30 - Village of Croton-On-Hudson

August 2016

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Croton-on-Hudson Community Microgrid
Final Report – NY Prize Stage 1: Feasibility Assessment

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PROJECT TEAM

Village of Croton-on-Hudson

- Janine King, Village Manager – Community Project Lead

Sustainable Westchester

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GI Energy

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Green Energy Corps.

- Paul Gregory

PROJECT STAKEHOLDERS

- The Village of Croton-on-Hudson Government
- Croton Harmon Schools
- Croton Free Library
- ShopRite Grocery
- Phelps Memorial Medical Clinic
- Gulf Gas Station

CROTON-ON-HUDSON COMMUNITY MICROGRID - KEY OVERVIEW METRICS

Team

Lead:	Village of Croton
Technical Partners:	Hitachi Microgrids
Additional Partners:	Green Energy Corp., Pace University, Sustainable Westchester, GI Energy

Utilities

Electric:	Consolidated Edison
Gas:	Consolidated Edison

Microgrid System Design

Size:	1,169 kW
Load Served per Year:	4,671,857 kWh

DER*	Qty	Capacity
Combined Heat & Power:	23	565 kW
Photovoltaic:	7	374 kW
Existing Photovoltaic:	1	5 kW
Energy Storage Systems:	7	190 kWh
Existing Emergency Gen:	7	1,445 kW

Microgrid Financials

Total Installed Cost:	$ 4,383,000
Net Installed Cost:	$ 3,536,000
Resiliency Savings:	$ 460,000/year
GHG Offset:	$ 84,000/year
Current Avg. Electric Rate:	$ 0.1645/kWh
Potential Savings with Microgrid:	2% - 5%

Supporting Organizations

Croton-Harmon School District	New York Power Authority
Con Edison	

Customer Types

Gov't Administrative:	2
Emergency Services:	4
Municipal Services:	0
Education	3
Health Care:	1
Large Commercial:	2
Small Commercial:	0
Multi-Unit Residential:	0
Total:	**12**

Electric Demand & Consumption with Microgrid

	Max kW	Avg kW	kWh / yr
Node 1	126	30	266,901
Node 2	73	12	104,727
Node 3	254	76	666,731
Node 4	42	10	87,319
Node 5	620	155	1,356,397
Node 6	80	14	126,127
Node 7	860	225	1,967,349
Node 8	35	11	96,306
Total	**2,090**	**533**	**4,671,858**

Benefit Cost Analysis Outputs

	Scenario 1	Scenario 2
Days of Major Outage	0 days/yr	2.3 days/yr
Total Benefits**	$ 6,530,000	$ 11,100,000
Total Costs**	$ 10,900,000	$ 10,900,000
Net Benefits**	$ -4,410,000	$ 193,000
Benefit-Cost Ratio	0.6	1.0

***Net Present Values*

**Distributed Energy Resources*

EXECUTIVE SUMMARY

The New York State Energy Research and Development Program (NYSERDA) established the New York Prize program to stimulate adoption and deployment of community microgrids throughout the state to:

- Reduce energy costs
- Increase the reliability of the power supply and community resilience
- Promote cleaner sources of energy

This report describes the results of Stage 1 of the NY Prize Feasibility Assessment for the Croton Community Microgrid. The Village of Croton-on-Hudson (Croton) collaborated with Hitachi Microgrids to develop the microgrid design based on the requirements of the NY Prize program, and the specific needs and priorities of Croton stakeholders. Hitachi also led the feasibility assessment, in collaboration with the Croton government. Various community organizations and partners, including the future customers of the Croton Community Microgrid, lent additional support.

Community Overview

Croton is a small, picturesque village located on the shores of the Hudson River, about 30 miles north of New York City. The Croton-Harmon Metro North rail stop has allowed the village to develop as a bedroom community for those who work in the city. The rail stop is also used by city dwellers who visit as tourists on weekends to enjoy the village's shops, setting, and cultural events. The community hosts the annual Great Hudson River Revival, a folk music, art, and environmental festival on the waterfront.

The village's economy was originally based on the labor associated with the rail station. The Croton-Harmon station was, until 1968, the site at which northbound trains would trade their electric motors for other means of conveyance. When that function was shut down, the area experienced a period of economic stagnation. The development of Croton both as a residential community for those who work in the city and a tourist destination for those who live in the city has helped the village to return to prosperity. Today Croton is home to 8,200 residents.

The Croton Community Microgrid design includes two clusters of nodes, a "Microgrid South" cluster near the train station that includes the Harmon Fire Station and EMS Station, and several businesses, including the ShopRite Grocery and Pharmacy. The "Microgrid North" cluster includes the Municipal Building and two additional fire stations, the Croton Free Library, and three public schools.

Community Requirements and Microgrid Capabilities

The Croton Community Microgrid is designed to meet specific needs within the community. These include the need to harden infrastructure against storm damage and the need to ensure continuity of emergency operations and services.

First, the microgrid is designed to protect the operation of the community's emergency services. The microgrid includes three fire stations and an EMS which together serve a population of 11,000 in Croton and the surrounding area. The microgrid also covers the municipal building, which could serve as a center of operations in an emergency. Finally, several facilities in the microgrid could be used as emergency shelters if there is a need, including the library and the three public schools. The fire and EMS facilities have existing backup diesel generators. However, these facilities report that their operational capacity is curtailed when relying on backup generation. The microgrid will allow all of these facilities to remain 100% operational even during outages to the utility grid. Minimizing the use of diesel backup generators will limit the emissions and fuel costs associated with their operation.

The microgrid is also designed to improve the resilience of critical facilities and services not directly related to emergency response. The inclusion of the municipal building in the microgrid will ensure that the operation of city government will not be interrupted or limited by a power outage. The microgrid will also ensure that the Carrie E. Tompkins Elementary School, the Pierre Van Cortlandt Middle School, and the Croton Harmon High School can all remain open and operational, even when other parts of the village are without power. This will prevent interruption to classroom instruction and school activities, and allow parents and guardians to attend work as normal. Finally, the microgrid will include a grocery store, a medical clinic, and a gas station. All three of these services become critical in an extended power outage or emergency situation.

The village's location adds to the vulnerability of these facilities to storm damage. Like its neighbors in Westchester County, Croton is vulnerable to both coastal storm activity and hazardous snow and ice conditions. Croton was hit hard by Hurricane Irene in 2011, Hurricane Sandy in 2012, and several recent severe snow events that left the city or portions of the city without power for days.

Croton is located downstate directly adjacent to the Hudson River. This location increases the village's vulnerability to flooding and wind damage during major storm events. The current design for the Croton microgrid takes this into account, with the southern cluster of nodes located near the water, across from the railyard – an area that saw significant flooding in the aftermath of hurricane Irene. It is expected that a system of this type would yield considerable lessons learned and could be a model replicable for other towns designed around a group of critical facilities that are close to the water.

The Croton Community Microgrid is designed to address these resiliency needs with clean, efficient, and cost effective technologies and architecture.

The microgrid is also designed to provide benefits to the utility. The site of the microgrid is within the Westchester Opportunity Zone for NY Prize and in an area in need of congestion reduction, as identified by Con Edison. In addition to bringing new distributed generation onto the grid, the microgrid will facilitate participation in Con Edison's demand response programs, which will help the utility to cost effectively meet peak demands.

Technical Design

Analysis of the Croton Community Microgrid design indicates that the project is technically viable and meets the community's requirements with commercially available and proven technologies.

The proposed design for the Croton Community Microgrid is based on the strategic placement of distributed energy resources (DER) among the included facilities. The DER in the microgrid design include solar photovoltaics (PV), combined heat and power (CHP), energy storage systems (ESS), and existing backup diesel and propane generators. (No new backup generators will be installed). The microgrid DER selection is based on Hitachi's *Microgrid Portfolio Approach.* This approach uses a careful analysis of energy requirements and the electric load profile of all covered facilities to determine optimal size and specification of DER. The goal of this approach is to enable microgrid resources to serve the microgrid loads more efficiently, more cost effectively, and with lower emissions per unit of energy consumed.

Under this strategy, base-load CHP will be designed to run at design output for a majority of hours each year. The peak demand for critical facilities in a community occurs only a few hours per year, and all critical facility services can be provided by a set of "always-on" microgrid resources for the majority of hours in a year. To meet the load that varies above the base load, PV and ESS will be integrated into the system. ESS are specified based on their capability to change their output rapidly and address the ramp rate issue to support load following, and buffering the differences between CHP, electrical load, and PV throughout the day. The design also incorporates active microgrid controls that enable optimal operation of energy storage, PV, and building management systems to manage load and reduce the afternoon peak load when needed.

The design addresses Croton's critical facilities that are located throughout the community. As such, the design is represented as eight nodes that each have their own microgrid resources and are able to island individually. In grid connected mode, the resources will be dispatched in a manner to create energy costs savings and minimize emissions.The table below, which also appears in the report that follows, summarizes the DER, new and existing, that will be included in the proposed microgrid design.

Executive Summary Table 1 - Microgrid Resources Comparison

Node	Operation Scenario	Grid Peak kW	PV		Battery Energy Storage		Natural Gas Engine or CHP Qty	kW	Backup Generators	
			# of Inverters	kW	Qty	kW / kWh			Qty	kW
1	Currently	126	-	-	-	-	-	-	1	200
	Microgrid	53	1	25	1	5/10	3	30	1	200
2	Currently	73	-	-	-	-	-	-	-	-
	Microgrid	10	1	30	1	15/30	1	10	-	-
3	Currently	254	-	-	-	-	-	-	1	200
	Microgrid	90	1	90	1	20/40	6	60	1	200
4	Currently	42	1	5	-	-	-	-	1	125
	Microgrid	14	1	14	1	5/10	1	5	1	125
5	Currently	620	-	-	-	-	-	-	2	700
	Microgrid	80	2	200	2	20/40	11	230	2	700
6	Currently	80	-	-	-	-	-	-	2	220
	Microgrid	40	2	20	1	5/10	1	10	2	220
7	Currently	860	1	15	-	-	-	-	1	60
	Microgrid	300	3	215	3	20/40	9	210	1	60
8	Currently	35	-	-	-	-	-	-	-	-
	Microgrid	7	1	10	1	5/10	2	10	-	-

Executive Summary Table 2, which also appears in Section 2 of this report, gives an overview of the normal operation of the prosed microgrid design in terms of electricity demanded and consumed, thermal load, and thermal recovery (through new CHP systems).

