblocks pertaining to the Eighth Avenue microgrid and the potential workarounds and solutions under consideration. The ERS team is engaged with many stakeholders in discussing these roadblocks and expects to continue these conversations in preparation for and during Stage 2 of the NY Prize program.

Table ES-4. Eighth Avenue Microgrid Roadblocks and Potential Solutions

Roadblock Faced by the Microgrid	Potential Workaround or Solution
There are unresolved right-of-way issues when connecting multiple electrical meters across a public street.	This is a known challenge affecting all NY Prize projects under consideration. This item needs to be addressed collectively with all NYS utilities.

Roadblock Faced by the Microgrid	Potential Workaround or Solution
The NYC Building Code requires that any generation system producing steam at pressure greater than 15 psi have 24/7 monitoring by a licensed operator, which adds significant operation and management costs to the microgrid.	The proposed configuration produces steam below 15 psi, thereby sidestepping the monitoring requirement. The team has held initial conversations with Con Edison regarding the utility operating the microgrid to potentially avoid this cost. A single larger generation unit would greatly improve the economics of this project if this roadblock can be resolved.
There are potentially many unknown challenges and costs involved in digging up a major Manhattan street to lay cable for the microgrid.	The team has consulted with contractors installing similar services in NYC to build the estimates. A significant safety factor has been built in. In addition, the team has begun to explore the potential for Con Edison to assist in resolving this challenge; ideas include either leasing cable or ducts and allowing the team to use existing pipe, or some alternate solution. This is an ongoing conversation between the project team and Con Edison.
NYCHA has federal restrictions on realizing the full benefits from reducing energy costs at their facilities.	This roadblock affects the revenue structure of the project. Rather than reduce its steam expense from the heat supplied by the CHP plant, NYCHA will pay One City Block for the steam it consumes and in return will receive a market-based lease payment for the space provided for the CHP plant siting. This agreement will be further developed during NY Prize Stage 2.
The thermal load at Fulton Houses is not large enough to use the entire heat output from the CHP plant.	The ERS team has held multiple conversations with the Con Edison Steam Group regarding participation in a steam buyback pilot program. This discussion will continue through the summer as the team prepares its NY Prize Stage 2 proposal.

Conclusions and Recommendations

The ERS team conducted a full technical analysis and review of the infrastructure requirements and utility and stakeholder involvement. Both One City Block and Fulton Houses have a unique opportunity to create an energy symbiosis through this microgrid; One City Block is seeking electric rate relief, has an excess of back-up capacity, and does not need additional thermal energy, while Fulton Houses has favorable New York Power Authority rates, no existing electric back-up capacity, and a continuous need for thermal energy. The Fulton Houses is further constrained in efforts to implement energy efficiency, since energy costs savings result in reduced reimbursements from federal agencies. Finally, Con Edison sees merits in the plant from both the electric and steam distribution viewpoints.

The operation of the Eighth Avenue microgrid will generate many value streams, including the following:

- Electricity production at lower cost per kWh than One City Block's current costs
- Steam production at a lower cost per MMBtu than NYCHA's current costs

- The combined operation reduces GHG with CHP efficiency of about 56%
- Emergency electric back-up service for Fulton Houses' 2,000 moderate-income residents
- Additional steam capacity for Con Edison steam distribution in a steam-constrained area
- Additional electric capacity for Con Edison electrical distribution

Next Steps

The Eighth Avenue microgrid has the stakeholder support and technical merit to be a feasible project that should continue to seek support during Stage 2 of the NY Prize program. There are several activities that the project team will need to complete as the proposal for Stage 2 is developed, many of which have already begun:

- The project team will continue to engage the key stakeholders: One City Block, NYCHA, Con Edison, and Google. These conversations will focus on processing the results of this feasibility study and considering any additional configuration options available.
- The project team will continue to hold conversations with Con Edison to discuss potential participation in the steam pilot buyback program. Con Edison will be an important stakeholder and partner throughout the microgrid design stage, and continued engagement will help maintain the momentum built through recent conversations.
- As the microgrid moves into Stage 2, which contains a cost-share component, a partnership agreement between One City Block and NYCHA will likely be required to outline the contributions and benefits that each party will receive throughout the microgrid design stage.

This feasibility study has demonstrated that the proposed Eighth Avenue microgrid achieves the goal of the NY Prize program: to identify projects that incorporate resiliency, emergency power availability, and financial success. The project has the stakeholder support, technical merit, and financial viability to be a strong contender to move on to Stage 2 of the NY Prize program. This project bridges many of the stakeholder gaps that exist in developing successful microgrid projects and is an excellent example of a public-private partnership to provide resiliency services while reducing GHG emissions.

INTRODUCTION

This report presents the final results of the Eighth Avenue Microgrid feasibility study completed by the ERS team as outlined below:

- **Section 1: Summary of Microgrid Capabilities** – This section presents an overview of the microgrid facilities, outlining minimum and preferred capabilities considered during the feasibility study.
- **Section 2: Technical Design Considerations** – This section presents the preliminary assessment of the technical design and system configuration of the microgrid.
- **Section 3: Commercial and Financial Feasibility** – This section presents the assessment of commercial and financial feasibility of the microgrid.
- **Section 4: Technical Design Costs and Benefits** – This section presents the costs and benefits developed for the feasibility study.
- **Section 5: Conclusions and Recommendations** – This section outlines the roadblocks faced by the microgrid and their potential solutions and workarounds, and discusses the next steps for the project.

1 SUMMARY OF MICROGRID CAPABILITIES

This section presents the minimum required and preferred capabilities for the Eighth Avenue Microgrid, including descriptions of the facilities and distributed energy resources included in the microgrid.

1.1 Description of the Facilities

The proposed microgrid includes two buildings: One City Block and NYCHA's Robert Fulton Houses (the Fulton Houses).

1.1.1 One City Block

One City Block is a 2,900,000 sq ft facility that is primarily used for office space. Originally owned by the Port Authority of New York for warehousing and shipping, it was later used by large IT and telecom firms for their servers. Google purchased the building in 2010 to serve as their New York headquarters. The building's other tenants include a small cancer treatment center. The portion of space dedicated to data center operations has been on the decline, a trend that is expected to continue. Building demand has been reduced from a historical maximum of 45 MW to its current peak of about 30 MW. The building has 25 MW of existing diesel back-up generation. The facility is served by multiple HVAC systems and a complex internal electrical distribution network with twenty-one Con Edison feeds. During an emergency event, the occupancy and normal functions are expected to be sharply curtailed, reducing the building's electric demand well below the existing back-up generation capacity.

1.1.2 Fulton Houses

The Fulton Houses complex consists of eleven buildings, three high-rises (twenty-five stories) and eight low-rise (seven stories) buildings situated on three separate blocks fronting Ninth Avenue. There are a total of 945 apartments with associated common area spaces. All eleven buildings have elevators. The buildings are heated by Con Edison steam with a single feed. The high pressure Con Edison steam is distributed through customer-owned lines to individual buildings where the pressure is reduced to 15 psi via a pressure reducing valve for distribution within each building. There is no central air-conditioning, although tenants are permitted to install window units. The buildings are master metered. Table 1-1 summarizes the electrical rate and distribution information for each facility.

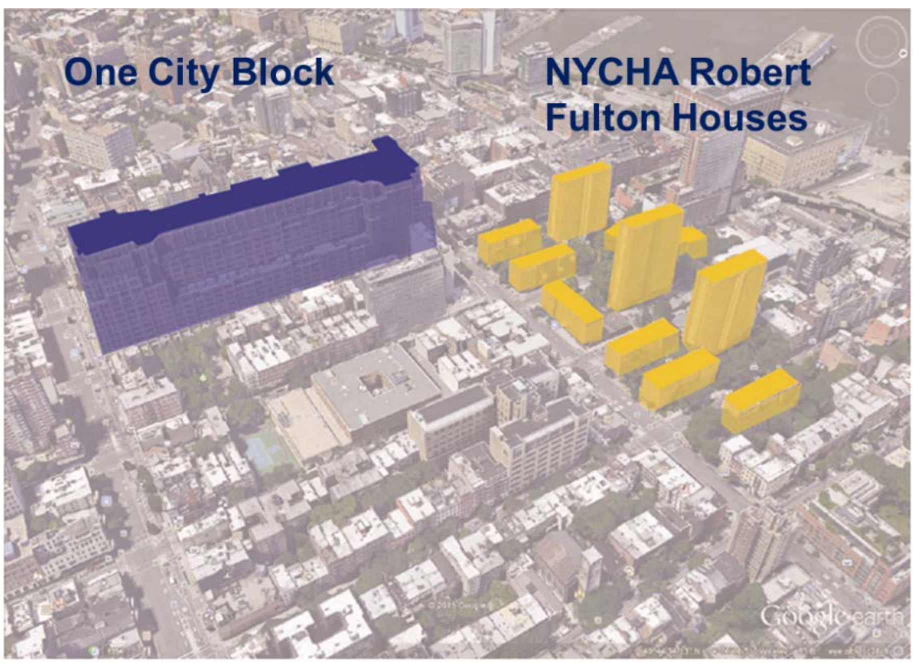
Table 1-1. Facilities Summary

Facility	One City Block	Fulton Houses
Sq ft	2,900,000	272,988
Electric utility rate	Con Edison SC-9 rate 5	NYPA allocation
Steam utility rate	Con Edison SC-2 rate 2	Con Edison SC-4 rate 4
Economic sector	Large commercial	Residential
Annual electricity use	190,000 MWh	7,603 MWh
Peak electric demand	30 MW	1.744 MW
Percentage of the facility served by the microgrid during a major power outage	0% (served by existing back-up)	100%
Number of hours per day that the facility requires electricity from the microgrid	24	0%

1.1.3 Facility Layout

The overview map in Figure 1-1 shows the facilities included in the microgrid. The facilities would be connected by underground electrical wires across Ninth Avenue. The ERS team has held multiple discussions with Con Edison regarding the potential of using its existing wires or conduit to run wires between the facilities; this ongoing conversation will continue into Stage 2 of NY Prize.

Figure 1-1. Overview Map of Microgrid Facilities



1.2 Power Generation Mix

Table 1-2 shows the power generation capabilities under consideration for the facilities either as part of the configuration budgeted in this study (new), existing, or in-planning. The table notes the generation fuel source and availability during emergency events.

Table 1-2. Current and Planned Power Generation Resources

Location	Generation Resource	Generation Capacity (kW)	Normal Operations	Emergency Operations	Emergency Operation Duration	Back-Up Generation
Fulton Houses	New natural gas CHP unit(s)	900	X	X	7 days	
	New solar PV generation	50	X		N/A	
	New back-pressure turbine	150	X	X	7 days	
One City Block	In-planning natural gas CHP unit	4,800		X	7 days	
	Existing back-up diesel/natural gas generators	25,000		X	7 days	X
Total generation capacity for microgrid		**1,100**[a]				

[a] Total generation capacity does not include One City Block resources, which would only be available during grid outages.

The project configuration includes new distributed generation resources at the Fulton Houses that are intended to be installed as part of the project and are budgeted as such. The configuration is also designed to incorporate generation resource at One City Block for back-up including the in-planning unit as well as the multiple existing back-up generators. The cost of interfacing to these back-up units is also included in the budget. ERS is also in discussions with Con Edison to evaluate if and how this system can be easily incorporated into the Con Edison infrastructure.

1.3 Microgrid Controls, Isolation, and Islanding

The controls, communications, islanding capabilities, and seamless operation of the microgrid will provide the Fulton Houses and potentially One City Block with the added resiliency and emergency operations needed for the residences at the Fulton Houses. During an emergency event the microgrid will automatically go into isolation if power is lost during grid-connected mode. This utility loss will be detected by the IEEE 1547 protective relay at the isolation point of the circuit. A remotely controlled recloser will isolate the microgrid circuit from the utility. All of the devices will be reviewed with the utility to ensure proper operation; where possible, components that the utility uses will be utilized. Each has a full complement of protection and communication functions.

In the event, the switch will open and the generation resources will be electrically isolated. The operation will be an open transition. The synchronous generators will be switched to voltage control mode and simultaneously closed onto the microgrid. The microgrid control system will manage the generation to ensure optimum voltage and frequency control. The loads will be evaluated for real and reactive requirements as part of the sizing of synchronous generators plus a generous margin. These measures will help ensure that the requirements of ANSI C84.1 are met.

Communication and interoperability with the local utility and primary operator of the One City Block microgrid will be incorporated into the final design of the project. It is anticipated that such communication will be based on standard protocols such as OpenADR. Both hard-wired and wireless communication topology and infrastructure will be studied in the next phase of the project's development and design to ensure a forward-compatible system. Black start is similar to the loss of islanding sequence; the utility isolation switch would be opened and the islanding sequence would be followed.

1.4 Additional Capabilities

In addition to the minimum capabilities required by NY Prize, the Eighth Avenue Microgrid incorporates a variety of capabilities to leverage prior activities and satisfy interests and needs of the project stakeholders. These features include:

- **Extensive demand-side management to minimize generation requirements.** Behind-the-meter efficiency will play a large role in reducing peak demand needs and annual energy usage in the Eighth Avenue Microgrid. One City Block has already implemented significant energy efficiency improvements in alignment with Google's commitment to the NYC Carbon Challenge. The Fulton Houses property is planning an energy performance contract to upgrade all of its facility lighting. These projects will continue, and additional opportunities will be explored as part of an investment grade energy audit conducted during Stage 2 of NY Prize.
- **Commitment to greenhouse gas reductions.** Reducing GHG emissions is at the forefront of Google's commitment to the Carbon Challenge. One City Block has exceeded the initial 10-year 30% target and has set even more aggressive goals of 50% carbon reduction by 2025.
- **Leverage private capital.** The Eighth Avenue Microgrid is uniquely positioned to leverage private capital in conjunction with NY Prize funding to design and build the microgrid. One City Block provided cost share during Stage 1 of NY Prize and will likely adopt a similar approach as this project moves through Stage 2.

2 Technical Design Configuration

This section of the report contains the proposed Eighth Avenue microgrid design and configuration, including a characterization of electrical and thermal loads, distributed energy resources, microgrid infrastructure and controls, and IT/telecommunications infrastructure.

2.1 Proposed Microgrid Infrastructure and Operations

The microgrid will serve One City Block and Fulton Houses, and will operate continuously to provide electric energy and steam. Section 1.1 provides a complete description of the facilities in the Eighth Avenue microgrid, highlighted in Table 2-1.

Table 2-1. Facilities Served by the Microgrid

Facility	Facility Type	Area (Sq ft)
One City Block	This facility is of mixed use and primarily functions as office space. A large fraction of the space was used as data centers, but this function has been declining over time. The facility houses a small cancer treatment center and a small retail space.	2,900,000
Fulton Houses	The complex comprises 945 moderate-income apartments in 11 buildings on 3 separate blocks. The buildings are a mix of eight low-rise (7-story) and three high-rise (25-story) towers. The buildings are master-metered.	272,988

2.1.1 Microgrid Equipment and Layout

All of the new generation sources targeted for the microgrid's normal operation will be located on the Fulton Houses campus. The proposed microgrid will include three new 300 kW CHP plants, a new 50 kW photovoltaic (PV) array, and a new 150 kW back-pressure turbine as shown in Table 2-2. A natural gas-fired CHP plant is in the planning stages at One City Block and if it is implemented it will supply electricity to the Fulton Houses during an islanding event and generate power for One City Block under normal operation. Existing diesel back-up generators at One City Block will provide emergency back-up generation, depending on need and availability. The microgrid will run parallel with the grid during normal operation and will run islanded from the grid during an emergency event.