Executive Summary Table 2 - Microgrid Energy Overview: Grid Connected Operation

Node	Electric Demand		Electric Consumption		Thermal Load		Thermal Recovery	
	Max (kW)	Avg (kW)	kWh/year	kWh/ month	kBTU/ year	kBTU/ month	kBTU/ year	kBTU/ month
1	126	30	266,901	22,242	1,398,064	116,505	608,100	50,675
2	73	12	104,727	8,727	530,479	44,207	99,209	8,267
3	254	76	666,731	55,561	5,792,913	482,743	1,079,487	89,957
4	42	10	87,319	7,277	732,871	61,073	137,244	11,437
5	620	155	1,356,397	113,033	8,842,167	736,847	2,669,165	222,430
6	80	14	126,127	10,511	732,871	61,073	164,436	13,703
7	860	225	1,967,349	163,946	4,470,702	372,558	3,745,253	312,104
8	35	11	96,306	8,026	19,341	1,612	19,336	1,611
Total	**2,090**	**533**	**4,671,858**	**389,321**	**22,519,408**	**1,876,617**	**8,522,230**	**710,186**

The microgrid controller will operate the microgrid to maximize economic benefits, minimize emissions, and maximize reliability of service in the event of a fault on the grid. The microgrid controller will also track the hours of operation of each microgrid resource, and will employ a predictive maintenance strategy to schedule maintenance before any failure occurs and dispatch a technician in the event of an alarm. As the microgrid operates, a history of performance, trending, and signature analyses will develop, adding to the microgrid's ability to anticipate and avoid failures.

The ability of the Croton Community Microgrid to provide critical facilities with an uninterrupted supply of electricity and heat during power outages depends on successful transitions into and out of "island mode." Island mode refers to the mode of operation in which the microgrid disconnects from the utility grid and powers critical facilities solely from on-site resources.

The microgrid controller will manage all microgrid resources for island mode operational and performance objectives. The microgrid design ensures a seamless transition into and out of island mode operation. The microgrid controller will also have the capability to provide information to the electric utility.

Financial Feasibility

The project team developed a general budget for the Croton Community Microgrid project and incorporated it into the technical model to ensure that the design meets both the technical and economic requirements of the project. This budget includes costs for engineering, permitting, capital equipment, site preparation, construction, controls, start-up, commissioning, and training. The cost associated with "site preparation" includes the addition and modification of electrical infrastructure, PCC controls, monitoring, and protection equipment. Some of these infrastructure costs may be paid to the electric utility. The estimated installed cost for this project is $4,383,000 with an accuracy of +/- 25% (within the +/- 30% set by NYSERDA). The net cost with the federal investment tax credit (ITC) that was recently extended by the US Congress is $3,536,000. This cost does not include other incentives that may be applicable to the project that will be applied during the detailed analysis in Stage 2.

The outputs of the technical modeling process described above were used to evaluate the financial viability of the proposed microgrid from two perspectives. First, the project team analyzed the financial strength of the project when deployed using the proposed third-party ownership business model. Under this model, the project is funded through outside investment and debt which is recouped through power purchase agreements (PPAs) with each facility. In addition, NYSERDA contracted with Industrial Economics, Incorporated (IEc) to perform a benefit-cost analysis. The focus of this analysis is to evaluate the societal benefit of the microgrid, including benefits from emissions reductions, cost reductions, and resilience improvements.

Business Model Financial Results: Under the proposed business model, a third party would fund all development and construction of the microgrid, own and operate the assets, and sell the energy generated from the microgrid to community customers through PPAs. The community would incur no costs to build the project and would receive all of the benefits of energy resilience during a grid outage, and improved sustainability. Community stakeholders have indicated that third party ownership of the microgrid is currently the preferred ownership structure. The current weighted electric rate of the key critical facilities included in the proposed microgrid is approximately $0.1645/kWh. Based on the estimated energy savings, assumed project financing costs, and the 25 year contract term, the study supports a PPA electric rate with an electric cost that represents an average discount of approximately 2-5% for the facilities in this project.

Benefit-Cost Analysis Results: NYSERDA contracted with IEc to conduct a benefit-cost analysis. The project team provided detailed information to IEc to support this analysis. IEc ran two scenarios for this proposed microgrid. The first scenario modeled no power outages, and evaluated the grid connected mode of operation. The second scenario modeled the number of days (or partial days) outage at which the costs of the microgrid would be equal to its various benefits, thus yielding a cost benefit ratio of 1. For the Croton Community Microgrid, the breakeven outage case is one outage per year for a duration 2.3 days. The cost benefit results are presented in Executive Summary Table 3.

Executive Summary Table 3 – Cost Benefit Analysis Results

Economic Measure	Assumed average duration of major power outages	
	Scenario 1: 0 DAYS/YEAR	Scenario 2: 2.3 DAYS/YEAR
Net Benefits - Present Value	-$4,410,000	$193,000
Total Costs – Present Value	$10,900,000	$10,900,000
Benefit-Cost Ratio	0.6	1.0
Internal Rate of Return	-15.6%	6.5%

This benefit-cost analysis differs from the financial feasibility analysis performed by the project team in several ways. In addition to the differing objectives of these two analyses, the underlying assumptions used in each also differed. A few of these differences affected the results of these analyses in significant ways, including:

- Gas rates used in IEc's benefit-cost analysis were based on a state-wide average for commercial end-use customers. The rates used in Croton's financial feasibility analysis are based on Con Edison's distributed generation rate. This resulted in year 1 gas rates of $6.34 and $5.84, for the benefit-cost analysis and the financial feasibility analysis, respectively. If Con Edison's distributed generation rate were applied to the benefit-cost analysis, net benefits would be increased by $70,000.
- The financial feasibility assessment incorporates the tax benefits of the Federal Investment Tax Credit, whereas the benefit-cost analysis does not. This benefit reduces the capital cost of the project by $847,000.
- Capital replacement costs used in the benefit-cost analysis (BCA) were calculated as full replacement costs, whereas the project team assumed a 'rebuild' cost that is not equal to the full cost of replacement. The rebuild cost for the Croton Community Microgrid is $268,000 less than the full cost of replacement.
- The benefit-cost analysis derives a price for electricity based on average wholesale energy costs, whereas the financial feasibility assessment evaluates the savings to the community based on actual costs paid by community participants.
- The period of analysis in the benefit cost analysis is 20 years and the third party ownership model is based on a period of analysis of 25 years.

The entirety of the IEc analysis can be found in Appendix D of this report.

Conclusions and Next Steps

The NY Prize feasibility assessment indicates that the Croton Community Microgrid is both technically and economically viable. In addition to protecting the city's ability to respond to emergencies, the microgrid will provide direct benefit to the entire population within Croton by protecting critical services in an area that is particularly vulnerable to storm damage. The microgrid will result in lower energy costs and lower carbon footprint for the microgrid customers. The project team believes that the proposed microgrid design will serve as a leading example for New York, and will be beneficial and replicable to other communities across the state and beyond.

The next steps that the Croton community will need to undertake are to finalize the ownership structure to be proposed, and identify a team of partners to engage in the detailed design phase of the project. Once these decisions are made, the project team will draft a proposal to NYSERDA to compete in Stage 2 of NY Prize. This Stage 2 funding will help defray the additional cost and risk associated with a multi-stakeholder community microgrid. Stage 2 of the NY Prize program will require additional cost share, and a determination will need to be made about which parties will take this on.

TECHNICAL DESIGN OVERVIEW

The proposed microgrid solution will focus on community resiliency based on distributed resources co-located at or near the critical facilities serving the community emergency response, municipal services, and student populations of Croton. The microgrid will cover two main locations in Croton – the North and South. Within each location, there are smaller “nodes” that group microgrid operations for nearby facilities and/or individual critical facilities. Each node will be fed by its own portfolio of distributed generation, and each will be capable of staying powered in island mode during a grid outage. However, when the grid is powered, the eight nodes will be grid-connected and can be managed as a single microgrid system. In this way, generation resources will be optimized to meet loads across the larger microgrid with a focus on economical operation and minimization of the system’s environmental footprint.

The proposed microgrid will include government support services, two fire stations and an EMS station, a library, several schools, and critical retail facilities. Collectively, there is a total of 8 “nodes” that make up the Croton Community Microgrid. The eight Croton nodes and included facilities and functions are listed in the Table 1.

Table 1 – Overview of Microgrid Nodes

Node Location	Microgrid Node #	Node Name	Facilities	Functions
North	1	Municipal	• Municipal Building	• Municipal offices and services
North	2	Library	• Croton Free Library	• Library • Shelter
North	3	Elementary	• Carrie E Tompkins Elementary School	• Education • Shelter
North	4	Fire Station #1	• Grand St. Fire Station	• Fire response
North	5	Schools	• Croton-Harmon High School • Pierre Van Cortlandt Middle School	• Education • Public services (e.g., meetings)
South	6	Emergency Services	• Harmon Fire Station • EMS Station	• Fire and emergency response
South	7	Commercial Partners	• ShopRite Grocery/Pharmacy • Phelps Memorial Medical Clinic • Gulf Gas Station	• Food • Medicine / Medical services • Gas
North	8	Fire Station #2	• Washington Fire Station	• Fire response

The utility feeders are mainly overhead lines, which cannot be relied upon in the event of a major storm. The microgrid design employs underground cabling to support each microgrid node in key areas where it is cost effective for the overall project. While this greatly improves resiliency within a microgrid node, the cost of the underground cabling limits the reach of the node. The same general protection schemes are employed in each microgrid node as are used in utility distribution networks. Some pole-top transformers will be replaced with pad-mount distribution transformers, and additional isolating switches and breakers will be added at the PCC as described above.

The existing thermal infrastructure consists mainly of hot water systems. If there is a steam system, we will not attach to it, because the output temperatures of the natural gas engines do not meet the quality standards for a steam system. The CHP connections to the hot water systems are installed in parallel with the existing boiler(s), and fed into the supply and return headers.

Table 2 - Microgrid Electrical and Thermal Infrastructure Plan

Infrastructure	Class	Associated Device	Comment / Description
4.16 kV, 3 phase, 4 wire Underground Cabling	New	Nodes 5, 6, & 7	Added for Microgrid Nodes that have multiple electric accounts
PCC (All Nodes)	New	4.16 kV line to distribution transformer	Transition from overhead to underground
4.16 kV Transformers	Updated	Critical Facilities	Conversion from pole-top to pad mount
Synchronizing Switches	New	CHP	Each CHP at a critical facility will require a synchronizing switch with protection to enable remote synchronization with the microgrid bus
M, C, P	New	All resources	Monitoring (sensing), Control, and Protection relays for proper management of resources in all modes
Automatic Transfer Switch	Existing	Emergency Generators	All emergency generation (diesel or propane) have automatic transfer switches installed in critical facilities. This will remain unchanged.
Hot Water Supply Connection	New	CHP & heating	Tie-in from CHP to facility thermal loop for each facility with new CHP
Hot Water Return Connection	New	CHP & heating	Tie-in from CHP to facility thermal loop for each facility with new CHP

The area covered by the proposed Croton-on-Hudson Community Microgrid will positively impact all of the village's 8,200 residents. The emergency services facilities in the microgrid provide services beyond the Village to a total population of 11,000 residents in the region. Key institutions covered by the microgrid are listed below, along with the impact the microgrid will have on their operation:

Table 3 – Community Stakeholders to Benefit from the Microgrid

Facility	Current Condition in Grid-Loss Scenario	Future Condition with Microgrid in Grid-Loss
Municipal Building	The Municipal Building is served by a 200 kW emergency diesel-fueled backup generator to support key functions during a grid outage.	The Municipal Building can remain open, making use of the DER included in Node 1. This added resiliency will help this building continue to support village government and emergency coordination. The existing emergency generator has been incorporated into the microgrid design but its use will be minimized to extend the hours of operation with the existing fuel storage and to minimize emissions.
Croton Free Library	The library is not served by any emergency generation and must close during an outage.	The microgrid will allow the library to remain powered and open through power outages. As a community center, the library could serve as a public shelter, provide internet access, and a place for residents to charge their cell phones.
Carrie E. Tompkins Elementary School	The school has an existing 200 kW emergency diesel-fueled backup generator to support critical systems during a power outage.	Carrie E. Tompkins Elementary has an enrollment of 630 students. The microgrid will allow the school to draw on the entire portfolio of microgrid resources to remain completely powered and open during an outage. This will ensure that students can attend school and allow parents of students to attend work as usual. This facility may also serve as a temporary shelter for community members in an emergency.

Facility	Current Condition in Grid-Loss Scenario	Future Condition with Microgrid in Grid-Loss
Grand Street Fire Station	The Grand St. Fire Station is supported by a 125 kW emergency diesel-fueled backup generator during grid outages to support essential functions. Fire Station staff report a 10% increase in response time during a power outage.	The fire stations provide services beyond the Village to a total population of 11,000 residents in the region. Under the microgrid, the fire station can remain fully operational during a grid outage, making use of the DER included in Node 4. This added resiliency will help this building continue to support emergency response activities. The existing emergency generator has been incorporated into the microgrid design, but its use will be minimized to extend the hours of operation with the existing fuel storage and to minimize emissions.
Croton Harmon High School	The school has an existing 350 kW emergency diesel-fueled backup generator to support critical systems during a power outage.	Croton Harmon High School has an enrollment of 540 students. The microgrid will allow the school to draw on the microgrid resources in Node 5 to remain completely powered and open during an outage. This facility will be able to serve as a temporary shelter for community members in an emergency.
Pierre Van Cortlandt Middle School	The school has an existing 350 kW emergency diesel-fueled backup generator to support critical systems during a power outage.	Pierre Van Cortlandt Middle School has an enrollment of 530 students. The microgrid will allow the school to draw on the microgrid resources in Node 5 to remain completely powered and open during an outage. This facility will be able to serve as a temporary shelter for community members in an emergency.
Harmon Fire Station	The Harmon Fire Station is supported by a 125 kW emergency diesel-fueled backup generator during grid outages to support essential functions. Fire Station staff report a 10% increase in response time during a power outage.	The fire stations provide services beyond the Village to a total population of 11,000 residents in the region. Under the microgrid, the fire station can remain fully operational during a grid outage, making use of the DER included in Node 6. This added resiliency will help this building continue to support emergency response activities. The existing emergency generator has been incorporated into the microgrid design but its use will be minimized to extend the hours of operation with the existing fuel storage and to minimize emissions.

Facility	Current Condition in Grid-Loss Scenario	Future Condition with Microgrid in Grid-Loss
EMS Station	The EMS Station is supported by a 125 kW emergency propane generator during grid outages to support essential functions. EMS staff report a 10% increase in response time during a power outage.	Together with the Harmon Fire Station, the EMS Station serves an area that covers 11,000 people. Under the microgrid, the EMS Station can remain fully operational during a grid outage, making use of the DER included in Node 6. This added resiliency will help this building continue to support emergency response.
ShopRite Grocery/Pharmacy	Limited functions at the ShopRite grocery are served by a 60 kW emergency diesel-fueled backup generator.	The microgrid will allow the grocery to stay open and fully powered and operational. Uninterrupted refrigeration will allow the store to protect their stock from spoilage. Continued operation at the store will also help ensure the food supply for the local community.
Phelps Memorial Medical Clinic	The medical clinic is not served by any emergency generation and must close during a power outage.	Phelps Memorial Medical Clinic provides primary care and diagnostic radiology practice to the residents of Croton-on-Hudson. The microgrid will allow this facility to remain operational during a power outage and continue to provide medical care.
Washington Fire Station	The Washington Fire Station is not served by any backup generation. Doors must be manually opened during a power loss. Trucks can be deployed from the fire station during an outage, but services must be curtailed and response time will increase.	The fire stations provide services beyond the Village to a total population of 11,000 residents in the region. The microgrid will allow this station to remain powered and operational during a power outage, ensuring the safety of local residents during an emergency.

In addition to the potential facilities identified above, the Croton Community Microgrid will create benefits for other stakeholders. If selected for the next stage of NY Prize, the project team will continue to solicit their advice and participation. These stakeholders include:

Table 4 – Community Stakeholders to Benefit from the Microgrid

Organization	Benefits from Croton Community Microgrid
Con Edison	By serving the local load and providing resilient energy, the system will allow the utility to delay potential investments in the existing substation equipment. Con Edison is implementing other resiliency upgrades to their system, and the microgrid complements these other efforts.
Hudson Valley Gateway Chamber of Commerce	The microgrid will protect mission continuity for several essential services in Croton, including fire and public works, which serve all businesses in town. Even those businesses that are not included in the microgrid will benefit from the improved public service the microgrid supports.
Sustainable Westchester	Croton is a member municipality of Sustainable Westchester, and Sustainable Westchester is a partner in this project. The microgrid will provide greater resilience and sustainability to the region, helping Sustainable Westchester to advance its stated goal to "to turn our environmental challenges into opportunities to improve the quality of life, economy, and future prospects of the citizens of the county."

KEY FEATURES OF THE MICROGRID

Community Microgrid Controller

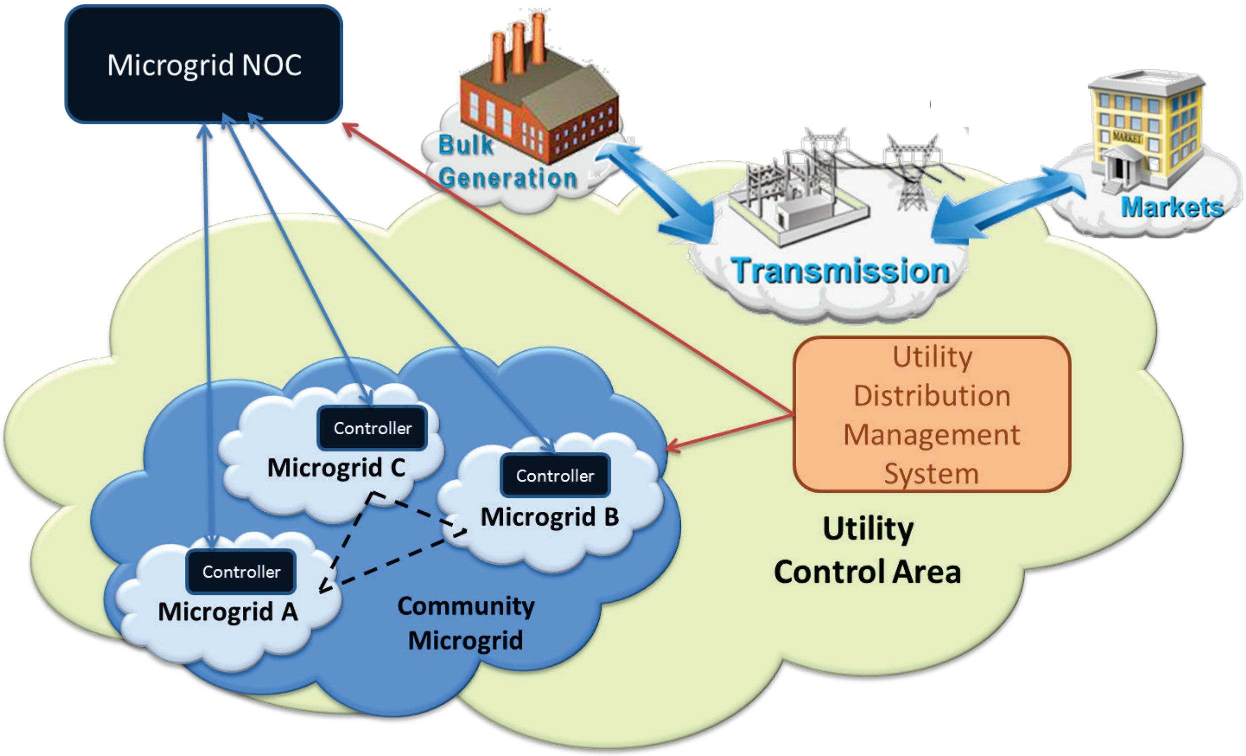
One of the challenges of community microgrids is that the facilities and the microgrid resources are distributed. To maximize the economics, reliability, and emissions reduction potential of the community microgrid, the microgrid controller architecture must have the capability to coordinate and control different groups of resources as well as provide control for localized operations.