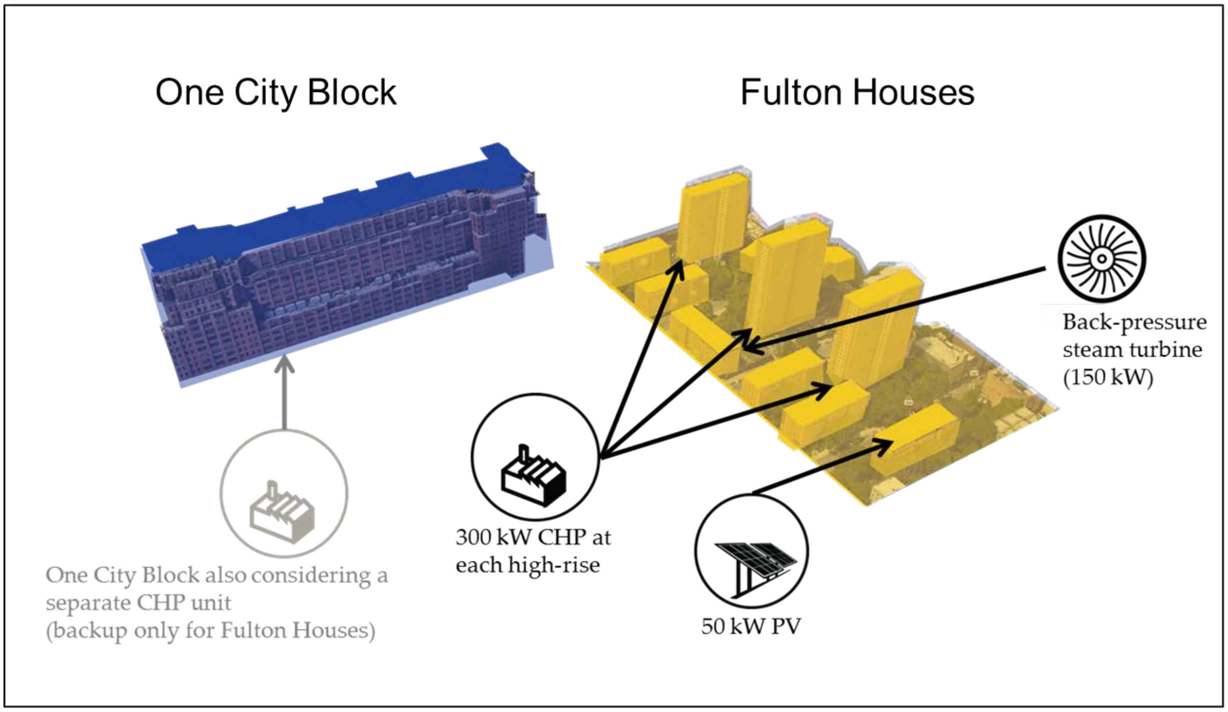
Table 2-2. Current and Planned Power Generation Resources

Location	Generation Resource	Generation Capacity (kW)	Normal Operations	Emergency Operations	Emergency Operation Duration	Back-Up Generation
Fulton Houses	New natural gas CHP unit(s)	900	X	X	7 days	
	New solar PV generation	50	X		N/A	
	New back-pressure turbine	150	X	X	7 days	
One City Block	In-planning natural gas CHP unit	4,800		X	7 days	
	Existing back-up diesel/natural gas generators	25,000		X	7 days	X
Total generation capacity for microgrid		**1,100**[a]				

[a] Total generation capacity does not include One City Block resources, which would only be available during grid outages.

A one-line diagram of the Eighth Avenue microgrid was created by the ERS team and is included for reference in Appendix A: this shows the microgrid connection between One City Block and Fulton Houses. A simplified layout of the microgrid is shown in Figure 2-1.

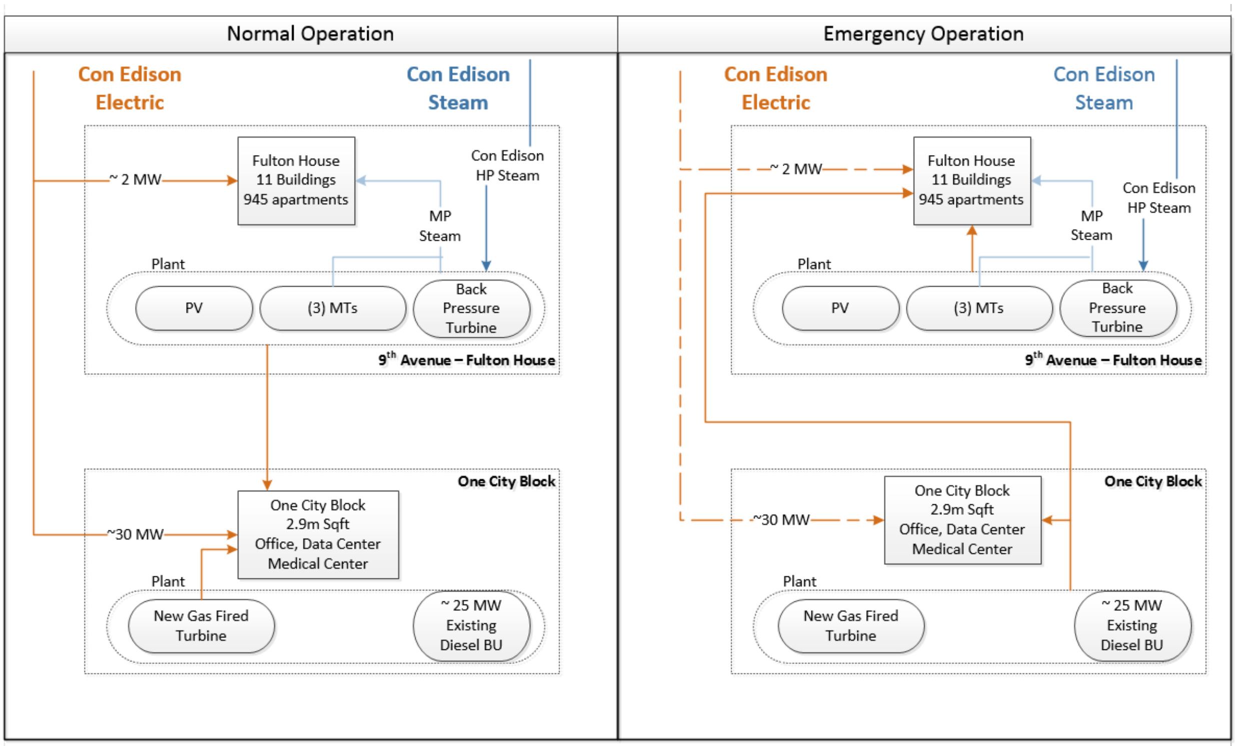
Figure 2-1. Eighth Avenue Microgrid Simplified Layout



2.1.2 Microgrid Operation

The microgrid will run in parallel with the grid, but will be largely power self-sufficient during normal operation. There is no plan to export power to the grid. The project's control systems will automatically island the microgrid during an emergency event and restore parallel operation after the event. The electrical infrastructure will be buried underground below Ninth Avenue, providing the best level of protection against weather and other disruptions. The flow of electricity and thermal energy during normal and emergency operation is illustrated in Figure 2-2 and discussed below.

Figure 2-2. Operational Flow Diagram



Normal Operation

During normal operations, all of the electricity from the Fulton Houses plant will be directed to serve One City Block and will operate in parallel with the grid. The Fulton Houses plant will provide approximately 5% of One City Block's annual electrical usage and will provide low-pressure steam to serve the Fulton Houses complex's high-rise space and domestic hot water (DHW) heating needs, meeting about 40% of the campus's annual thermal load.

On the electric side, the energy generated at the Fulton Houses plant will be coordinated and delivered to One City Block via an underground customer-dedicated line. The power will be used exclusively by One City Block, offsetting its current load; no power will be exported to the grid.

On the steam side, the three microturbines will produce low-pressure steam, which will be distributed to the three high-rises through a new dedicated steam distribution system. The balance of the campus steam usage will continue to be supplied by Consolidated Edison (Con Edison) high-pressure steam. A back-pressure steam turbine will replace the existing pressure-reducing valves, generating additional electricity; this mid-pressure steam will be distributed to the Fulton Houses campus through the existing steam distribution system. The control system will monitor all of the generation sources included in the microgrid to ensure that the systems are functioning and ready for an emergency event.

Grid Power Outage and Emergency Operation

During non-emergency outages and emergency operation, the electrical output from the Fulton Houses plant will be switched from serving One City Block to meeting the needs of the Fulton

Houses campus, with any shortage in capacity made up by output from an additional CHP/thermal storage system at One City Block which is currently in the planning stage. One City Block will use its existing back-up generation units to serve its emergency power needs, which are mostly run on diesel fuel. As the microturbine units at the Fulton Houses plant and the One City Block unit are natural gas-fired, their operation should be indefinite, exceeding the 7-day operational minimum. One City Block uses its back-up generation units to handle its emergency power loads, which are mostly run on diesel fuel.

2.1.3 Resiliency

The proposed microgrid will increase resiliency for the Fulton Houses. The Fulton Houses plant includes diverse and multiple sources of power with three independent gas-fired microturbines, a steam-power back-pressure turbine, and PV. The microturbines will be installed on elevated platforms, above possible flood or damage from vehicles. During an emergency, Fulton Houses will also be served by the One City Block generation. The One City Block generation capacity includes the potential inclusion of a natural gas CHP unit in planning at One City Block and 25 MW of existing diesel back-up generation. In total, this capacity well exceeds One City Block requirements during an emergency, providing N+1 redundancy to ensure operation during an event.

Since solar power may not be available at all times and during all types of emergencies, it will not be counted on to deliver power during emergencies but will be included in the control software and hardware configuration to save fuel and prolong operational durations.

2.2 Load Characterization

Determining the CHP performance requires a characterization of the hourly thermal and electric usage of a building. Optimum CHP performance occurs when the thermal and electric loads are highly coincident.

Since One City Block will absorb all of the Fulton Houses' plant electric production, the key economic driver of the system will be the Fulton Houses campus's thermal load. The most economic operation of the system will occur when CHP production is offsetting the thermal usage of the campus.

The thermal load profile of the Fulton Houses was developed using information collected from site observations, Con Edison monthly billing data, and an in-house 8,760 hourly model. Utility interval billing data was not available for this site, nor was it practical to conduct end-use metering. Fortunately, multifamily building load profiles, particularly the thermal loads, are well understood and can be accurately characterized when reconciled with site-specific billing and weather data.

One City Block's electric demand (30 MW) is more than an order of magnitude larger than that of the Fulton Houses (1.8 MW); therefore, all of the electricity produced by the Fulton Houses will be consumed by One City Block. In addition, none of the thermal output will be consumed by One City Block. As a consequence, the development of specific hourly electric or thermal load profiles for One City Block and electric profiles for Fulton Houses are not necessary for the analysis.

2.2.1 Thermal Load Profile

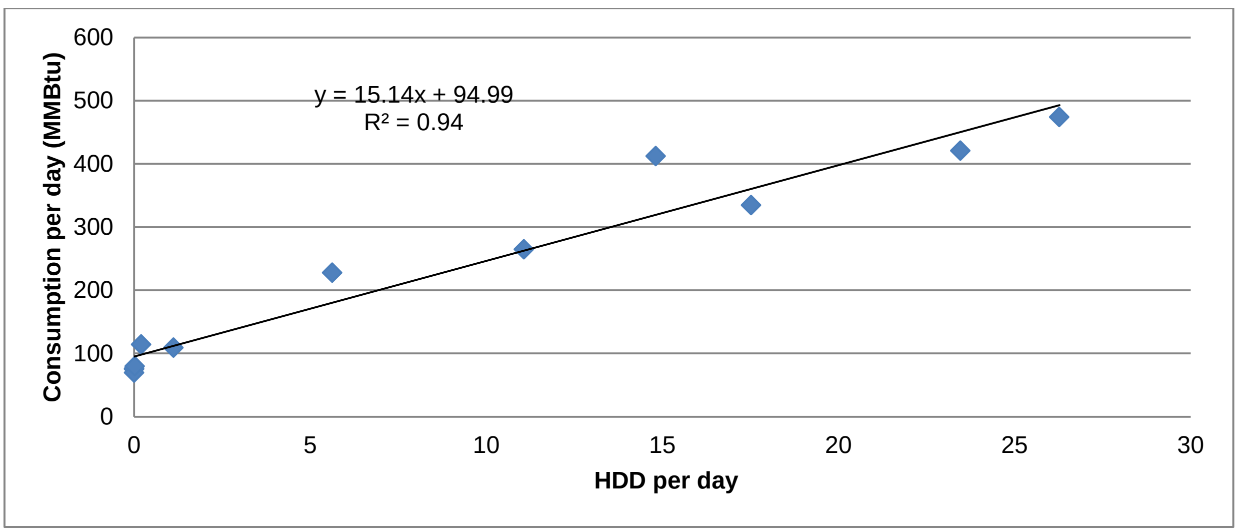
Con Edison steam is used for space heating and DHW for all eleven Fulton Houses. Steam is stepped down from Con Edison's high-pressure delivery of 150–180 psi to 15 psi at each building via pressure-reducing valves. The low-pressure steam provides space heating through a low-pressure distribution system with individual terminal radiators. Heat exchangers in each building provide DHW. Condensate is sent to drains at a temperature of approximately 150°F. Since the steam enters the customer distribution at a single feeder, there is no individual building billing or usage data available.

In general, the load profiles were developed by first using the bills to determine the DHW annual usage and weather-normalized space-heating usage. Hourly space-heating profiles were developed from a relationship between heating degree days (HDD) and billed usage. The hourly DHW profile was derived from applying the annual usage to typical hourly multifamily DHW profiles.

Space Heating

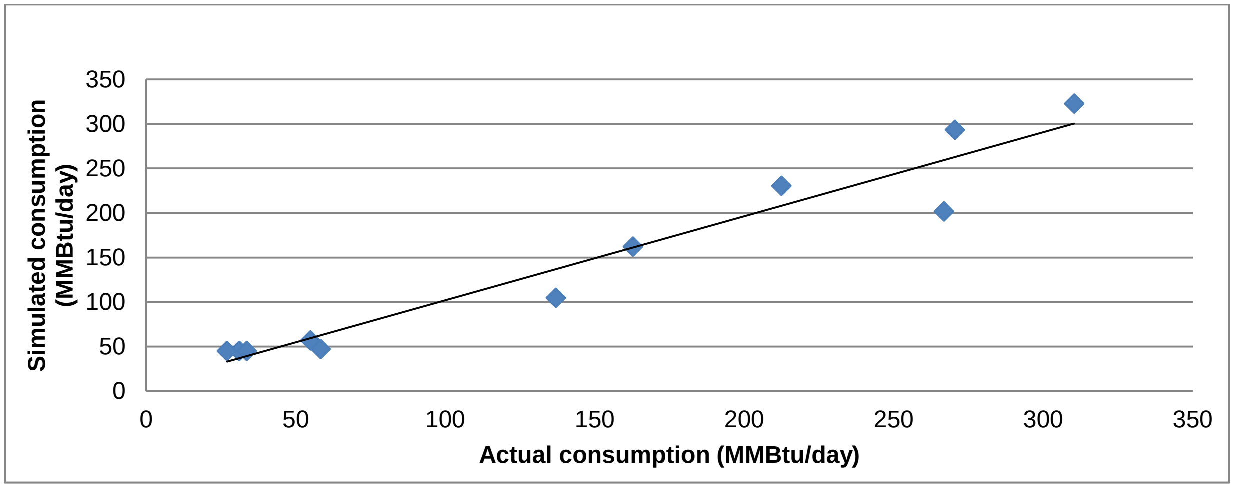
ERS used Con Edison steam billing data for the high-rises, with 2014 as the starting point for determining the thermal load. This was regressed against the HDD data recorded at New York's Central Park weather station to obtain a correlation between HDD and thermal load. To eliminate weather-specific biases, ERS normalized the billed steam usage with the typical meteorological year (TMY3) data for the Central Park weather station. The regression coefficient of 15.14 MMBtu/HDD per day is used to estimate the hourly space-heating requirements using the TMY3 outdoor air temperature data for that hour. Figure 2-3 shows the Fulton Houses steam usage versus the HDD regression results.

Figure 2-3. Fulton Houses Steam Usage vs. HDD Regression Results



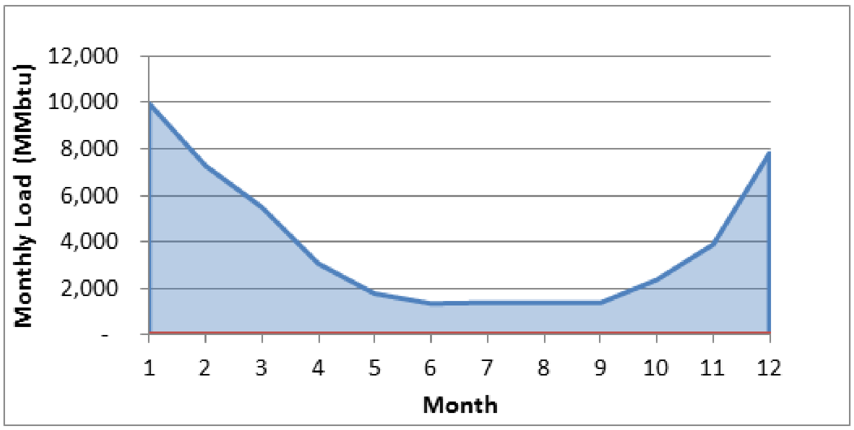
The weather data highly correlated with the monthly billing, and our model showed good agreement with the actual billed data as shown in Figure 2-4, which compares the simulated monthly usage to the actual thermal consumption.

Figure 2-4. Simulated Fulton Houses Steam Consumption vs. Actual Consumption



The weather-normalized steam load for the Fulton Houses campus is represented in Figure 2-5.

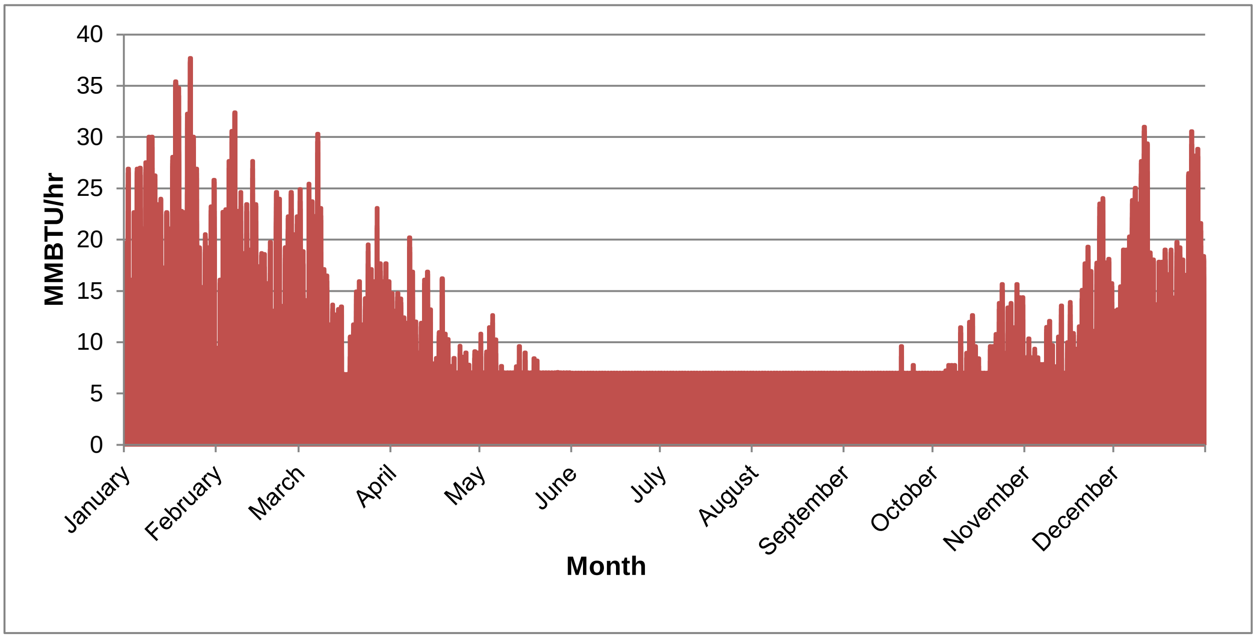
Figure 2-5. Weather-Normalized Fulton Houses Monthly Steam Load



Domestic Hot Water

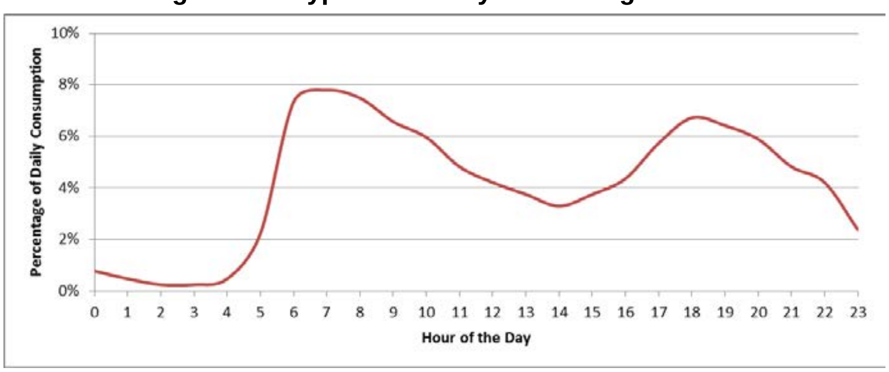
The daily DHW usage can be derived from the billed usage in the summer, when there is no space heating. The billed hourly steam usage for 2014 is presented in Figure 2-6.

Figure 2-6. Fulton Houses Hourly Steam Usage, 2014



ERS's model takes the normalized monthly DHW consumption and applies an hourly profile, published by the Department of Energy, of the typical DHW consumption for multifamily buildings of this size. The profile allows an estimate of the hourly DHW uses for a given month. An example from this model of an hourly load curve for a particular month is shown in Figure 2-7.

Figure 2-7. Typical Monthly DHW Usage Profile



Thermal Load Served by Combined Heat and Power

The final annual hourly profile for the Fulton Houses campus is the sum of the space heating and DHW hourly usage. Figures 2-8 and 2-9 show the profiles of a typical summer and winter day.

Figure 2-8. Fulton Houses Representative Summer Day Thermal Load

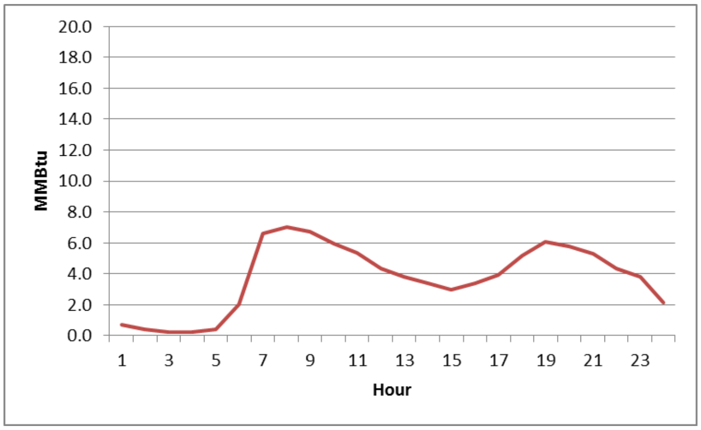
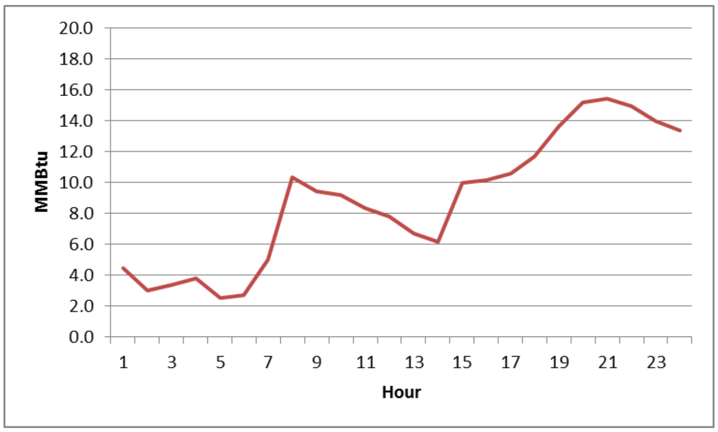


Figure 2-9. Fulton Houses Representative Winter Day Thermal Load



The proposed system configuration will serve the three high-rises only, since it is cost-prohibitive to pipe either steam or hot water to all eleven buildings. The three high-rises contain 70% of the apartment units and 59% of the total campus building square footage. The high-rise usage was based on an allocation of the total energy usage by the number of apartments. Table 2-3 summarizes the annual consumption that ERS calculated for the Fulton Houses versus the billed annual consumption.

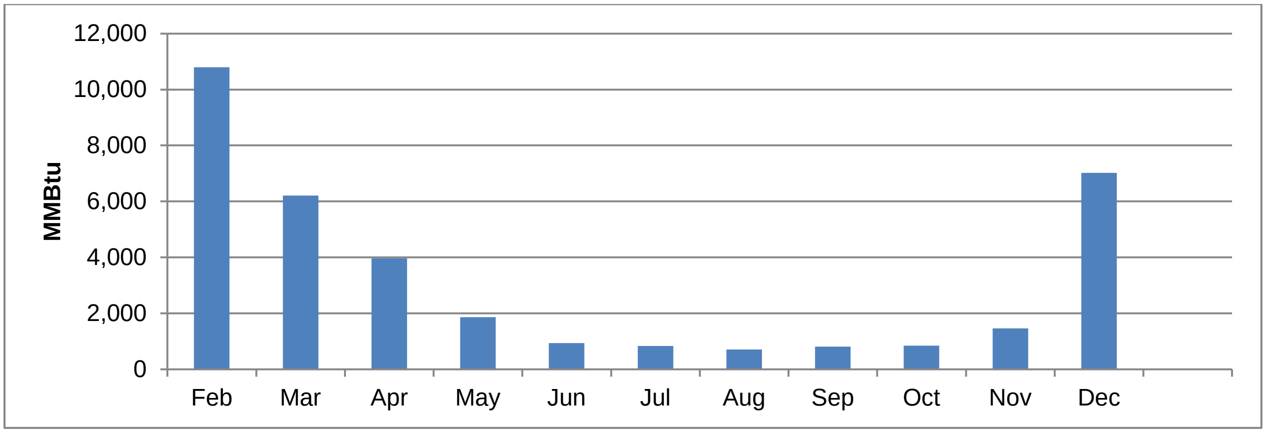
Table 2-3. Fulton Houses Campus 2014 Weather-Normalized Consumption Summary

Facility	Number of Apartments	Billed Annual Consumption (MMB**tu**/yr)	Weather-Normailzed Annual Consumption (MMB**tu**/yr)
Fullton Houses low-rises	288	24,541	22,820
Fulton Houses high-rises	656	55,899	51,979
Campus total	945	80,440	74,799

One City Block Steam Consumption

Although the microgrid will not be supplying thermal energy to One City Block, Figure 2-10 represents the thermal energy consumed as steam for One City Block.

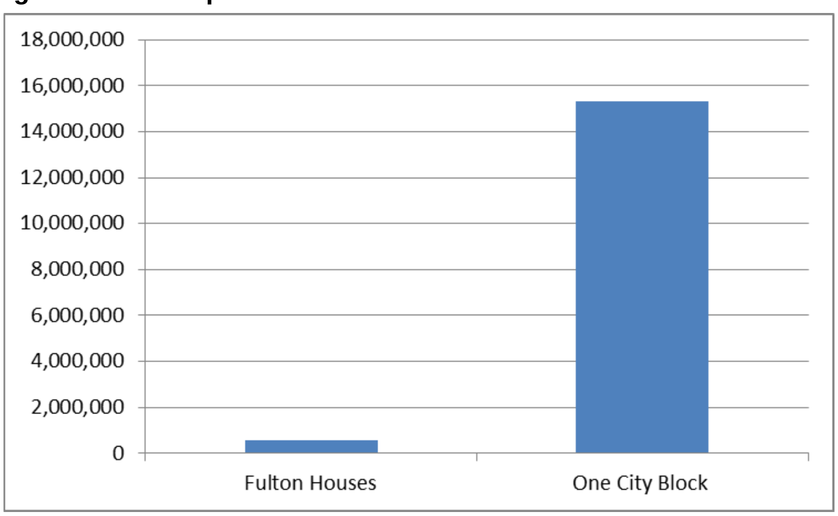
Figure 2-10. One City Block Steam Consumption



2.2.2 Electric Energy

The Fulton Houses plant's generation will displace Con Edison electricity at One City Block during normal operations; therefore, the relevant electrical profile is that of One City Block. There are twenty-one feeders for One City Block, and it has not yet been determined which of these feeders will be supplied; thus, it is not possible at this point to project how the CHP electricity will offset the consumption of any particular feeder. As the electricity demand at One City Block (approximately 30 MW) is more than an order of magnitude larger than that at the Fulton Houses (1.8 MW), ERS has assumed that One City Block can consume any and all electricity output from the microturbines, PV, and back-pressure turbine systems at the Fulton Houses. Figure 11 compares the potential kWh produced and consumed.

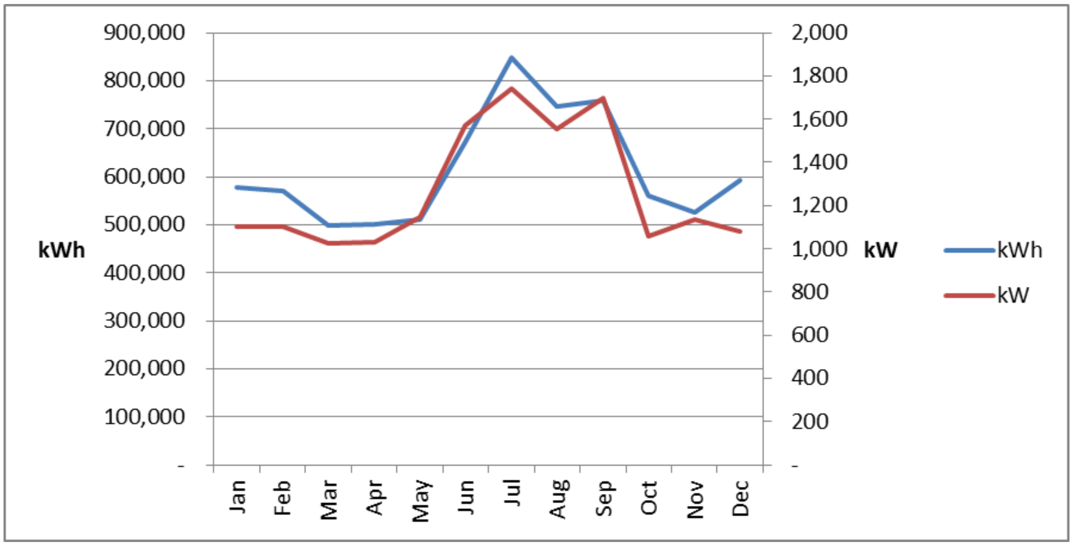
Figure 2-11. Comparison of Potential kWh Produced and Consumed



Fulton Houses Electricity Usage

Under normal operation, electricity will not be provided to the Fulton Houses complex. Figure 2-12 shows the monthly kWh usage and kW demand of the eleven-building campus.

Figure 2-12. Fulton Houses Monthly kWh and kW



During emergency operations, the Fulton Houses plant's electric production will be supplemented with power from One City Block, which will be more than adequate to meet the campus's need. Since there are no hourly constraints in power capacity, a Fulton Houses campus hourly electric profile is not required.

2.2.3 Emergency Operation Profile

During emergency operation, electricity will be switched from One City Block to serve the entire Fulton Houses complex load, including all of the 945 apartment loads. The size of the Fulton House emergency operation load was derived from the site's billed demand. One City Block will be served by its existing fleet of diesel generators with an installed capacity that exceeds the maximum load of the facility. Table 2-4 shows a building-building summary of emergency power requirements.

Table 2-4. Emergency Load Requirements

Building	Sq Ft	Normal Maximum Building Load (MW)	Emergency Maximum Building Load (MW)	Electric Load Served by Microgrid
One City Block	2,900,000	30	15 (est.)	0% (served by existing backup)
Fulton Houses	272,988	1.8	1.8	100%

2.2.4 Summary of Microgrid Preparation Activities

Energy efficiency is an important part of the overall microgrid project. NYCHA has a long track record on this front and has active and planned energy efficiency projects at Fulton Houses that will reduce their overall need for electrical energy. A major effort to upgrade the windows at One City Block is ongoing. A summary of these projects is shown in Table 2-5.