Our team has developed a project concept for the community microgrid that allows for simultaneous control of multiple microgrids in the community as well as coordination with the local utility. Specifically, the solution includes local controllers in each microgrid part as well as a hosted controller in the Microgrid network operating center (NOC) that can operate each microgrid part separately or collectively.

In the grid-connected mode, the primary operations will focus on maximizing economic benefits and minimizing emissions across all the microgrids within the community. In some cases, the aggregation of the microgrid resources can be leveraged to support utility firming request and/or RTO/ISO ancillary services such as demand response and frequency regulation. However, during a reliability event, the operation of each individual microgrid controller will focus on the load and generation assets only within its control. The local controller will transition to island mode while maintaining proper voltage and frequency.

Figure 1 presents our team's design approach for the community microgrid controller architecture.

Figure 1: Project Concept for Community Microgrid



The microgrid controller will have an active management and control architecture that supports the 10 EPRI/ORNL Use Cases:

1. **Frequency control**: In normal operations, the microgrid may not have enough resources to affect frequency on the grid. It could participate in the ancillary services markets by increasing output to support the frequency in the local grid, but total impact would be small. Nevertheless, the system will monitor frequency along several thresholds, providing a discrete high-low range; the system will detect if frequency is out of range and respond by taking resources off-line or dispatch other resources to manage frequency. Also, the system will analyze data to detect subtler trends that do not exceed thresholds but provide evidence of a possible problem.
2. **Voltage control**: In both grid-connected and islanded modes, the voltage control application will be used to provide stability to the microgrid and connected circuits. Voltage control leverages line

sensing and metering to provide control actions when necessary. This application will take into account traditional volt/VAr instruments such as tap changers and cap banks along with inverter-based resources, which should provide a greater degree of optimization.

3. **Intentional islanding**: For each microgrid node, the islanding process will be semi-automatic so that a utility operator or local energy manager will be able to move through each step before opening the PCC. The utility operator will provide the appropriate permissives for opening the PCC. The local microgrid controller for each microgrid node will be responsible for setting the voltage source and load following resource.
4. **Unintentional islanding**: The designed PCC structure, coupled with additional analysis compliant with IEEE 1547.4, enables the utility-controlled breaker or switch to immediately open (frequency = 59.3 Hz) on loss of the grid. The microgrid managed synchronizing breaker will remain closed for a few more milliseconds until microgrid frequency reaches 57.0 Hz. Since the inverters and generator controls are keying off the synchronizing breaker, these few additional milliseconds enable the energy storage and power electronics to better manage the transient as the microgrid resources pick up the portion of the load served by the utility grid just before the grid was lost. When, or if, the frequency dips to 57.0 Hz and the synchronizing breaker opens, the microgrid will move into island mode. The microgrid controller will adjust all microgrid resources for the new state and island performance objectives.
5. **Islanding to grid-connected transition**: As with intentional islanding, the utility operator will provide the appropriate permission to close in the PCC. The local microgrid controller will support the reconfiguration of each dispatchable resource.
6. **Energy management**: The microgrid design incorporates a portfolio of resources. The EPRI Use Case takes a traditional energy management approach– economic dispatch, short-term dispatch, optimal power flow, and other processes typical in utility control room environments. The microgrid controller will have corresponding applications that manage a set of controllable generation and load assets. Within that portfolio, the system will also optimize the microgrid based on load forecast, ancillary services events, changes in configuration, outage of specific equipment, or any other kind of change to determine the optimal use of assets 48 hours ahead.
7. **Microgrid protection**: The microgrid controller will ensure two primary conditions. The first is that each protection device is properly configured for the current state of the microgrid, either islanded or grid-connected. The second condition is that after a transition, the microgrid controller will switch settings or test that the settings have changed appropriately. If the test is false in either condition, the controller will initiate a shutdown of each resource and give the appropriate alarm.
8. **Ancillary services**: The controller will provide fleet control of the nested microgrid parts. Specifically, the utility operation will have the ability to request and/or schedule balance up and balance down objectives for the fleet. The cloud-based controller will take the responsibility to parcel out the objectives for each microgrid part based on the available capacity.
9. **Black start**: The local microgrid controller will provide a workflow process for restarting the system. Each microgrid part will have a unique sequence of operations for predetermined use cases. One

objective will be to provide this function both locally and remotely to meet the reliability requirements of the overall design.

10. **User interface and data management**: The solution provides local controllers in each microgrid part as well as a hosted controller that can operate each microgrid part separately or collectively. The primary actors are the utility operator, local energy managers, maintenance personnel, and analyst. The user experience for each actor will be guided by a rich dashboard for primary function in the system around Operations, Stability, Ancillary Services, and Administration.

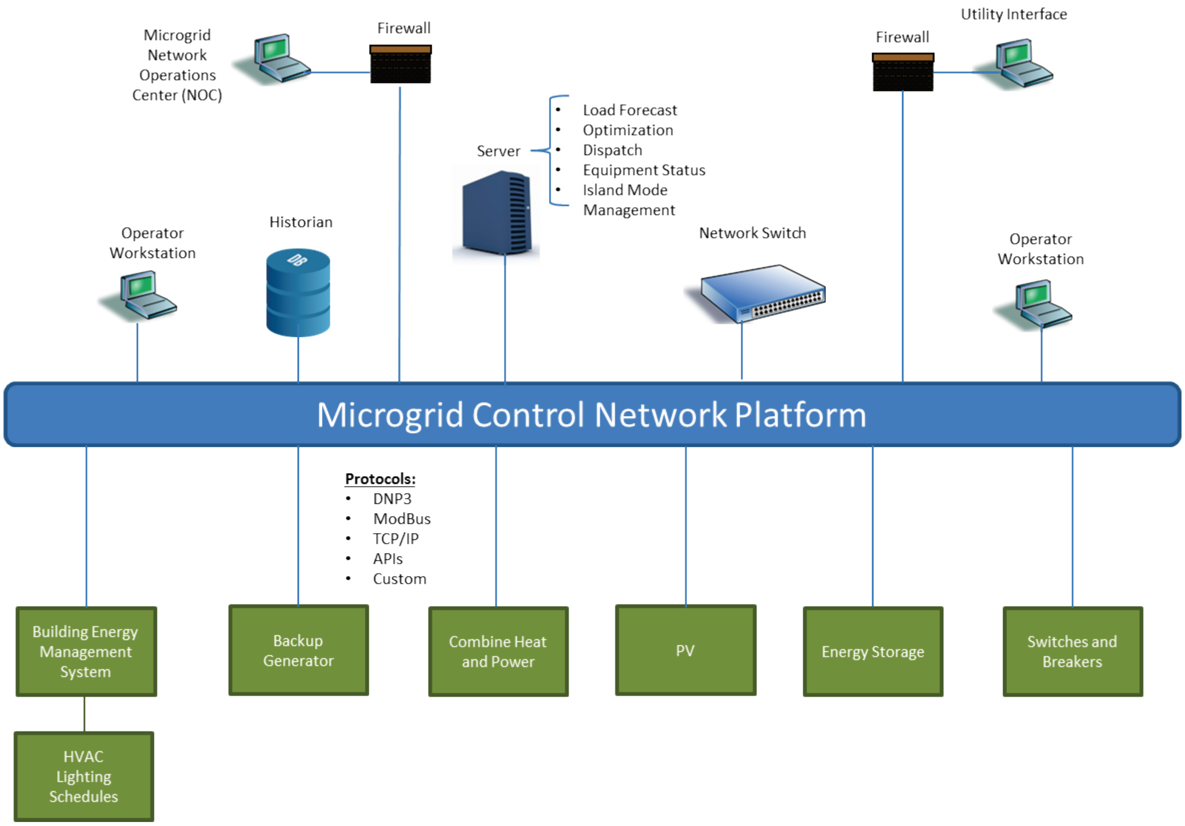
In addition, the microgrid controller will:

- Forecast variable aspects: load, wind, solar, storage
- Dispatch of DER to maximize economic benefit
- Continuously monitor and trend health of all system components
- Take into account utility tariffs, demand response programs, and ancillary service opportunities
- Understand operational constraints of various DER and vendor-specific equipment
- Interface to local utility
- Meet rigid and proven cyber security protocols

Ultimately, the control system will perform all of the functions above to continuously optimize the operation of the microgrid for economic, resiliency, and emissions performance.

A microgrid controller design needs to be reliable and have redundancy comparable to the other microgrid resources. A standard controller approach such as central controller or PLC design will therefore not be sufficient. The architecture must support the capability to interface with field devices, provide a platform for communications and data management, provide for both local and remote operator access, have a data historian, and provide for applications to meet the microgrid Use Cases highlighted above. A conceptual controller topology is presented in the Figure 2.

Figure 2 – Conceptual Microgrid Controller Topology



To support the community node approach, the microgrid control scheme will provide for a secure external access to the NOC that can coordinate the various nodes within the community. In addition, remote access to the utility will be provided to inform them and their distribution operators of the microgrid status and to communicate protection relay permissives for the island-mode transitions. The system will be designed so the core control functions are located within the microgrid and so that loss of communication with the NOC will not significantly impact the local operations of any node. The NOC monitors equipment performance and coordinates across nodes. In the event of an outage, all control will move to local controllers and focus on site specific optimization and operations.