Table 2-5. Planned Energy Efficiency Improvements

Building	Energy Efficiency Reductions	EE Activities
Fulton Houses	82 kW 72,000 kWh	Lighting retrofit
Fulton Houses	3,205 MMBtu	Condensate heat recovery
One City Block	3,400 MWh	Window replacements

ERS has proposed recovering heat from the condensate of the DHW steam heat exchangers. Currently, steam condensate leaves the Fulton Houses buildings at 150°F. Based on the preliminary sizing of the condensate recovery heat exchangers, it is anticipated that incoming city water could be preheated by approximately 8°F, resulting in an 11.5% reduction in the amount of energy required to heat DHW. The savings are calculated as a fraction of the total DHW load and the expected change in temperature. The condensate heat recovery calculation is based on an assumed efficiency of a plate-and-frame heat exchanger that yields a 2°F approach temperature on the hot (low flow) side of the heat exchanger. The projected average contribution to DHW heating is 0.366 MMBtu/hour, or an annual total of 3,205 MMBtu/year.

2.3 Distributed Energy Resources Characterization

Three 300 kW natural gas-fired CHP systems will be the primary distributed energy resources at the Fulton Houses. The electrical output from the CHP units will be supplemented with a 50 kW PV array on the roof of building 1 and a 150 kW back-pressure turbine in building 6 performing the function of a pressure-reducing valve. ERS expects that the back-pressure turbine can reduce the current steam pressure, which ranges from 150–180 psi to 60 psi in the main steam header prior to the steam being sent to all eleven buildings.

In addition to the distributed energy resources within the microgrid, One City Block is currently assessing the feasibility of installing a larger CHP system at One City Block. This unit, if implemented, would generate power for One City Block under normal operation and during emergencies would be available for the NYCHA facilities and the hospital in One City Block, which will be isolated from the grid. Table 2-6 shows the generator sources planned for the microgrid.

Table 2-6. Proposed Microgrid Generation Sources

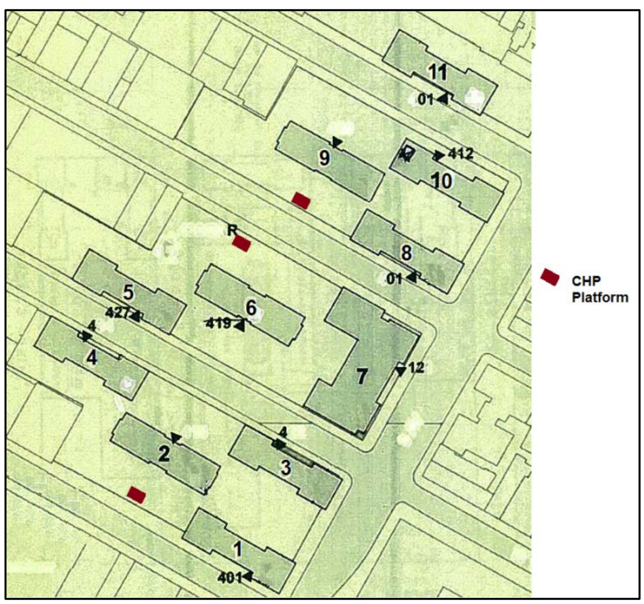
Building	Location	Capacity (kW)	Prime Mover	Peak Load Contribution	Percentage of Peak Load	Thermal Load (MMBtu/hr)	Percentage of Average Thermal Load
Fulton Houses building 2 CHP	W 16th St. and 9th Ave.	300	Natural gas	300 kW	17.2	0.77	8.4
Fulton Houses building 6 CHP	W 17th St. and 9th Ave.	300	Natural gas	300 kW	17.2	0.77	8.4
Fulton Houses building 9 CHP	W 18th St. and 9th Ave.	300	Natural gas	300 kW	17.2	0.77	8.4

Fulton Houses building 1 PV	W 16th St. and 9th Ave.	50	N/A	50 kW	Variable	None	None
Fulton Houses building 6 back-pressure turbine	W 18th St. and 9th Ave.	150	Steam	150 kW	8.6	None	None
Large CHP generator in planning (potential back-up only) for the Fulton Houses	111 8th Ave.	4,800	Natural gas	N/A	N/A	None	None

N/A = Not applicable

The three 300 kW natural gas-fired CHP systems will be installed on raised equipment platforms to be built above the existing parking lots adjacent to Fulton Houses buildings 2, 6, and 9. These platforms will be constructed such that parking spaces could be preserved under the platforms, minimizing the reduction in valuable parking assets. A map of the suggested locations for these platforms is shown in Figure 2-13. A 150 kW impulse back-pressure turbine will be installed in the mechanical room of building 6 on the high-pressure steam line entering the building. Three plate-and-frame heat exchangers will be installed in available space adjacent to the existing DHW heat exchangers in the mechanical rooms of buildings 2, 6, and 9. A 50 kW PV array will be installed on the open roof space of building 1.

Figure 2-13. Fulton Houses Site Map with CHP Locations



The three 300 kW CHP microturbines, in conjunction with additional generation from One City Block, will supply all of the electrical needs of the Fulton Houses during emergency islanding. Additionally, the three 300 kW CHP units at full load will supply approximately 36% of the peak DHW and heating loads of buildings 2, 6, and 9. During the summer, the three units will meet 67% of these buildings’ DHW load.

As the CHP units at both the Fulton Houses are fired by natural gas and supplemented by output from the rooftop PV, their operation should be indefinite. In the event that steam is not available from Con Edison, the electrical contribution from the back-pressure turbine can potentially be replaced by the capacity of the planned CHP generator at One City Block. The PV array is not dependent on a supply of fuel.

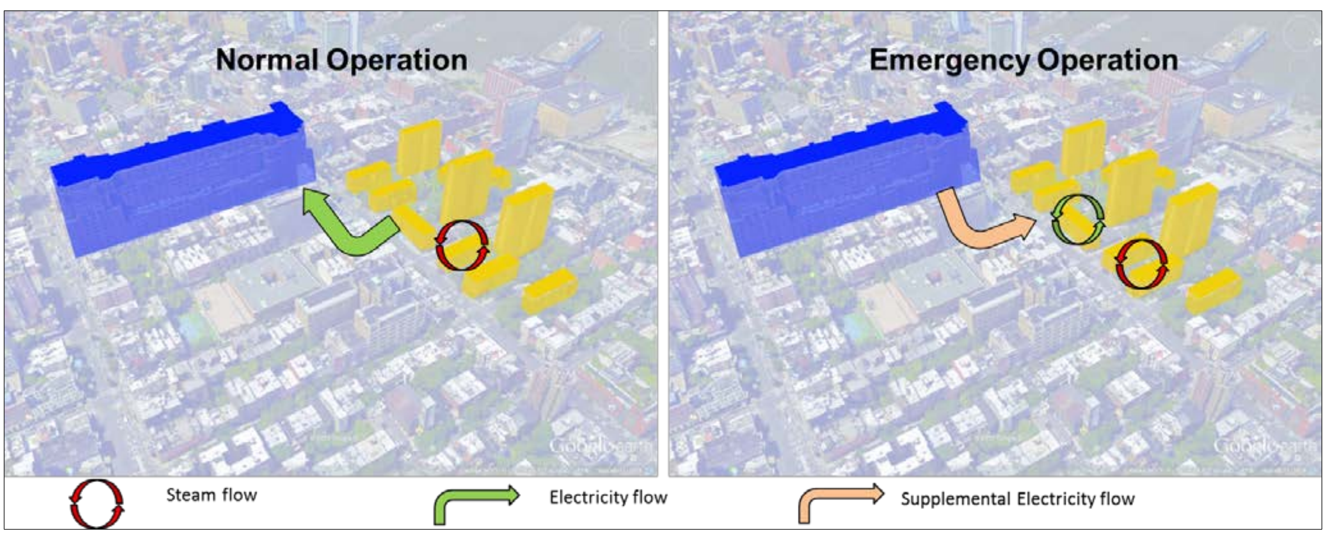
The CHP units at the Fulton Houses will have the same minimum specifications that are used for NYSERDA's CHP Acceleration Program, including black-start capability, grid-standard voltage, and frequency control and compliancy with UL 1741 protocols for voltage and frequency events. The CHP unit in planning at One City Block will have similar specifications. Each of the three 300 kW CHP systems will have the capability to turn down to 35%–40% of full load.

2.4 Electrical and Thermal Infrastructure Characterization

ERS and its team visited the facilities on multiple occasions to assess the electrical and thermal infrastructure. Figure 2-1, above, shows the facilities included in the microgrid and their spatial relation to each other. The main electrical feeder services come into One City Block at 480Y/277 VAC and into the Fulton Houses at 208Y/120VAC. The Fulton Houses, which is the only planned use for the usable heat stream, receives steam from Con Edison that is then distributed throughout the buildings from a central header. Each building has pressure-reducing stations to reduce the steam pressure to 15 psi before sending the steam to unit radiators to provide heating and a heat exchanger to provide DHW.

Figure 2-14 shows the flow of power and usable heat from the microgrid under normal operation, with the heat flow in red and the power flow in green. Under emergency operation, the heat flow would stay the same but the power flow would reverse.

Figure 2-14. Microgrid Power and Heat Flow Diagram



One City Block's electrical service from Con Edison consists of twenty-one feeders using 480Y/277 VAC services ranging from 3,000 to 5,000 amperes. The listing of the feeders for One City Block is as follows:

- West service: five Con Edison feeders, fourteen main switches
- Central service: six Con Edison feeders, eight main switches
- East service: six Con Edison feeders, sixteen main switches
- 16th floor: four Con Edison feeders and two future (trans. 13.2 kV to 480Y/277 VAC w/ network protector)

One City Block also has a significant number of standby diesel back-up generators that total over 25 MW of available back-up generation capacity. Some of these units are slated to be decommissioned and others to be updated to natural gas.

Fulton Houses includes eleven buildings and a garage. The main service switches are feeding distribution panelboards with open copper bus and fused knife switches. A list of the Fulton Houses electrical services are shown in Table 2-7.

Table 2-7. Fulton Houses Electrical Services

Block	Building	Electrical Service
Block A	1	401 W 16th St. (corner W 16th and 9th Ave), and 413 W 16th St. 7-story building, full basement 208Y/120 VAC electric service 800 A
Block A	2	418 W 17th St. and 422 W 17th St. 25-story building, full basement 208Y/120 VAC electric service 3,000 A
Block A	3	400 W 17th St. and 412 W 17th St. 7-story building, full basement, "has flooded" 208Y/120 VAC electric service 800 A
Block A	4	430 W 17th St. and 434 W 17th St. 7-story building 208Y/120 VAC electric service 800 A
Block B	5	427 W 17th St. and 431 W 17th St. 7-story building 208Y/120 VAC electric service 800 A
Block B	6	419 W 17th St. and 420 W 18th St. 25-story building, full basement 208Y/120 VAC electric service 3,000 A
Block B	7	117 9th Ave., 119 9th Ave., and 121 9th Ave. 7-story building 208Y/120 VAC electric service 800 A
Block B	12	432 W 18th St. (garage) 208Y/120 VAC electric service 800 A
Block C	8	401 W 18th St. and 411 W 18th St. 7-story building 208Y/120 VAC electric service 800 A

Block C	9	420 W 19th St. and 422 W 19th St. 25-story building, full basement 208Y/120 VAC electric service 3,000 A
Block C	10	400 W 19th St. and 412 W 19th St. 7-story building 208Y/120 VAC electric service 800 A
Block D	11	401 W 19th St. and 419 W 19th St. 7-story building 208Y/120 VAC electric service 800 A

All Fulton Houses buildings are master-metered, and there is no tenant metering. Electric is included in the tenants' rent.

2.5 Microgrid and Building Controls Characterization

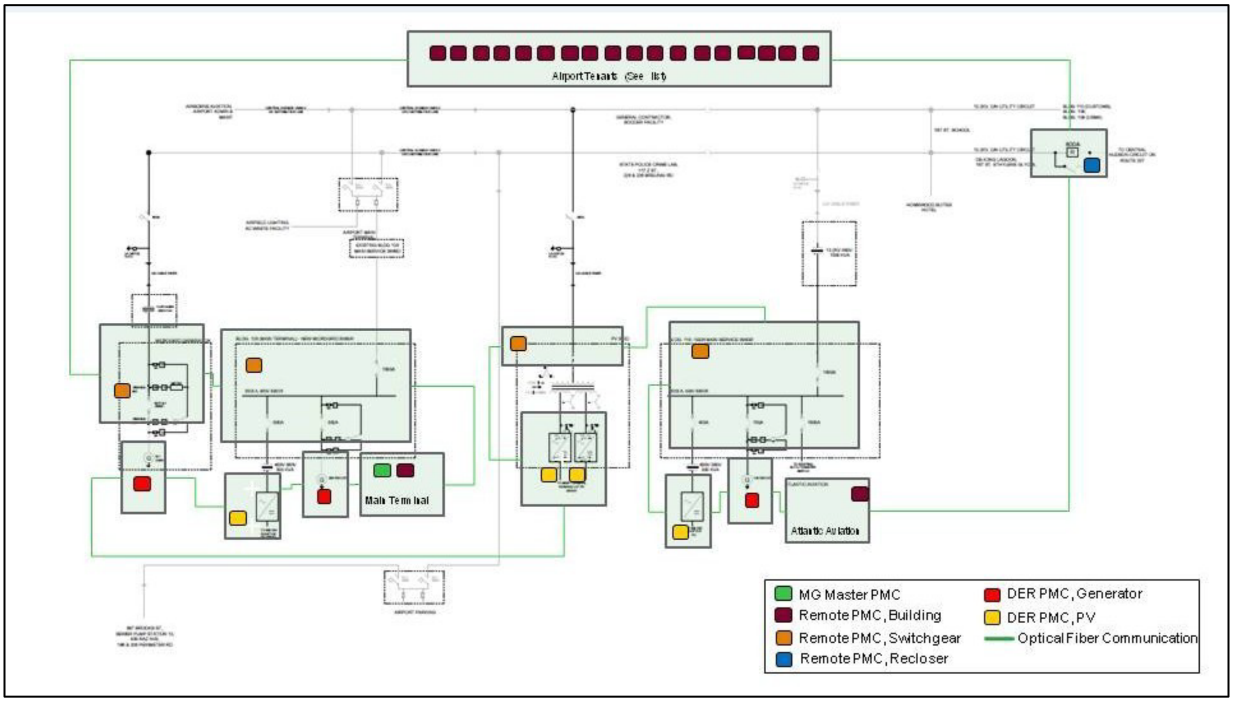
The controls, communications, islanding capabilities, and seamless operation of the microgrid will provide One City Block and the Fulton Houses with the added resiliency and emergency operations they will need to provide NYCHA with emergency services. The project will incorporate data collection and storage for multiple parameters to understand the building loading, power provided from the microgrid, and power provided from the utility. The data collection will also incorporate points to develop efficiency profiles for the microgrid.

The microgrid will go into isolation automatically if power is lost during grid-connected mode. This utility loss will be detected by the IEEE 1547 protective relaying at the isolation point of the circuit. A remotely controlled recloser will isolate the microgrid circuit from the utility. All of the devices will be reviewed with the utility to ensure proper operation; where possible, the utility components will be used. Each component has a full complement of protection and communication functions.

A distributed microgrid controller system will be provided to govern the operation of the microgrid. This controller consists of two components: the PowerLogic Microgrid Controller (PMC), a real-time controller that is operating by the millisecond and second time scale, and Struxureware Demand Side Operation (SDSO) software, a predictive controller that provides optimized distributed energy resources (DER) schedules in 15-minute windows for the day ahead. While the PMC maintains responsibility for balancing the generation with loads and islanding/reconnection events, SDSO uses outside information in the form of weather and load forecasts and energy tariff data such as time-of-use rates, demand response commands, and user-imposed system constraints.

The PMC will be capable of interfacing with the local controllers provided by the DER vendors. These local DER controllers will be responsible for the most basic level operation of the DER, i.e., maintaining the required voltage and frequency output for system stability. The PMC will provide a level of coordination above these local controllers such that the site load is shared between the DER and utility grid (when connected) at an optimal level. Figure 2-15 shows an example of the microgrid control architecture that will be fully designed in Stage 2 of NY Prize.

Figure 2-15. Microgrid Control Architecture Example



2.5.1 Proposed Control System Layout

A free-standing master PMC enclosure will be provided at the microgrid distribution switchboard. Wall-mounted distributed remote PMC enclosures will be located at each DER to enable secure and dedicated control of each resource. Remote PMC enclosures will also be located at each microgrid-participant building and at the utility recloser. Depending on feasibility, the microgrid building controller may be integrated with any existing building management controllers.

A modular architecture provides an optimized solution and can be easily expanded to control additional equipment in the future. The flexibility of the I/O and communications architecture allows it to be easily adapted to a wide range of distributed energy resources and microgrid equipment. When operating in normal grid-connected (parallel) mode, the utility voltage and frequency reference will be from the new utility recloser. If there is an outage, the recloser will open and the DER sources will isolate from the grid at their connection points. The PMC will then initiate the black start of the anchor generator, bringing it online and creating a microgrid voltage and frequency reference for the other DER sources.

Through a predetermined sequence, the DER sources will be made available to the microgrid, and the buildings will be brought back online. During the transition to microgrid islanded operation following an outage, critical facilities with existing back-up generators will exercise their normal back-up generator transfer sequence. Once the microgrid is established, the automatic transfer switches at these locations will perceive the microgrid voltage and frequency reference as a return of electrical service and transfer the facility to the microgrid. Load meters in each building will allow the PMC to manage the building loads in conjunction with available

DER. Should any DER source drop offline, the PMC will work via the remote PMC controllers in the buildings to shed appropriate loads or facilities and maintain a stable microgrid.

The PMC will constantly monitor for utility availability. Once utility service is restored, it will initiate a reverse sequence by shedding all of the loads and interrupting the islanded operation. The utility recloser will be closed, and the buildings will be brought back online. DER sources will be restarted in grid-tied operation compliance mode and synchronized to the utility.

The PMC system is built from the same standard, rugged, and reliable hardware platform used in thousands of critical applications in the industrial automation and process industries. To ensure resilience against severe weather conditions, control system components will be housed in protective indoor or outdoor-rated enclosures, and control points will be linked via an overhead self-healing optical fiber ring. The control panels will be equipped with a battery-based uninterruptible power supply.

2.6 Information Technology/Telecommunications Infrastructure Characterization

During an event, the switch will open and the generation resources will be electrically isolated. The operation will be an open transition. The synchronous generators will be switched to voltage control mode and simultaneously closed onto the microgrid. The microgrid control system will manage the generation to ensure optimum voltage and frequency control. The loads will be evaluated for real and reactive requirements as part of the synchronous generators' sizing plus a generous margin. These measures will help ensure that the requirements of American National Standards Institute C84.1 are met.

Communication and interoperability with the local utility and the primary operator of Eighth Avenue microgrid will be incorporated into the final project design. It is anticipated that such communication will be based on standard protocols such as OpenADR, et al. Both hard-wired and wireless communication topology and infrastructure will be studied in the next phase of the project development and design to ensure a forward-compatible system. Black start is similar to the loss of an islanding sequence; the utility isolation switch would be opened, and the islanding sequence would be followed.

A closed self-healing underground optical fiber ring will form the physical communication medium between the control components within the microgrid. The master PMC will communicate with the local controllers and utility interfaces using Modbus TCP, DNP3, and proprietary remote I/O protocols. The PMC will interface with the distribution system operator hardware via Modbus TCP. If facilities participate in any independent system operator (ISO) and/or utility demand response programs, external communications between the microgrid and the utility will be in accordance to the specifications of the ISO and/or utility to be further determined.

If communications with the utility are lost during normal grid-tied operation, the PMC will assess whether there is also a loss of the utility voltage and frequency reference. If the determination is that the utility voltage is present and within requirements but communication to the utility has been lost, the microgrid will operate and be seen as a load center on the utility electronic payment system. If the utility stipulates that a loss of communication under any circumstance should direct islanded operation of the microgrid, then the PMC will act accordingly. If the loss of communications with the utility can be associated with a loss of utility voltage and frequency reference, the microgrid will disconnect from the utility and commence the islanded operation sequence. Once the microgrid is islanded from the utility, the microgrid can operate in the absence of communications with the utility.

3 Eighth Avenue Microgrid Commercial and Financial Feasibility

This section outlines the primary stakeholders and customers served by the Eighth Avenue Microgrid and the assessment of commercial and financial feasibility of the project

3.1 Customer Relationships (Commercial Viability – Customers)

The microgrid will serve One City Block and the Fulton Houses. One City Block's building at 111 Eighth Avenue is a 2.9 million-square-foot property in the Chelsea neighborhood of Manhattan. Originally developed as the headquarters of the Port Authority of NY, the property occupies one square block between Eighth and Ninth Avenues and 15th and 16th Streets and sits above the 14th Street/Eighth Avenue subway station. Substantial baseline building renovations in the early 2000s transformed it into a first-class office building. Google purchased the property in 2010, and it is now managed by the Taconic Management Company. The building houses substantial and critical infrastructure, including 911 and Federal Aviation Administration telecommunications and data centers. It also has medical and other critical facilities.

The Fulton Houses cover three blocks, with three high-rise buildings of twenty-five stories each, eight low-rise buildings of seven stories each, and a parking garage. The Fulton Houses have 945 apartments with over 2,000 total residents. The buildings are separately master-metered; there is no tenant metering. The main service feeds are old open copper bus and fused knife switches that should be upgraded. These upgrades will be included in the project costs to set up the emergency back-up system.

Since 2011, One City Block has completed many projects to reduce the building's carbon emissions, increase its efficiency, and decrease its operational costs, including the installation of lighting replacements, occupancy sensors, lighting timers, an ice storage cooling system, and new HVAC equipment. Building on that progress, Google and One City Block developed a road map to achieve the remaining carbon reductions that are needed to meet the New York City (NYC) Carbon Challenge goal, identifying additional projects and strategies for lighting, HVAC, building envelope, and on-site generation projects that are expected to reduce greenhouse gas (GHG) emissions by approximately 4,932 metric tons of equivalent CO_2. The commitment to the Carbon Challenge included an initial target of reducing building-based GHG emissions by 30% of more in 10 years and has since been increased to a greater challenge of 50% carbon reduction by 2025. These aggressive targets demonstrate Google's commitment to environmental sustainability and to helping NYC reduce its emissions; participation in NY Prize to help drive microgrid solutions forward is another step along this path.

3.2 Value Proposition

The Eighth Avenue Microgrid will provide value to the participants, community, and stakeholders in a variety of ways. The Fulton Houses experienced significant outages during Superstorm Sandy; all of its buildings and apartments were without power for over 4 days. There were no elevator services, which caused considerable hardship for its moderate income population, which has a relatively high proportion of elderly residents. Each participant in the microgrid will realize GHG reductions from the existence of the CHP plants on a year-round basis. The Fulton Houses' residents will benefit from the increased system resiliency. One City Block will benefit from reduced costs. Con Edison steam delivery will benefit from additional steam generation being located in a part of the city in which it is needed. Tying this project to existing equipment and planned generation projects at One City Block mitigates the overall cost burden to the greatest extent possible. One City Block will oversee the additional direct costs for the construction and operation of the project.

The microgrid is designed to allow the critical operations at both facilities to remain operational for 7 days or more during extended outages in order to address the Fulton Houses' urgent need for a more reliable grid and better preparedness for storm events.

This project promotes a wide variety of technologies and puts many of the issues and objectives of NY Prize front and center. On the technology side, the microgrid leverages a broad mix of resources to achieve the program-required islanding duration. Technologies that are incorporated into the project in addition to the natural gas CHP units include photovoltaics and a back-pressure steam turbine. Further, a modular architecture for the controls will provide an optimized solution and can be easily expanded in the future. The flexibility of the overall architecture allows it to be easily adapted to a wide range of distributed energy resources and future microgrid equipment, essentially future-proofing the installation to the greatest extent possible.

Behind-the-meter efficiency as previously described will continue to play a large role in the reduction of peak demand needs and annual energy usage as One City Block looks to further reduce its GHG emissions. One City Block is also planning to change existing diesel generators at the site to natural gas. The Fulton Houses property is planning an energy performance contract to upgrade all of its lighting.

In terms of state policy objectives, providing a means to maintain critical services for a large and highly diverse population in the heart of Manhattan is first and foremost. This project achieves that by allowing a full 7 days of islanding operation. In addition, there are the larger issues to be confronted by NY Prize and the NY Reforming the Energy Vision (REV) process, including right-of-way, standby capacity, communication, interconnections for wheeling power, and integration with the local utility. For this and every NY Prize project, complicated questions remain about the ability and/or willingness of the NY utilities to account for the full value delivered by the presence of a microgrid. This is analogous to the question of externalities and non-energy benefits that has raged for decades in the energy efficiency world. While the benefits are real, this NY REV process and the utilities themselves will ultimately need to determine how and to whom these externalities accrue.

3.3 Project Team

ERS led the project team for the feasibility study and, partnering with Schneider Electric to develop the proposed distributed energy resources and control infrastructure. The project team has worked extensively with Taconic Management Company, the operator and management firm for One City Block, throughout the feasibility study, holding weekly meetings to discuss and review the design scenarios. During the study's design process, the project team held stakeholder meetings with senior leadership from NYCHA, One City Block, and Google to solicit feedback. The partnership between Google and NYCHA is a core tenet of this project and is a great opportunity to increase the resiliency of the surrounding community.

The microgrid will most likely be owned and operated by a third-party vehicle created for the microgrid and with significant backing from One City Block. This entity will enter into a contractual agreement with the Fulton Houses for lease of the necessary space to install the CHP units and the related infrastructure. The microgrid will sell steam to the Fulton Houses at the current Con Edison rates and, during islanding events, will charge NYCHA for the electricity consumed. This arrangement will allow all benefits to be shared in what should be a reasonable and equitable fashion. While the details of the agreements have yet to be determined, they will be specified prior to the next phase of the project. The microgrid has substantial financial resources and commitment backed by participants with extremely strong balance sheets.

This public-private partnership project has great potential for replication in the city and elsewhere. Many housing projects in major metropolitan areas around the country are exposed to the risks of power outages due to weather events and other emergencies. By themselves, these facilities lack the means to provide extended back-up power solutions to their tenants. A 4-day outage without elevator service presents an extreme hardship and safety concern for many of the tenants. This project showcases the benefits of leveraging the resources of a private sector actor – in this case, Google – to provide increased resiliency and energy security to housing and other services in its local community. These community benefits align with Google's commitment to the NYC Carbon Challenge.

The project has not required legal or regulatory advisors beyond what could be answered by in-house capabilities. Specific contractors and suppliers for the build out will be drawn from a long list of existing relationships extant amongst the parties.

3.4 Commercial Viability – Creating and Delivering Value

To ensure that the proposed microgrid will deliver value to the participants as described in the prior sections, ERS conducted an extensive analysis of the building loads for both project sites and an inventory of existing resources that could be leveraged for the microgrid. ERS calculated the electric energy, steam, and natural gas consumption for the Fulton Houses and One City Block, calibrating the consumption with weather data and each facility's unique estimated load profile. A description of the loads and this characterization exercise was presented in the Section 2 of this report.

ERS incorporated planned energy efficiency upgrades into the load estimates to project future electric, steam, and natural gas needs. Through multiple interviews and site visits, ERS engineers inventoried the existing and planned equipment that could be leveraged for the microgrid. One City Block has engaged Con Edison in discussions regarding the installation of CHP units in the recent past. The microgrid will leverage this relationship to guide the Fulton Houses' three CHP units through the design and permitting process.

For this microgrid, the project team explored generation technologies – including solar PV, CHP, and back-pressure steam turbines – to provide sufficient normal and emergency generation to meet the building loads. The technologies planned for this microgrid have been used in projects with NYSERDA and the utilities throughout and beyond NY.

This project offers a unique approach to sharing benefits between the participants and the community. NYCHA needs to preserve their current spending, funding, and ability to enter into performance contracting for energy savings. This project allows that to happen. In addition, NYCHA would like to share in the financial benefit and this project achieves that through lease payments for hosting key microgrid components on their site. The local community wins by having a permanent, unlimited back-up power source serving a disadvantaged population while the larger city community wins with carbon reduction gains. Finally, even with all of that sharing, financial benefits remain for One City Block in the form of lower-cost electricity.

Con Edison can assist the project in several ways. The project as defined in this feasibility study can move ahead with Con Edison support facilitating any necessary interconnections. If greater involvement is sought, there is a concept for a larger installation that could incorporate greater electric generation and increased steam generation. Under this scenario, Con Edison’s Steam Group would potentially assume a role in operating the plant. The ERS team has held regular discussions with the Con Edison Steam Group and plans to continue these conversations in preparation for Stage 2 of NY Prize.

3.5 Financial Viability

The Eighth Avenue microgrid has been developed to be mutually beneficial during normal and emergency operations. Table 3-1 shows the project’s simplified economics. The revenue for One City Block comes from a reduction in overall electric utility costs and from some of the power and heat being sold to the Fulton Houses. Revenue for the Fulton Houses will come from lease agreements for the space to locate the CHP units being situated on their property. The revenue streams will be relatively fixed annually over the life of the equipment and contracts.

Table 3-1. Summary of Benefits

Parameter	Fulton Houses	One City Block
Existing Operation – No Microgrid		
Electric energy load	7,603 MWh/year	190,000 MWh/year
Peak demand, monthly average	1.27 MW	23.7 MW
Thermal energy load	74,799 MMBtu/year	N/A
Electric energy (kWh) cost	$684,270/year	$17,100,000/year
Electric energy (demand) cost	$608,240/year	$15,200,000/year
Natural gas cost (excluding appliance fuel)	$0/year	N/A
Steam costs	$1,920,090/year	N/A
Total energy cost	$3,212,600/year	$32,300,000/year
Proposed Operation with Microgrid		
Electric energy supplied by the microgrid	0 MWh/year	9,125 MWh/year
Demand supplied by the microgrid, monthly average	0 MW	1.05 MW
Electric energy supplied by the utility	7,603 MWh/year	180,875 MWh/year
Demand supplied by the utility, monthly average	1.27 MW	22.65 MW
Thermal energy supplied by the microgrid	31,487 MMBtu/year	0 MMBtu/year
Net natural gas used by the microgrid	0 MMBtu/year	86,979 MMBtu/year
Electric energy (kWh) cost from utility	$684,270/year	$16,278,759/year
Electric energy (demand) cost	$608,240/year	$14,954,561/year
System maintenance costs	N/A	$194,000/year
Steam costs	$1,920,090/year	($758,761)/year
Net cost of natural gas used by the microgrid	N/A	$669,738/year
Energy facility lease payment	TBD	TBD
Total energy cost	$3,212,600/year	$31,337,961/year
Net energy savings	$0/year	$962,039/year

N/A = Not applicable
TBD = To be determined

Based on the pricing and annual fees associated with the project, the simple payback for the project is 14 years, with a total project cost of $13,529,000, annual savings of $1,155,702, and annual maintenance fees of $194,000. The annual maintenance costs include the maintenance of the CHP units at the Fulton Houses, the distribution equipment, and the control hardware. This payback, while it is financially feasible, is outside of an acceptable rate of return for One City Block. Additional incentives and support, including participation in the subsequent phases of NY Prize, would bring the payback closer to 10 years, keeping both parties interested and enabling more revenue sharing between One City Block and NYCHA.

While the cost estimates were developed through real vendor pricing, there are a few variables that will be further clarified during Stage 2 of NY Prize. These include unknown costs involved in digging up a major Manhattan street to lay cable for the microgrid, and potential additional monitoring, operations, and maintenance costs for the microgrid.

3.6 Legal Viability

While the Eighth Avenue Microgrid will most likely be owned and operated by a third-party vehicle with primary contributions from One City Block, the project will be located within the Fulton Houses properties, using a lease agreement for the space. One City Block will remain the lead stakeholder throughout the NY Prize program. Depending on how much involvement it would like to have in the ownership of the project, NYCHA could become a part owner in the microgrid instead of paying One City Block for the steam it receives. Con Edison has also expressed interest in the microgrid and potentially operating it, depending on their needs, which will be worked through Stage 2 of NY Prize. One significant regulatory hurdle for this project, and all NY Prize projects, is the challenge of crossing a public street with the microgrid's power lines. The project team has had several conversations with Con Edison regarding this obstacle, and the NY Prize effort has brought this issue to the forefront with the NY state utilities.

The project team considered an alternate microgrid that would replace the three smaller generation units at the Fulton Houses with one larger generation unit. However, this project would face additional regulatory hurdles under the NYC building code, which requires a licensed steam operator to be within eyesight of the generator 24/7 for any generation system producing steam at a pressure above 15 psi. This requirement adds a significant annual cost to the project that makes it financially infeasible. This alternative design will be reviewed during Stage 2 of the NY Prize since it could be more valuable to all parties. The project team has held initial conversations with the Con Edison steam program representatives regarding participation in a pilot buy-back program to offset a portion of this additional cost.