The microgrid controller will leverage existing equipment to the greatest extent possible. This will include building energy management systems, backup generators, and local area networks. For the purposes of reliability and security, the microgrid control system will consist of new and independent infrastructure.

Telecommunications Infrastructure

Each microgrid node will have a wireless LAN specific to the microgrid, powered by microgrid resources, and extended to every resource, device, sensor, and load interface (e.g., building management system). This communications infrastructure will be designed with dual-redundant access points to ensure reliable onboard communications.

The architecture will conform to requirements established by the SGIP and generally accepted communications protocols, such as ModBus (TCP/IP), DNP3 (TCP/IP), and IEC61850, as well as field networks for buildings such as LonWorks and BACnet. ModBus will be used throughout the microgrid nodes for communications, as it is currently the most prominent communications protocol within the DER and inverter community. Communications with the utility distribution management systems will use DNP3, as that is the prominent protocol used by the utility industry.

In addition, the NIST IR 7628, “Guidelines for Smart Grid Cyber Security,” will be followed in the architecture and design of the microgrid controls’ IT and communications to ensure security and continuity of operations in all modes. Finally, the IT/telecommunications infrastructure will be new to secure the microgrid controls network separately from existing IT and communications systems at the facilities.

Communications – Microgrid and Utility

Communications between the microgrid and the utility will occur in two forms: (1) utility DMS will interface with the microgrid controls for monitoring and managing the PCC utility-controlled isolating switch and microgrid-controlled synchronizing breaker, and (2) a dashboard served by the microgrid controls to the utility via the internet will give the utility insight into the day to day operations of the microgrid.

In accordance with the EPRI/ORNL Microgrid Use Case 4, the microgrid will transition into island-mode operations upon loss of communications between the utility DMS and the microgrid, assuming loss of grid. No specific microgrid action will be taken on loss of the utility dashboard service via the Internet.

The microgrid control system will be local to the microgrid node in a secure, conditioned space, (e.g., electrical room) in one of the critical facilities within the microgrid node. This ensures that real-time control of the microgrid resources and loads will be maintained in the event of a loss of communications with the utility DMS and Internet services. Although economic optimization will be reduced for a period of time, the reliability and resiliency optimization will be maintained because those algorithms are in the microgrid control system local to the microgrid node and do not require off-board communications to function.

The onboard communications within the microgrid LAN will be a dual-redundant architecture, where every LAN access point is backed up by another access point.

DISTRIBUTED ENERGY RESOURCES CHARACTERIZATION

A variety of generation sources are planned for the community microgrid. They include the following:

- CHP
- PV
- ESS
- Building Load Control
- Energy Efficiency Measures (EEMs)
- Utility Grid
- Backup Generators

The Croton microgrid design is focused on the development of an overall energy strategy that incorporates both demand-side management and new distributed generation resources to support the microgrid's operational objectives. During operation in the grid-connected mode, the resources will typically be dispatched in an economic optimization mode. This approach will ensure that the microgrid will operate in a manner that the energy delivered to the critical facilities is at or lower than that the cost of electricity that could be purchased from the local utility. In this scenario, the CHP will operate in a constant output mode at its maximum efficiency and lowest emissions, the PV generation profile will be taken into account, the energy storage will operate in a manner to maximize microgrid benefits, and the grid will operate in a load following mode. The connection to the grid will also be used to manage the voltage and frequency of the microgrid.

The microgrid will take advantage of DER to remain in operation when the utility grid is not available. The microgrid controller will monitor island mode frequency and voltage and adjust equipment operation accordingly to maintain circuit stability. Existing backup generators will be leveraged to support island operations in conjunction with the new DER. New DER will minimize the need for the backup generator operation to minimize natural gas and diesel fuel usage. The microgrid will also support the transition back to the grid when the utility service is restored. The design ensures that the return to the grid is a seamless transition and is coordinated with the utility through appropriate protocols, safety mechanisms, and switching plans (to be communicated to the microgrid controller by the utility distribution management system).

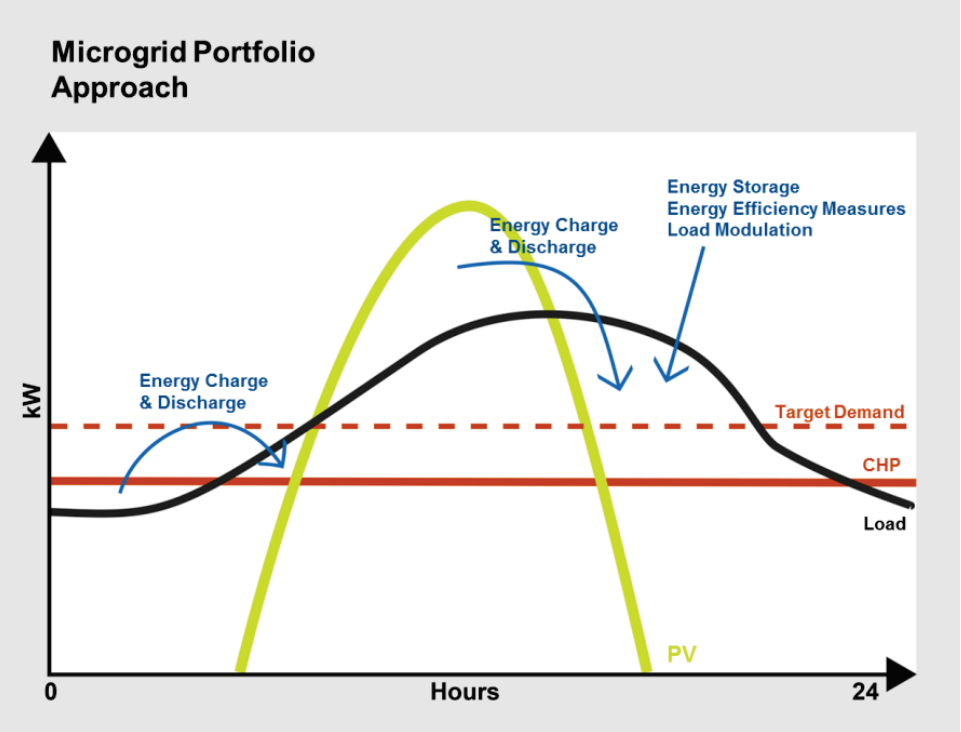
To support steady-state frequency requirements, as well as the ANSI 84.1-2006 standard voltage requirements and to support the customer power quality requirements at PCC, the microgrid controller will actively manage the dispatch of generation resources; actively manage the charge and discharge of energy storage; provide observability of microgrid-wide telemetry including frequency, power factor, voltage, currents and harmonics; provide active load management; and provide advance volt-VAr variability algorithms and other stability algorithms based on steady state telemetry of the system.

Normal and Emergency Operations

The microgrid DER selection is based on our *Microgrid Portfolio Approach* that focuses on energy requirements and a close match to the electric load profile of all covered facilities. The peak demand for critical facilities in the community occurs only a few hours per year. This means all critical facility services can be provided by continuously operating microgrid resources for the majority of hours in a year without over-building. The goal of this approach is to enable microgrid resources to serve the microgrid loads more efficiently, more cost effectively, and with lower emissions per unit of energy consumed.

Under this strategy, base-load CHP will be designed to run at design output for a majority of the hours per year. To meet the load that varies above the base load, resources such as PV and energy storage will be integrated into the system. Energy storage systems are specified based on their capability to change their output rapidly and address the ramp rate issue to support load following, and buffering the differences between CHP, electrical load, and PV throughout the day. This concept is presented in Figure 3.

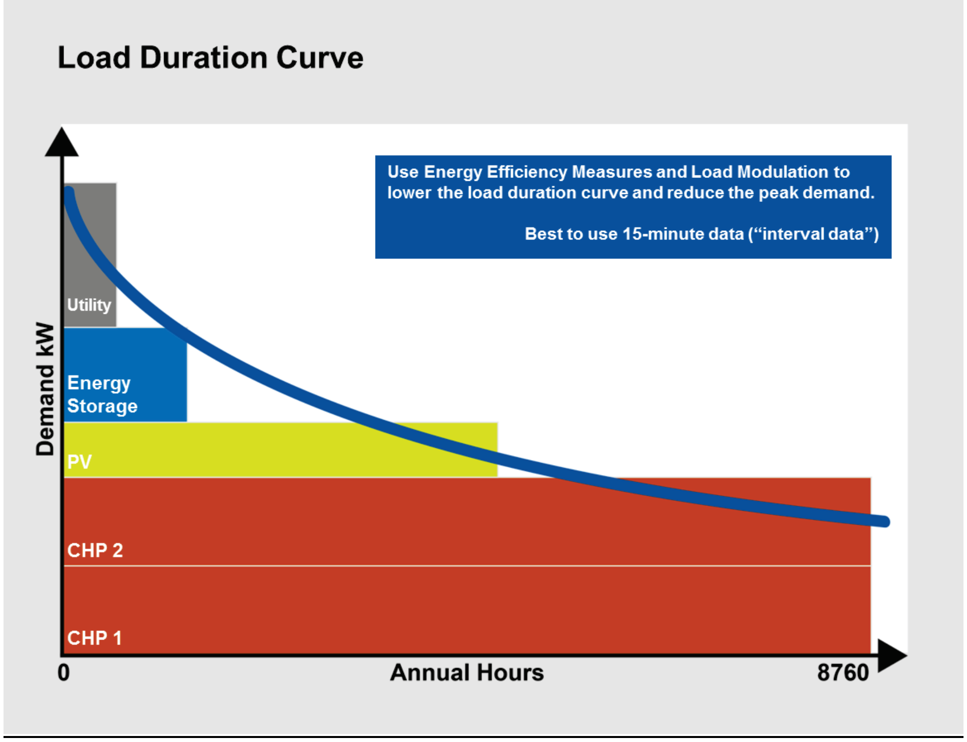
Figure 3 – Microgrid Portfolio Approach



From a long-term operations and maintenance standpoint, the Portfolio Approach enables the microgrid to operate energy resources within their design envelope. This keeps maintenance costs and fuel costs at a minimum, and helps to lower the total cost of ownership. The design also incorporates active microgrid controls that enable optimal operation of energy storage, PV, and building management systems to manage load and reduce the afternoon peak load when needed.