4 Technical Design Costs and Benefits

This section presents the analysis of benefits and costs of the Eighth Avenue Microgrid. The benefits and costs presented below reflect the perspective of One City Block and Fulton Houses; they incorporate actual load profiles and existing rate structures for the facilities. An additional benefit/cost analysis was conducted by Industrial Economics (IEc) to evaluate the societal benefits of the project; while this analysis is presented in Appendix B, it does not include actual site rates for the electrical and thermal costs from the grid. Thus, the economic feasibility shown in the model does not reflect the actual value to One City Block and Fulton Houses but rather a societal value.

4.1 Facility and Customer Description

The two microgrid facilities, One City Block and Fulton Houses, are described in detail in Section 1 of this report.

4.2 Characterization of Distributed Energy Resources

The proposed microgrid will include three new 300 kW microturbine combined heat and power (CHP) plants, a 50 kW photovoltaic (PV) array, and a 150 kW back-pressure (BP) turbine. These resources are described in detail in Section 2 of this report.

4.3 Capacity Impacts and Ancillary Services

The proposed One City Block microgrid is located in an area where Con Edison steam capacity is constrained. Con Edison has expressed interest in the steam capacity of the microgrid and is in the process of developing business models that may permit the exploitation of customer-added steam capacity. Con Edison noted the electrical constraints in the immediate area of the proposed microgrid, which will provide peak load support of 1.1 MW. However, it will not have additional capacity other than the back-up generators to provide demand response.

The microgrid will impact the transmission and distribution utility grid in the area. The system will be capable of black start, which means it will not need to have the utility grid available to start, but it will not provide any additional ancillary services for the utility. The proposed system size will fall under the natural gas CHP generation sizing requirements and will need minimal environmental permitting. Table 4-1 shows the values for the emission rates associated with the electric energy consumption at the site.

Table 4-1. Values for the Emission Rates

Component	CO_2	SO_2	NO_X	PM
Natural gas emission rate (tons/MMBtu)	0.058	2.9E-07	0.000049	0.000004
Power utility emission rate (tons/MWh)	0.538456	0.000290	0.000281	0
Steam utility emission rate (tons/MMBtu)	0.058423	0.000000	0.000049	0
Proposed microgrid emission rate (tons/MWh)	0.531227	0.000003	0.0008	0.000034
Existing Operation – No Microgrid				
One City Block emissions (tons/year)	102,307	55.13	53.40	0.00
Fulton Houses emissions (tons/year)	8,902	2.24	6.14	0.30

Proposed Operation – with Microgrid				
One City Block emissions (tons/year)	97,338	52.86	51.19	0.00
Fulton Houses emissions (tons/year)	6,565	2.23	4.19	0.16

4.4 Project Costs

ERS has developed the microgrid project costs using partner vendor quotes, RSMeans, and cost information gathered during ERS's CHP outreach project experience. Table 4-2 summarizes the costs for the proposed microgrid. Table 4-3 summarizes other associated costs.

Table 4-2. Capital Cost Estimates for Eighth Avenue Microgrid

Location	Capital Component	Installed Cost	Description of Component
Fulton Houses	CHP units (3), installed	$3,330,000	3 microturbines at 300 kW each
	BP turbine (1)	$190,000	1 unit at 150 kW
	PV	$200,000	1 installation at 50 kW
	CHP Infrastructure	$351,000	Piping, platforms, heat recovery
	Distribution equipment	$2,173,000	Switchboards, transformers, existing equipment modifications, installation
	Control and IT hardware	$410,000	Control panels, controllers, software
One City Block	Distribution equipment	$914,000	Switchboards, transformers, existing equipment modifications, installation
	Control and IT hardware	$275,000	Control panels, controllers, software
Cabling	Street excavation and conduit	$3,025,000	9th Avenue excavation, conduit, and restoration
General contractor	Project management	$887,000	
	Commissioning	$887,000	
Total capital cost		**$12,642,000**	

Table 4-3. Project Cost Summary

Indicator	Cost
Fully installed costs and engineering lifespan of all capital equipment	$12,642,000
Initial planning and design costs	$887,000
Fixed operations and maintenance (O&M) costs	$75,000/year
Variable O&M costs, excluding fuel costs	$25/MWh/year

The distributed energy resources (DERs) supply 100% of the electric energy load of the Fulton Houses microgrid and, by design, could operate continuously in islanded mode. Table 4-4 details the periods during which each DER will operate in islanded mode without replenishing the fuel supply. ERS assumed that natural gas would be available during an emergency event.

Table 4-4. Islanded Mode Operation Summary

DER	Energy Source	Operating Hours in Islanded Mode	Fuel Consumption (MMBtu/hr)
Microturbines (3)	Natural gas	24/7	3.61
BP turbine	Steam	24/7	N/A
PV array	Sun	24/7	N/A
Gas turbine generator	Natural gas	24/7	10.2

N/A = Not applicable

4.5 Costs to Maintain Service during Outages

During a power outage, the Fulton Houses' microturbines and BP turbine power output will be directed to the Fulton Houses. Since this equipment runs continuously, there are no manpower requirements for bringing it online. The One City Block gas turbine also runs continuously and will not require additional manpower for its operation. Table 4-5 shows a summary of the cost of an islanding event.

Table 4-5. Islanding Event Cost Summary

Indicator	Fulton Houses (Microturbines)	Fulton Houses (BP turbine)	One City Block (Gas turbine)
Energy source	Natural gas	Steam	Natural gas
Nameplate capacity	0.900 MW	0.150 MW	4.8 MW
Loading during an extended power outage	100%	100%	18.8%
Production during major power outage	7.2 MWh/day	3.6 MWh/day	7.2 MWh/day
Fuel consumption	11.9 MMBtu/MWh	No additional steam consumption	11.3 MMBtu/MWh
One-time cost associated with connecting and starting each BG	$0	$0	$0
Cost (excluding fuel) associated with operating each BG	$92/day	$0/day	$87/day
Emergency measures (during power outage) cost – BGs available	$0/day	$0/day	$0/day
Emergency measures (during power outage) cost – BGs not available	$0/day	$0/day	$0/day

The capacity available during an islanding event far exceeds the maximum building load of the Fulton Houses complex. Service will not diminish during an event. The BP turbine consumes no additional energy since it operates off the existing step-down in pressure from high-pressure service to the building distribution pressure.

4.6 Services Supported by the Microgrid

The Fulton Houses are home to over 2,000 residents in their 945 apartments. The on-campus buildings include three high-rises (each is twenty stories and, combined, they contain 80% of the apartments) and eight low-rises (maximum of three stories). During Superstorm Sandy, the buildings and apartments were without power for over 4 days. There was no elevator service, causing considerable hardship for this moderate-income population, which has a relatively high proportion of elderly residents.

The proposed microgrid configuration will provide complete and indefinite backup for all of the common areas (such as the elevators), and individual apartments' power. The facility is not equipped with emergency power, and there is no near-term plan for back-up generation outside of this project. During an emergency event, the Fulton Houses' microturbines will be supplemented with power from back-up generators at One City Block., which has a capacity that well exceeds the needs of the Fulton Houses. The Eighth Avenue microgrid will not support One City Block, since that facility has excess back-up capacity and does not require microgrid generation to remain operational.

4.7 Microgrid Financial Benefits

One City Block and the Fulton Houses have a unique opportunity for energy symbiosis. One City Block is seeking electric rate relief and has an excess of back-up capacity and no need for thermal load. The Fulton Houses have favorable New York Power Authority (NYPA) rates, have no back-up capacity, and are a good thermal heat sink. The Fulton Houses are further constrained in their efforts to implement energy efficiency, since any cost savings must be returned to federal agencies. The operation of the Eighth Avenue microgrid generates the following value streams:

- Electrical production at lower costs per kWh than those offered by the grid
- Steam production at a lower cost per MMBtu than those offered by the grid
- Emergency back-up service for the Fulton Houses

The generation plant will be located at the Fulton Houses; however, it will be owned and operated by One City Block. The microgrid can provide steam for the high-rises, offsetting the steam purchases. All of the electricity generated by the plant will be directed to One City Block, providing lower-cost power except during emergency events. One City Block will lease space from the Fulton Houses to build the plant, providing a mechanism for balancing the share of the value. Table 4-6 summarizes the annual net financial benefits. The system's net benefit is approximately $1 million per year, to be shared by the Fulton Houses and One City Block.

Table 4-6. Summary of Benefits

Parameter	Fulton Houses	One City Block
Existing Operation – No Microgrid		
Electric energy load	7,603 MWh/year	190,000 MWh/year
Peak demand, monthly average	1.27 MW	23.7 MW
Thermal energy load	74,799 MMBtu/year	N/A
Electric energy (kWh) cost	$684,270/year	$17,100,000/year
Electric energy (demand) cost	$608,240/year	$15,200,000/year
Natural gas cost (excluding appliance fuel)	$0/year	N/A
Steam costs	$1,920,090/year	N/A
Total energy cost	$3,212,600/year	$32,300,000/year

Parameter	Fulton Houses	One City Block
Proposed Operation – with Microgrid		
Electric energy supplied by the microgrid	0 MWh/year	9,125 MWh/year
Demand supplied by the microgrid, monthly average	0 MW	1.05 MW
Electric energy supplied by the utility	7,603 MWh/year	180,875 MWh/year
Demand supplied by the utility, monthly average	1.27 MW	22.65 MW
Thermal energy supplied by the microgrid	31,487 MMBtu/year	0 MMBtu/year
Net natural gas used by the microgrid	0 MMBtu/year	86,979 MMBtu/year
Electric energy (kWh) cost from utility	$684,270/year	$16,278,759/year
Electric energy (demand) cost	$608,240/year	$14,954,561/year
System maintenance costs	N/A	$194,000/year
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Net cost of natural gas used by the microgrid	N/A	$669,738/year
Energy facility lease payment	TBD	TBD
Total energy cost	$3,212,600/year	$31,337,961/year
Net energy savings	$0/year	$962,039/year

N/A = Not applicable
TBD = To be determined

5 RECOMMENDATIONS AND CONCLUSIONS

The ERS team evaluated the microgrid project, conducting a full technical analysis and review of the infrastructure requirements and utility and stakeholder involvement. There is a unique opportunity for both of the microgrid's key stakeholders: One City Block is seeking electric rate relief, has an excess of back-up capacity, and does not need additional thermal energy, while Fulton Houses has favorable New York Power Authority rates, no existing electric back-up capacity, and a continuous need for thermal energy. The Fulton Houses is further constrained in efforts to implement energy efficiency, since energy costs savings result in reduced reimbursements from federal agencies. The Eighth Avenue microgrid pairing of a public housing development with a private entity to increase resiliency in the community is a unique project design that is replicable throughout and beyond New York. The project team has held regular discussions with Con Edison to present the merits of the plant from both the electric and steam distribution viewpoints.

5.1 Eighth Avenue Microgrid Benefits and Value

The operation of the Eighth Avenue microgrid will generate many value streams, including the following:

- Electricity production at lower cost per kWh than One City Block's current costs using a diverse generation, including natural gas-fired microturbines, photovoltaics, and a back-pressure turbine
- Steam production at a lower cost per MMBtu than NYCHA's current costs
- CHP efficiencies of approximately 56% provide GHG reductions over conventional generation
- Emergency electric back-up service for Fulton Houses' 2,000 moderate-income residents
- Additional steam capacity for Con Edison steam distribution in a steam-constrained area
- Additional electric capacity for Con Edison electrical distribution

5.2 Microgrid Roadblocks and Potential Solutions

Throughout the course of this feasibility study, the ERS team encountered and/or identified several roadblocks that can have significant influences on project structure, financing, or feasibility. Many of these roadblocks are likely faced by many of the NY Prize projects currently under analysis. Table 5-1 highlights the primary roadblocks pertaining to the Eighth Avenue microgrid and the potential workarounds and solutions under consideration. The ERS team is engaged with many stakeholders in discussing these roadblocks and expects to continue these conversations in preparation for and during Stage 2 of the NY Prize program.

Table 5-1. Eighth Avenue Microgrid Roadblocks and Potential Solutions

Roadblock Faced by the Microgrid	Potential Workaround or Solution
Right-of-way issues. There are unresolved right-of-way issues when connecting multiple electrical meters across a public street.	• This is a known challenge affecting all NY Prize projects under consideration. This item needs to be addressed collectively with all NYS utilities.
Building Code monitoring requirements. The NYC Building Code requires that any generation system producing steam at pressure greater than 15 psi have 24/7 monitoring by a licensed operator which adds significant operation and management costs to the microgrid.	• The proposed configuration produces steam below 15 psi, thereby sidestepping the monitoring requirement. • Initial conversations with Con Edison were held regarding the utility operating the microgrid to potentially avoid this cost. • A single larger generation unit would greatly improve the economics of this project if this roadblock can be resolved.
Unknown costs of street excavation. There are potentially many unknown challenges and costs involved in digging up a major Manhattan street to lay cable for the microgrid.	• The team has consulted with contractors installing similar services in NYC to build the estimates. A significant safety factor has been built in. • The ERS team has explored the potential for Con Edison to assist in resolving this challenge; ideas include either leasing cable or ducts and allowing the team to use existing pipe, or some alternate solution. • This is an ongoing conversation between the project team and Con Edison.
NYCHA energy benefit restrictions. NYCHA has federal restrictions on realizing the full benefits from reducing energy costs at their facilities.	• This roadblock affects the revenue structure of the project. Rather than reduce its steam expense from the heat supplied by the CHP plant, NYCHA will pay One City Block for the steam it consumes and in return will receive a market-based lease payment for the space provided for the CHP plant siting. • This agreement will be further developed during NY Prize Stage 2.
Thermal load at Fulton Houses. The thermal load at Fulton Houses is not large enough to use the entire heat output from the CHP plant.	• The ERS team has held multiple conversations with the Con Edison Steam Group regarding participation in a steam buyback pilot program. • This discussion will continue through the summer as the team prepares its NY Prize Stage 2 proposal.

5.3 Recommendations and Next Steps

The Eighth Avenue microgrid has the stakeholder support and technical merit to be a feasible project that should continue to seek support during Stage 2 of the NY Prize program. There are several activities that the project team will need to complete as the proposal for Stage 2 is developed, many of which have already begun:

- The project team will continue to engage the key stakeholders: One City Block, NYCHA, Con Edison, and Google. These conversations will focus on processing the results of this feasibility study and considering any additional configuration options available.

- The project team will continue to hold conversations with Con Edison to discuss potential participation in the steam pilot buyback program. Con Edison will be an important stakeholder and partner throughout the microgrid design stage, and continued engagement will help maintain the momentum built through recent conversations.
- As the microgrid moves into Stage 2, which contains a cost-share component, a partnership agreement between One City Block and NYCHA will likely be required to outline the contributions and benefits that each party will receive throughout the microgrid design phase.

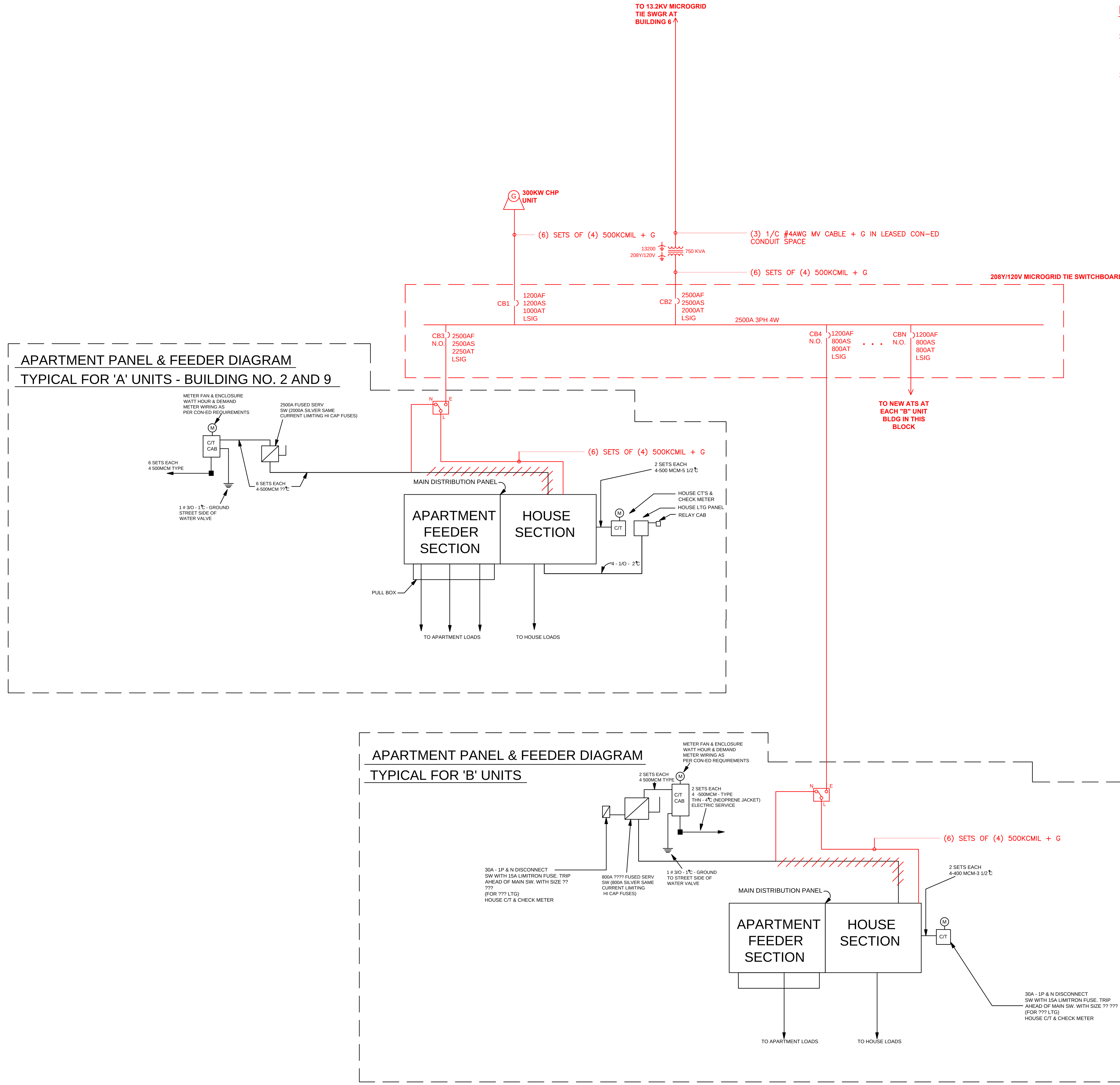
This feasibility study has demonstrated that the proposed Eighth Avenue microgrid achieves the goal of the NY Prize program in identifying projects that incorporate resiliency, emergency power availability, and financial success. This project bridges many of the stakeholder gaps that exist in developing successful microgrid projects and is an excellent example of a public-private partnership that is a replicable model throughout and beyond New York to provide resiliency services while reducing GHG emissions.

Appendix A

Conceptual One-Line Microgrid Design

MICROGRID TIE SWITCHBOARD SEQUENCE OF OPERATION

1. CIRCUIT BREAKERS CB1, AND CB2 ARE CLOSED DURING NORMAL OPERATION. CIRCUIT BREAKERS CB3..CBN ARE OPEN DURING NORMAL OPERATION. THIS ALLOWS ALL CHP-GENERATED ELECTRIC POWER TO BE SUPPLIED TO ONE CITY BLOCK DURING NORMAL OPERATION, WITH NYCHA FACILITY ELECTRIC POWER BEING SUPPLIED BY THEIR RESPECTIVE CON-ED SERVICES.
2. UPON LOSS OF CON-ED UTILITY VOLTAGE, ONE CITY BLOCK GENERATION WILL SYNCHRONIZE AND CLOSE IN IN PARALLEL WITH NYCHA GENERATION VIA BREAKER OPERATION AT ONE CITY BLOCK. AFTER GENERATION STABILIZATION, BREAKERS CB3..CBN WILL CLOSE, PROVIDING EMERGENCY POWER TO NYCHA LOADS.



COLOR LEGEND

EXISTING INFRASTRUCTURE

CONCEPTUAL ADDITIONS FOR MICROGRID

Schneider Electric

SCHNEIDER ELECTRIC ENGINEERING SERVICES, LLC
1601 Mercer Rd
Lexington, KY 40511
(859) 296-3600

PROFESSIONAL SEALS

NOT FOR CONSTRUCTION

NO.	DESCRIPTION	DATE
1		
2		
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"ONE CITY BLOCK"

NY PRIZE FEASIBILITY

CONCEPTUAL MICROGRID DESIGN

ELECTRICAL ONE-LINE DIAGRAM

SEES PROJECT NO.	#########
CUSTOMER PROJECT NO.	#########
DATE	1/14/2016
CURRENT REVISION DRAWN BY	BAP
CURRENT REVISION CHECKED BY	Checekd By
CURRENT REVISION APPROVED BY	Approved by

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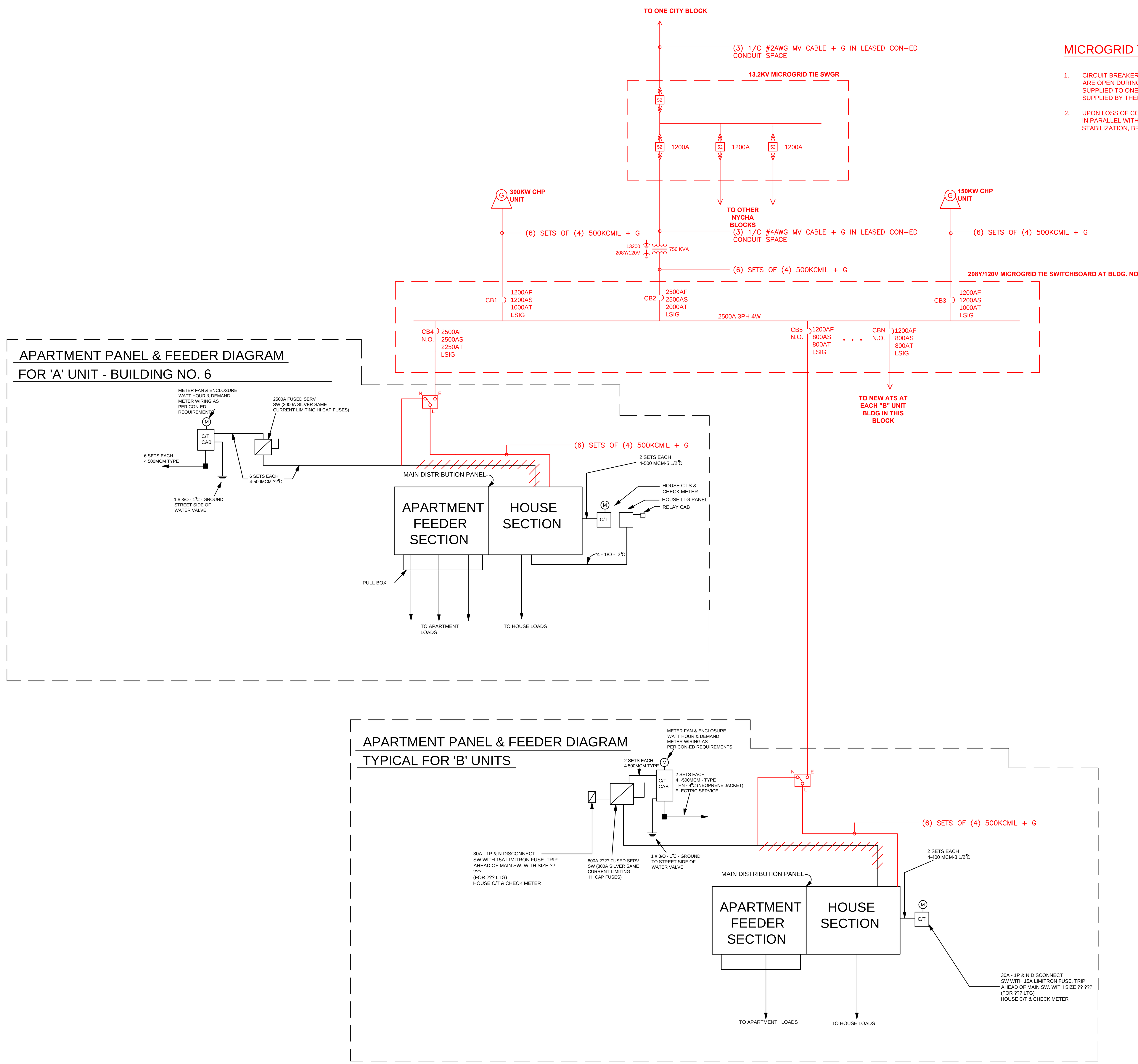

MICROGRID TIE SWITCHBOARD SEQUENCE OF OPERATION

1. CIRCUIT BREAKERS CB1, CB2, AND CB3 ARE CLOSED DURING NORMAL OPERATION. CIRCUIT BREAKERS CB4..CBN ARE OPEN DURING NORMAL OPERATION. THIS ALLOWS ALL CHP-GENERATED ELECTRIC POWER TO BE SUPPLIED TO ONE CITY BLOCK DURING NORMAL OPERATION, WITH NYCHA FACILITY ELECTRIC POWER BEING SUPPLIED BY THEIR RESPECTIVE CON-ED SERVICES.

2. UPON LOSS OF CON-ED UTILITY VOLTAGE, ONE CITY BLOCK GENERATION WILL SYNCHRONIZE AND CLOSE IN IN PARALLEL WITH NYCHA GENERATION VIA BREAKER OPERATION AT ONE CITY BLOCK. AFTER GENERATION STABILIZATION, BREAKERS CB4..CBN WILL CLOSE, PROVIDING EMERGENCY POWER TO NYCHA LOADS.

COLOR LEGEND

- EXISTING INFRASTRUCTURE (black line)
- CONCEPTUAL ADDITIONS FOR MICROGRID (red line)

SCHNEIDER ELECTRIC ENGINEERING SERVICES, LLC
1601 Mercer Rd
Lexington, KY 40511
(859) 296-3600

PROFESSIONAL SEALS

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"ONE CITY BLOCK"

NY PRIZE FEASIBILITY

CONCEPTUAL MICROGRID DESIGN

ELECTRICAL ONE-LINE DIAGRAM

SEES PROJECT NO.	#########
CUSTOMER PROJECT NO.	########
DATE	1/14/2016
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CURRENT REVISION APPROVED BY	Approved by

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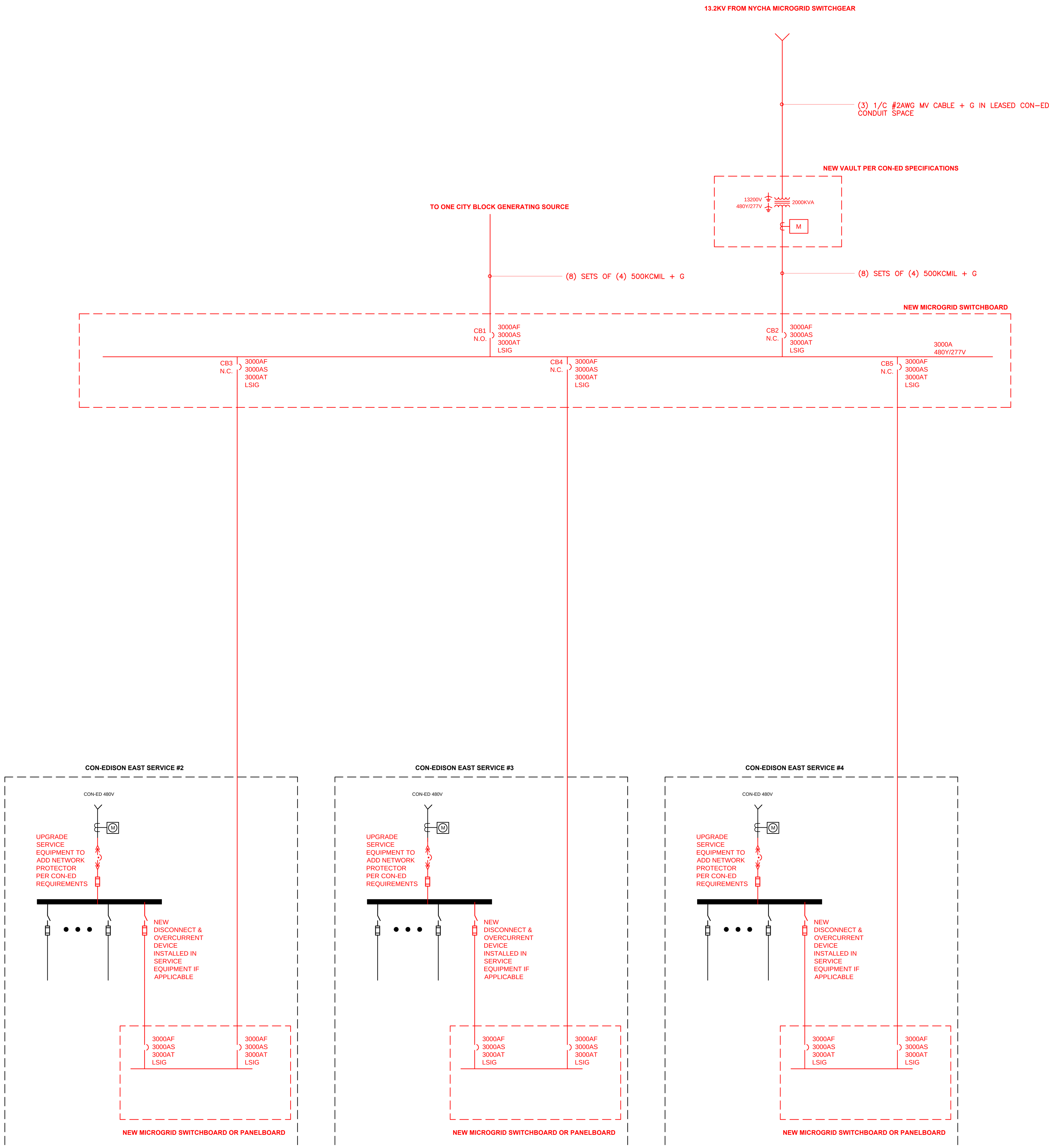

MICROGRID SWITCHBOARD SEQUENCE OF OPERATION

1. CIRCUIT BREAKERS CB2..CB5 ARE CLOSED DURING NORMAL OPERATION. CIRCUIT BREAKER1 CB1 IS OPEN DURING NORMAL OPERATION. THIS ALLOWS ALL CHP-GENERATED ELECTRIC POWER AT NYCHA TO BE SUPPLIED TO ONE CITY BLOCK IN PPARALLEL WITH CON-ED SERVICE DURING NORMAL OPERATION.
2. UPON LOSS OF CON-ED UTILITY VOLTAGE, CIRCUIT BREAKERS CB3..CB5 OPEN. AFTER A DELAY, ONE CITY BLOCK GENERATION WILL SYNCHRONIZE AND CLOSE IN PARALLEL WITH NYCHA GENERATION VIA CLOSURE OF CIRCUIT BREAKER CB1. THIS ALLOWS ONE CITY BLOCK TO SUPPLEMENT NYCHA GENERATION IN EMERGENCY.

COLOR LEGEND

EXISTING INFRASTRUCTURE

CONCEPTUAL ADDITIONS FOR MICROGRID

Schneider Electric

SCHNEIDER ELECTRIC ENGINEERING SERVICES, LLC
1601 Mercer Rd
Lexington, KY 40511
(859) 296-3600

PROFESSIONAL SEALS

NOT FOR CONSTRUCTION

NO.	DESCRIPTION	DATE
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"ONE CITY BLOCK"

NY PRIZE FEASIBILITY

CONCEPTUAL MIGROGRID DESIGN

ELECTRICAL ONE LINE DIAGRAM

SEES PROJECT NO.	#########
CUSTOMER PROJECT NO.	########
DATE	1/14/2016
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CURRENT REVISION CHECKED BY	Checekd By
CURRENT REVISION APPROVED BY	Approved by

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Appendix B

The Benefit-Cost Analysis Summary Report

Benefit-Cost Analysis Summary Report

Site 21 – Eighth Avenue Microgrid (Manhattan)

PROJECT OVERVIEW

As part of NYSERDA's NY Prize community microgrid competition, the City of New York and its partners have proposed development of a microgrid that would enhance the resiliency of electric service for the residents of the Robert Fulton Houses, a housing complex in Manhattan operated by the New York City Housing Authority (NYCHA). The complex consists of 11 apartment buildings ranging in height from six to 25 stories. It occupies approximately six acres along Ninth Avenue, between West 16th and West 19th Streets. The complex's 945 apartments provide a home to more than 2,000 city residents.[1]

The primary source of energy for the microgrid would be three new natural gas combined heat and power (CHP) units, each with a nameplate capacity of 0.3 MW. In addition, the microgrid would incorporate a 0.15 MW back-pressure turbine driven by steam and a 50 kW rooftop photovoltaic (PV) array. The operating scenario submitted by the project's consultants indicates that these systems together would produce approximately 9,227 MWh of electricity per year, more than enough to meet the average energy requirements of the housing complex. During an outage, the power from these sources would be supplemented, if necessary, by a 4.8 MW CHP system that is scheduled to be installed at a large office building known as One City Block, which is located at 111 Eighth Avenue. Installation of the CHP system at One City Block is not dependent upon development of the microgrid and is not treated as a cost associated with the microgrid proposal.