The load duration curve presented in Figure 4 illustrates another element of the resource selection and sizing strategy for the Croton microgrid. When operating in a grid-connected mode, the microgrid uses the grid as a resource to meet intermittent peak demand periods. When operating in island mode, the microgrid supply and demand will be managed through the dispatch of microgrid generation resources, load management, and to a minimum extent, the use of existing backup generation. This methodology allows the designers to evaluate the appropriate balance of grid service, generation resources, and load management capabilities, and provide both a technical and economic solution.

Figure 4 – Load Duration Curve



One of the most important attributes of the Croton Community Microgrid will be the ability to operate when the utility grid is not available. The methods of transitioning into an island mode are characterized as either a (1) planned transition or (2) unplanned transition.

- Planned Transition*:* In a planned transition, outside information is used to ramp up resources so there is zero grid import to the microgrid. A seamless transition occurs into island operations at the appropriate time. Outside information includes weather forecasts, grid frequency deviations, local voltage sags, or other information provided by the utility.

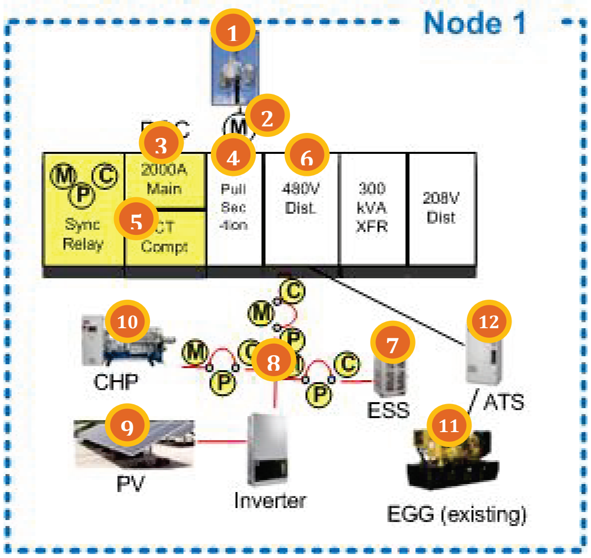
- Unplanned Transition*:* In an unplanned transition, an unanticipated outage takes place such as the loss of a transformer or a car hitting a distribution power pole. Depending on the microgrid resources operating at the time, an outage may take place that requires the microgrid to establish itself through a black start sequence of operation.

A complete layout of the design showing all microgrid nodes is presented in Appendix A. This geospatial image shows the facilities and location of electrical infrastructure and major new microgrid resources. More details about each individual node are presented on the following pages.

In addition, a microgrid one-line diagram is presented in Appendix B. The diagram includes the substation, major electrical equipment, and the rated capacity for each microgrid distributed energy resource. The PCCs are shown with associated monitoring (M), control (C), and protection (P) devices.

The figure below includes a brief explanation of the elements included in the one-line diagram.

Figure 5 – One-Line Diagram Explanation



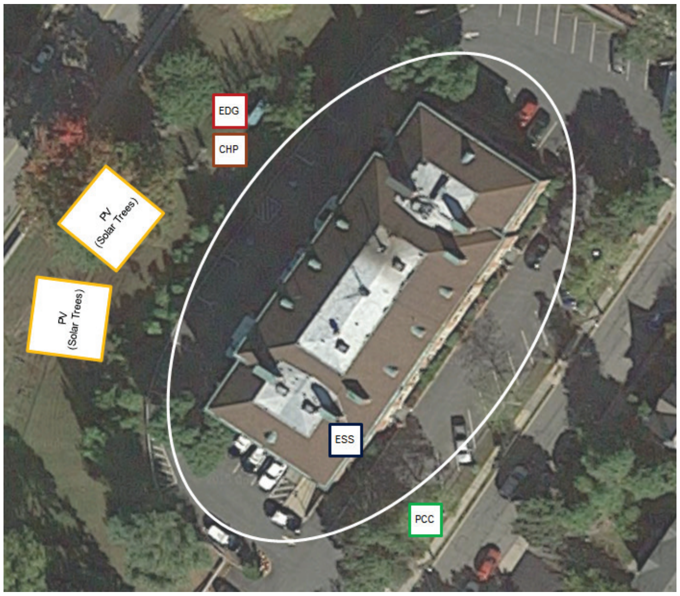
1. Transformer to the critical facility
2. Utility meter
3. Synchronizing relay controls / main breaker with monitoring (M), protection relays (P), and controls (C)
4. Main disconnect (pull section)
5. Instrument current transformer compartment
6. Main 480V 3-phase distribution panel; step-dov transformer and 208 V 1-phase distribution par
7. ESS with M, P, C
8. New 480 V 3-phase cable (red)
9. Solar PV array and associated inverter with M, P, C
10. Combined heat & power (CHP) with M, P, C
11. Emergency backup generators: natural gas (EGG) or diesel (EDG)
12. Automatic transfer switch (ATS)

The following pages highlight the layout design and one-line diagram subsection for the eight nodes as well as a brief explanation of included energy resources.

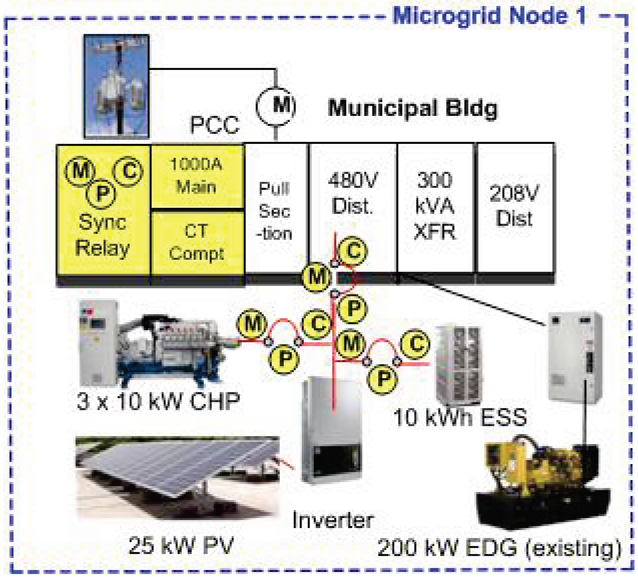
Geospatial Diagrams and One-Line Subsections

Node 1 System Configuration

Geospatial Diagram



One-Line Diagram



Key Facilities

- Municipal Building

Description

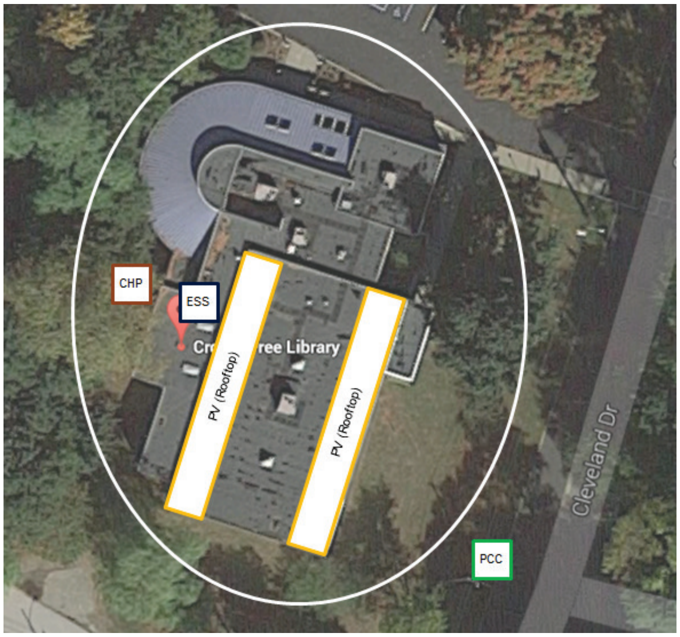
Node 1 includes an existing emergency diesel generator (200 kW). The PCC will be located in the front corner of the building.

As part of the microgrid, the following will be installed:

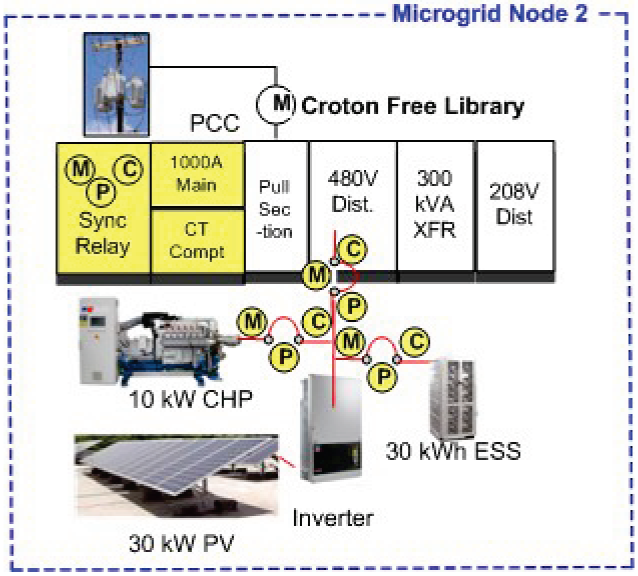
- **PV (25 kW):** Two new solar trees will be placed behind the municipal building, as to not limit parking or visibility in the front. A few existing trees will need to be removed to minimize PV shading and maximize output.
- **CHP (30 kW):** A small CHP unit will also be placed behind the building near the existing emergency diesel generator.
- **ESS (10 kWh):** An ESS unit will be placed to the left of the entrance to the building.