To assist with completion of the project's NY Prize Stage 1 feasibility study, IEc conducted a screening-level analysis of the project's potential costs and benefits. This report describes the results of that analysis, which is based on the methodology outlined below.

METHODOLOGY AND ASSUMPTIONS

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

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

[1] http://www.nyc.gov/html/nycha/html/developments/manfulton.shtml.

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

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[2] It also calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the ratio of project benefits to project costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2014 dollars.

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

The BCA considers costs and benefits for two scenarios:

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

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[2] The seven percent discount rate is consistent with the U.S. Office of Management and Budget's current estimate of the opportunity cost of capital for private investments. One exception to the use of this rate is the calculation of environmental damages. Following the New York Public Service Commission's (PSC) guidance for benefit-cost analysis, the model relies on temporal projections of the social cost of carbon (SCC), which were developed by the U.S. Environmental Protection Agency (EPA) using a three percent discount rate, to value CO_2 emissions. As the PSC notes, "The SCC is distinguishable from other measures because it operates over a very long time frame, justifying use of a low discount rate specific to its long term effects." The model also uses EPA's temporal projections of social damage values for SO_2, NO_x, and $PM_{2.5}$, and therefore also applies a three percent discount rate to the calculation of damages associated with each of those pollutants. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.]

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

RESULTS

Table 1 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 22 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

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

ECONOMIC MEASURE	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 22 DAYS/YEAR
Net Benefits - Present Value	-$11,700,000	$28,100
Benefit-Cost Ratio	0.6	1.0
Internal Rate of Return	-16.1%	7.3%

Scenario 1

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

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

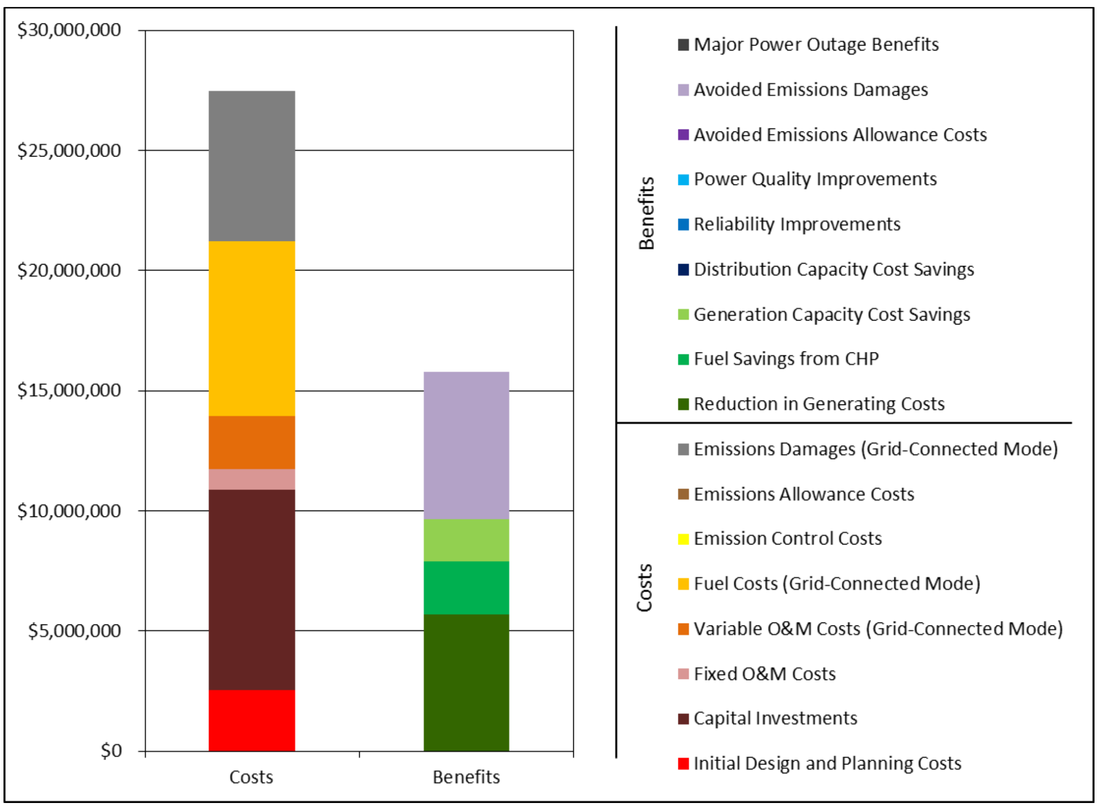

Table 2. Detailed BCA Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$2,560,000	$226,000
Capital Investments	$8,330,000	$720,000
Fixed O&M	$850,000	$75,000
Variable O&M (Grid-Connected Mode)	$2,220,000	$196,000
Fuel (Grid-Connected Mode)	$7,250,000	$640,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$6,280,000	$410,000
Total Costs	**$27,500,000**	
Benefits		
Reduction in Generating Costs	$5,700,000	$503,000
Fuel Savings from CHP	$2,190,000	$194,000
Generation Capacity Cost Savings	$1,750,000	$155,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$7,220	$642
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$3,130	$276
Avoided Emissions Damages	$6,110,000	$399,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$15,800,000**	
Net Benefits	**-$11,700,000**	
Benefit/Cost Ratio	**0.6**	
Internal Rate of Return	**-16.1%**	

Fixed Costs

The BCA relies on information provided by the project team to estimate the fixed costs of developing the microgrid. The project team's best estimate of initial design and planning costs is approximately $853,000. To this figure the analysis adds an estimated $1.71 million in project management and commissioning costs, bringing the project's total upfront costs to $2.56 million. The present value of the project's capital costs is estimated at approximately $8.33 million, including costs associated with installing the three new CHP units; CHP steam piping and fittings; CHP platforms and enclosures; the back-pressure turbine; distribution equipment at the Fulton Houses and at One City Block; control and IT hardware at these facilities; and low voltage cabling between the buildings in the housing complex. The present value of the microgrid's fixed operations and maintenance (O&M) costs (i.e., O&M costs that do not vary with the amount of energy produced) is estimated at $850,000, based on an annual cost of $75,000.

Variable Costs

A significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's three CHP units.[4] To characterize these costs, the BCA relies on estimates of fuel consumption provided by the project team and projections of fuel costs from New York's 2015 State Energy Plan (SEP), adjusted to reflect recent market prices.[5] Based on these figures, the present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $7.25 million.

The project's consultants estimate a variable O&M cost of $25 per MWh to maintain and periodically overhaul the three CHP units. Based on this figure and the operating scenario the team has specified, the analysis estimates variable O&M costs of approximately $196,000 per year.[6] Over a 20-year operating period, the present value of these costs is $2.22 million.

In addition to fuel and O&M costs, the analysis of variable costs considers the environmental damages associated with pollutant emissions from the distributed energy resources (DERs) that serve the microgrid, based on the operating scenario and emissions rates provided by the project team and the understanding that none of the system's generators would be subject to emissions allowance requirements. In this case, the damages attributable to emissions from the microgrid's DERs are estimated at approximately $410,000 annually. The majority of these damages are attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $6.28 million.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. These include generating cost savings resulting from a reduction in demand for electricity from bulk energy suppliers. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $5.70 million. In addition, the new CHP systems would reduce demand for steam from the district heating system, which would in turn reduce the fuel costs incurred by the district supplier; the present value of these savings over the 20-year period analyzed is approximately $2.19 million.[7] The reduction in demand for electricity and steam from centralized suppliers would also reduce their pollutant emissions, yielding emissions allowance cost savings with a present value of approximately $3,130 and avoided emissions damages with a present value of approximately $6.11 million.[8]

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[4] The back-pressure turbine would be driven by steam from the heating system at no additional cost.

[5] The model adjusts the State Energy Plan's natural gas and diesel price projections using fuel-specific multipliers calculated based on the average commercial natural gas price in New York State in October 2015 (the most recent month for which data were available) and the average West Texas Intermediate price of crude oil in 2015, as reported by the Energy Information Administration. The model applies the same price multiplier in each year of the analysis.

[6] The analysis applies the $25 per MWh figure solely to the energy that would be produced by the three CHP units.

[7] The project's consultants estimate the annual reduction in steam consumption at approximately 12,542 MMBtu. The analysis relies on a formula provided by the U.S. Environmental Protection Agency's Energy Star program to convert this figure to energy savings at the district heating system's source of 15,175.82 MMBtu per year. It values these savings using the BCA's price forecast for petroleum, based on the understanding that two of Con Edison's six steam plants have boilers that can only burn oil and that the remaining four plants may burn oil, either when it is cost-effective to do so or when natural gas is in short supply (when gas is in short supply, it must be given to Con Edison's gas customers before any is used in Con Edison's own facilities). For additional information on Con Edison's steam heating system, see http://www.coned.com/steam/kc_faqs.asp.

[8] Following the New York Public Service Commission's (PSC) guidance for benefit cost analysis, the model values emissions of CO_2 using the social cost of carbon (SCC) developed by the U.S. Environmental Protection Agency (EPA). [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.] Because emissions of SO_2 and NO_x from bulk energy suppliers are capped and subject to emissions allowance requirements in New York, the model values these emissions based on projected allowance prices for each pollutant.

In addition to the savings noted above, development of a microgrid could yield cost savings by avoiding or deferring the need to invest in expansion of the conventional grid's energy generation or distribution capacity.[9] The Eighth Avenue team does not anticipate that the project would participate in NYISO's capacity markets, nor would it affect the local utility's distribution capacity requirements. For consistency with the evaluation of other sites, however, the analysis credits the project with a generating capacity impact of 1.053 MW, based on the projected utilization of the project's DERs. The present value of this impact over a 20-year operating period is $1.75 million.

Reliability Benefits

An additional benefit of the proposed microgrid would be to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $600 per year, with a present value of approximately $7,000 over a 20-year operating period. This estimate was developed using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[10]

- System Average Interruption Frequency Index (SAIFI) – 0.11 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 181.2 minutes.[11]

The estimate takes into account the number of customers the project would serve and average annual electricity usage per customer, as provided by the project team.

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

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.6; i.e., the estimate of project benefits is approximately 60 percent that of project costs. Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

Scenario 2

Benefits in the Event of a Major Power Outage

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve.

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

[10] www.icecalculator.com.

[11] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for Con Edison. Although the 945 apartments in the housing complex are not independently metered, the analysis treats each of them as a residential customer.

It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[12,13]

The Eighth Avenue microgrid would serve an 11-building public housing complex that is currently not equipped with backup generators. The project's consultants indicate that the use of rented generators in the event of an outage is unlikely, as are other emergency measures. Accordingly, the analysis of Scenario 2 assumes as a baseline that in the event of an outage, the estimated 2,077 residents of the Robert Fulton Houses would be left entirely without power. It relies on FEMA's standard methodology for the loss of residential electric services to calculate the social cost of this impact, which it estimates at approximately $48,000 per day. Successful operation of the Eighth Avenue microgrid for the duration of an outage would avoid these costs.

Summary

Figure 2 and Table 3 present the results of the BCA for Scenario 2. The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 22 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

[12] The methodology used to estimate the value of lost services was developed by the Federal Emergency Management Agency (FEMA) for use in administering its Hazard Mitigation Grant Program. See: FEMA Benefit-Cost Analysis Re-Engineering (BCAR): Development of Standard Economic Values, Version 4.0. May 2011.

[13] As with the analysis of reliability benefits, the analysis of major power outage benefits assumes that development of a microgrid would insulate the facilities the project would serve from all outages. The distribution network within the microgrid is unlikely to be wholly invulnerable to service interruptions. All else equal, this will lead the BCA to overstate the benefits the project would provide.

Figure 2. Present Value Results, Scenario 2 (Major Power Outages Averaging 22.0 Days/Year; 7 Percent Discount Rate)

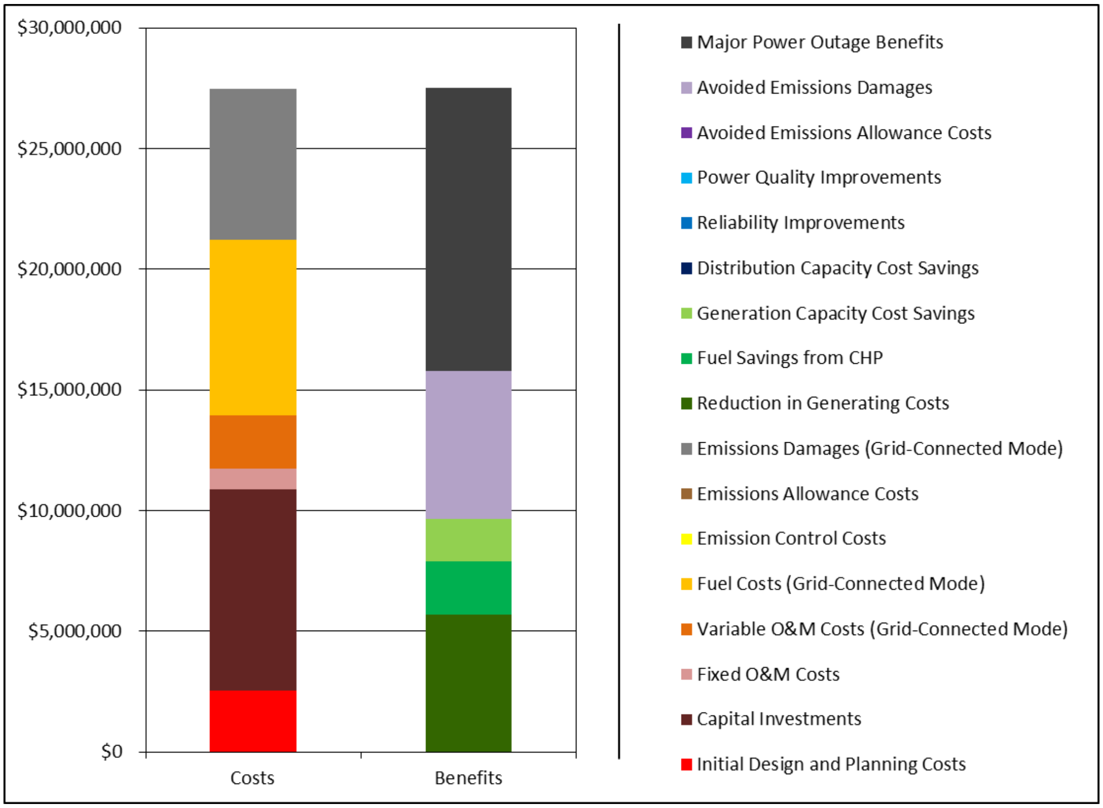

Table 3. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 22.0 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$2,560,000	$226,000
Capital Investments	$8,330,000	$720,000
Fixed O&M	$850,000	$75,000
Variable O&M (Grid-Connected Mode)	$2,220,000	$196,000
Fuel (Grid-Connected Mode)	$7,250,000	$640,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$6,280,000	$410,000
Total Costs	**$27,500,000**	
Benefits		
Reduction in Generating Costs	$5,700,000	$503,000
Fuel Savings from CHP	$2,190,000	$194,000
Generation Capacity Cost Savings	$1,750,000	$155,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$7,220	$642
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$3,130	$276
Avoided Emissions Damages	$6,110,000	$399,000
Major Power Outage Benefits	$11,800,000	$1,050,000
Total Benefits	**$27,500,000**	
Net Benefits	**$28,100**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**7.3%**	