Node 2 System Configuration

Geospatial Diagram



One-Line Diagram



Key Facilities

- Croton Free Library

Description

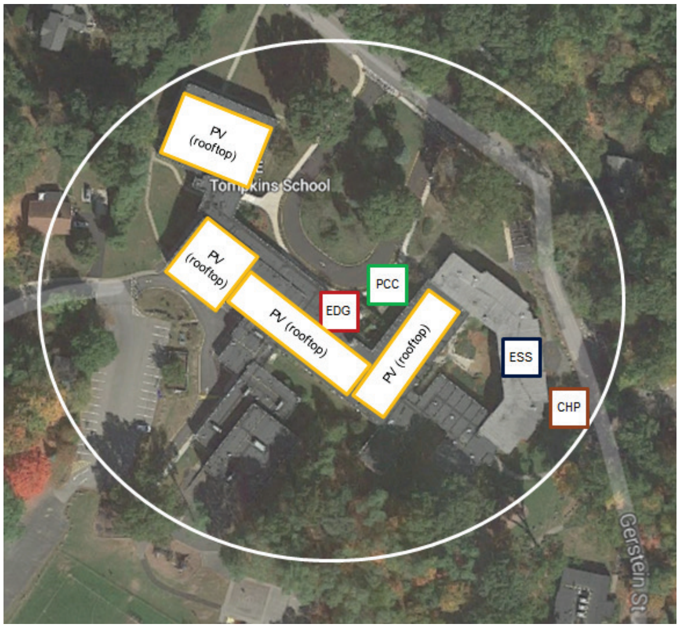
Node 2 is a single facility node. The PCC will be located in the right back corner of the facility.

As part of the microgrid, the following will be installed:

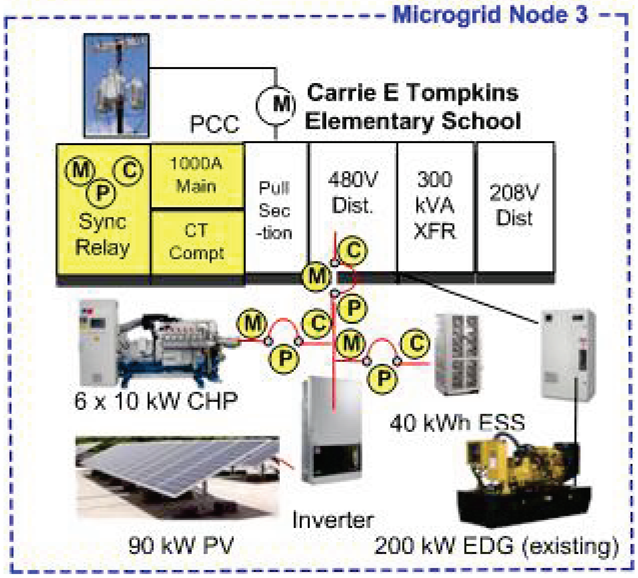
- **PV (30 kW):** A PV system will span both sides of the roof.
- **CHP (10 kW):** A small CHP unit will be placed in an open field to the side of the building.
- **ESS (30 kWh):** An ESS unit will be placed near the CHP unit to the side of the building.

Node 3 System Configuration

Geospatial Diagram



One-Line Diagram



Key Facilities

- Carrie E. Tompkins Elementary School

Description

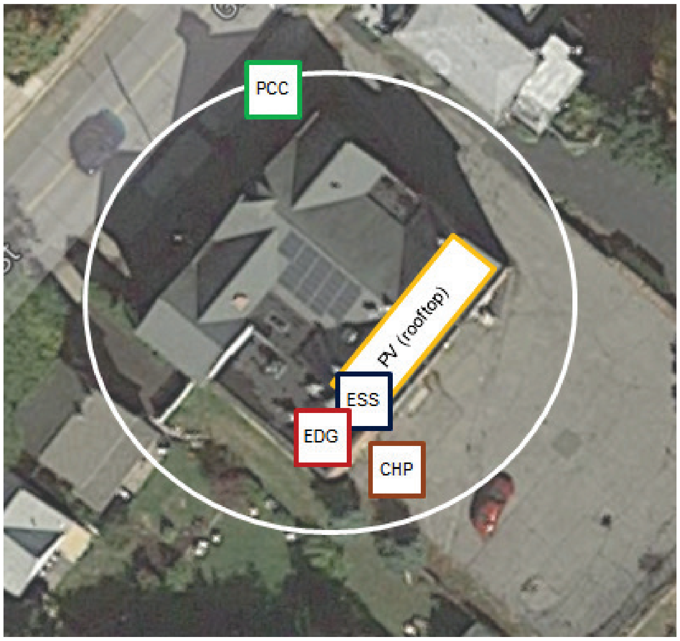
Node 3 is a single facility node. It includes an existing emergency diesel generator (200 kW), and the PCC will be located near the back of the building.

As part of the microgrid, the following will be installed:

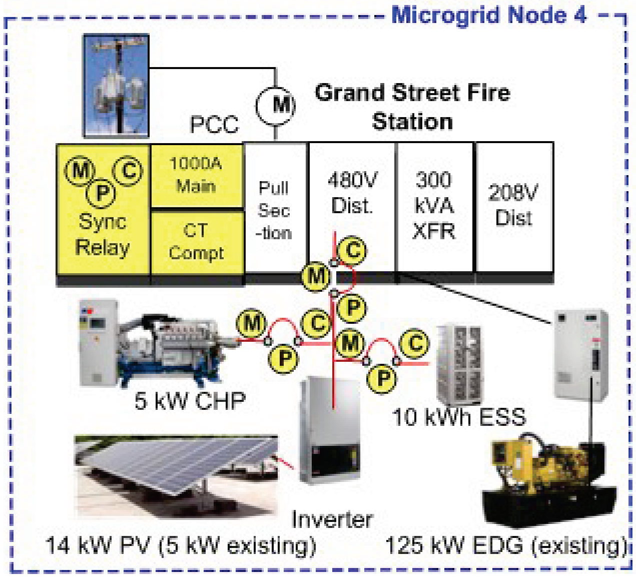
- **PV (90 kW):** A PV system will cover the roof across most of the school.
- **CHP (60 kW):** A CHP unit will be placed in the open space near Gersten St. and the side of the school.
- **ESS (40 kWh):** An ESS unit will be placed near the CHP unit to the side of the building.

Node 4 System Configuration

Geospatial Diagram



One-Line Diagram



Key Facilities

- Grand Street Fire Station

Description

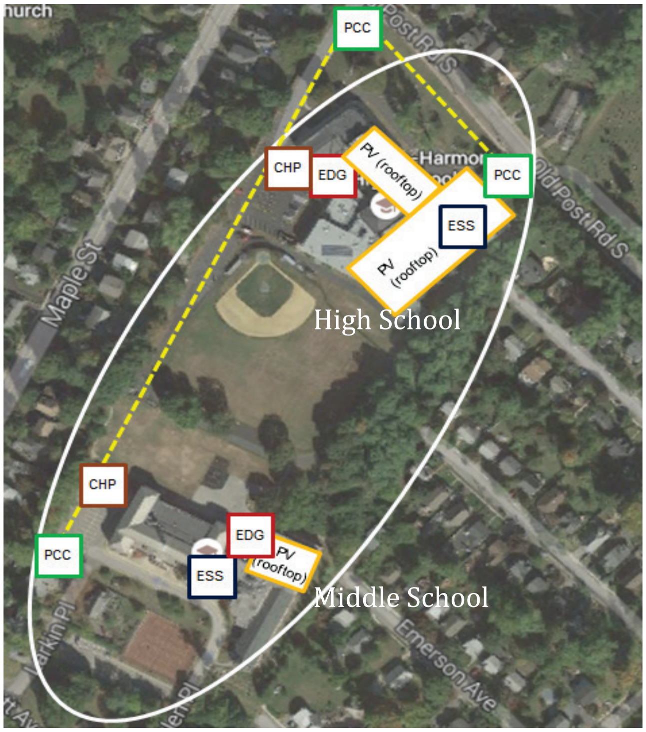
Node 4 is a single facility node. It includes an existing emergency diesel generator (125 kW) and 5 kW PV. The PCC will be located at the front of the building by Grand St.

As part of the microgrid, the following will be installed:

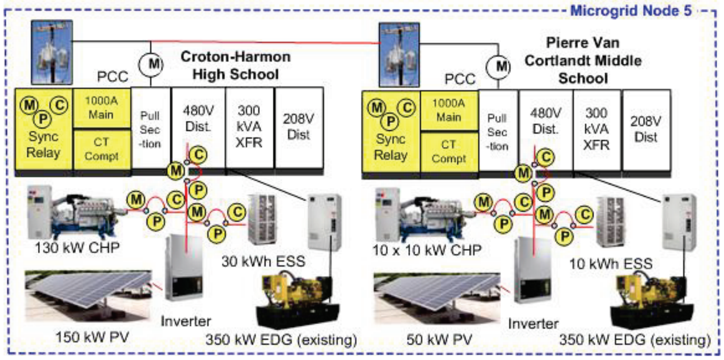
- **PV (14 kW):** A rooftop PV system will cover the back part of the roof and add more capacity to the existing array.
- **CHP (5 kW):** A small CHP unit will be placed in the back parking lot near the emergency generator. There is sufficient parking to allow for this unit.
- **ESS (10 kWh):** An ESS unit will be placed near the PV system inverters.

Node 5 System Configuration

Geospatial Diagram



One-Line Diagram



Key Facilities

- Croton-Harmon High School
- Pierre Van Cortlandt Middle School

Description

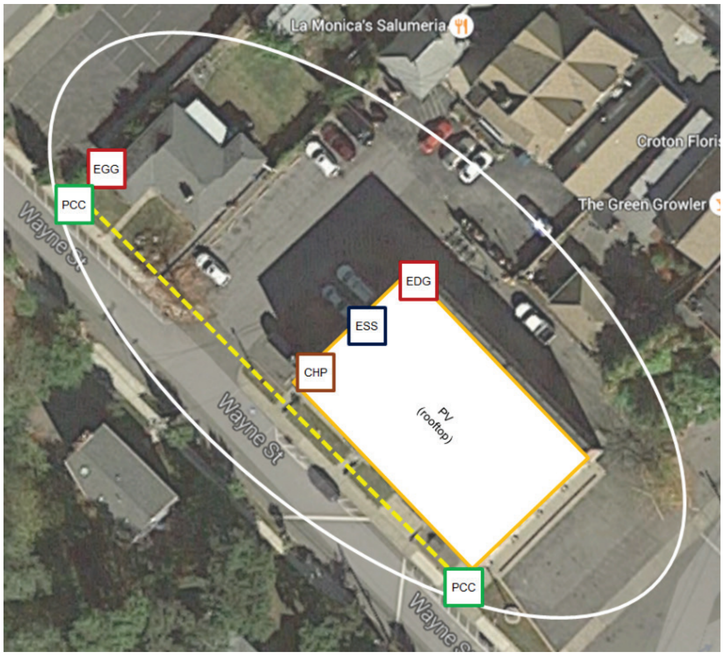
Node 5 includes two facilities. It includes two existing emergency diesel generators (350 kW each), and three PCCs, two near the high school and one near the middle school. The facilities will be connected via new underground lines.

As part of the microgrid, the following will be installed:

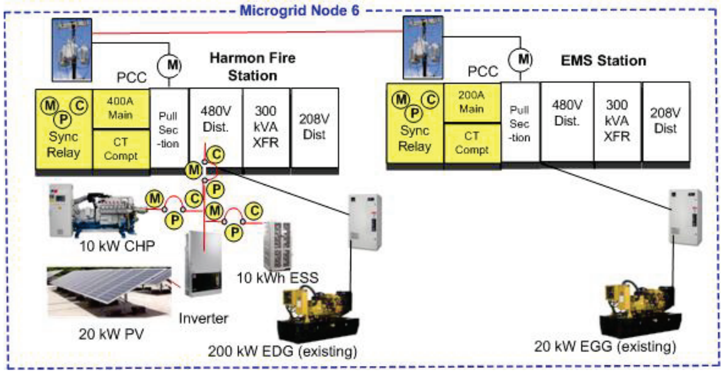
- **PV (150 kW):** A rooftop PV system will cover most of the Croton-Harmon High school.
- **PV (50 kW):** A rooftop PV system will cover one section of the Pierre Van Cortland Middle School.
- **CHP (130 kW):** A CHP unit will be placed in the parking lot of the Croton-Harmon High School.
- **CHP (100 kW):** A CHP unit will be placed in the parking lot of the Pierre Van Cortland Middle School.
- **ESS (30 kWh):** An ESS unit will be placed on the roof next to the PV system of the Croton-Harmon High School.
- **ESS (10 kWh):** An ESS unit will be placed on the roof next to the PV system.

Node 6 System Configuration

Geospatial Diagram



One-Line Diagram



Key Facilities

- Harmon Fire Station
- EMS Station

Description

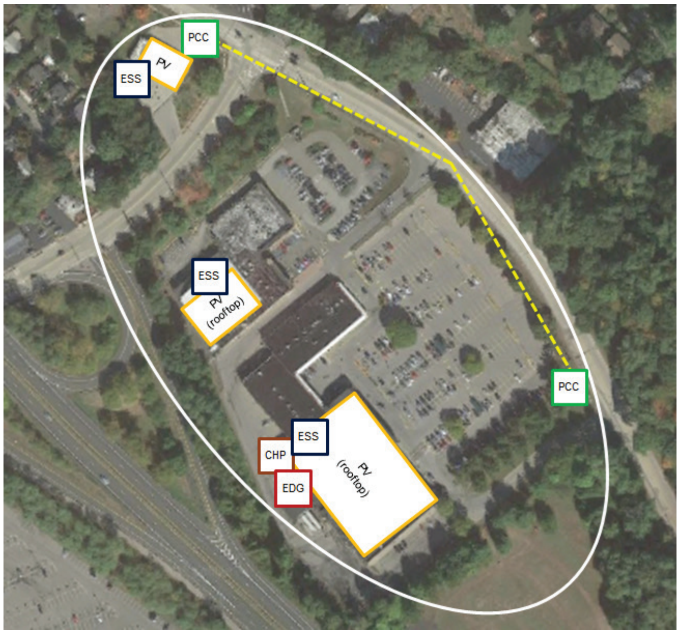
Node 6 includes two facilities; however, the EMS Station has a very small energy footprint. Therefore, the new microgrid resources will be installed at the Harmon Fire Station, which will then be connected to the EMS Station. There is currently one existing emergency diesel fuel backup generator (200 kW) at the Fire Station and a small propane backup generator (20 kW) at the EMS Station. Two PCCs will be located to the side of both buildings adjacent to Wayne St. that will be connected by a new underground line.

As part of the microgrid, the following will be installed:

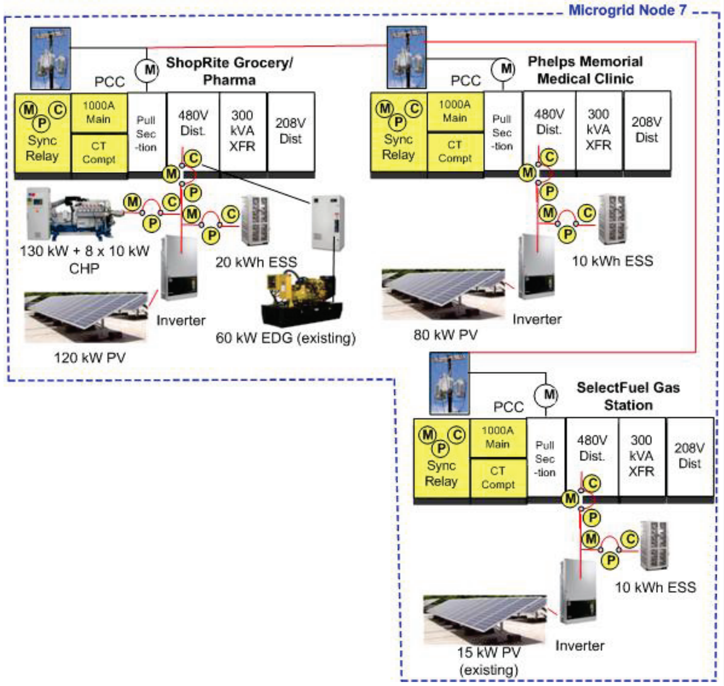
- **PV (20 kW):** A rooftop PV system will cover the entire roof of the Harmon Fire Station.
- **CHP (10 kW):** A small CHP unit will be placed on the roof of the Harmon Fire Station.
- **ESS (10 kWh):** An ESS unit will be placed on the roof next to the PV system at the Harmon Fire Station.

Node 7 System Configuration

Geospatial Diagram



One-Line Diagram



Key Facilities

- ShopRite Grocery / Pharmacy
- Phelps Memorial Medical Clinic
- Gulf Gas Station

Description

New underground lines will connect the two PCCs located along the S. Riverside Ave at the northwest and southeast end of the node. There is an existing emergency diesel generator (60 kW) at the ShopRite and an existing PV system (15 kW) at the gas station.

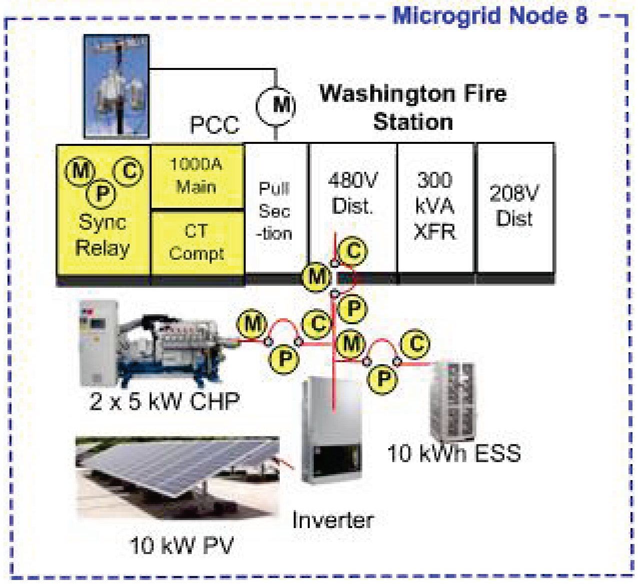
As part of the microgrid, the following will be installed (upon final approval from these commercial partners):

- **PV (120 kW):** A rooftop PV system will cover most of ShopRite.
- **PV (80 kW):** A rooftop PV system will cover most of the Medical Clinic.
- **CHP (210 kW):** A large CHP unit will be placed behind ShopRite.
- **ESS (20 kWh):** An ESS unit will be placed next to the CHP unit at ShopRite.
- **ESS (10 kWh):** An ESS unit will be placed next to the Medical Clinic.
- **ESS (10 kWh):** An ESS unit will be placed next to the PV system inverter at the Gas Station.

Node 8 System Configuration

Geospatial Diagram

One-Line Diagram



Key Facilities

- Washington Fire Station

Description

Node 8 is a single facility node. The PCC will be at the edge of the property.

As part of the microgrid, the following will be installed:

- **PV (10 W):** A rooftop PV system will cover half of the roof.
- **CHP (10 kW):** A small CHP unit will be placed on the roof. There is limited parking and property space for this unit on the ground.
- **ESS (10 kWh):** An ESS unit will be placed near the PV system inverter on the roof.

Modeling Methodology

The microgrid was modeled with HOMER Pro software. HOMER Pro is a microgrid software tool originally developed at the NREL and enhanced and distributed by HOMER Energy. HOMER nests three integrated tools in one software product, allowing microgrid design and economics to be evaluated concurrently. The key features of HOMER Pro are:

- **Simulation:**
  HOMER simulates the operation of a hybrid microgrid for an entire year, in time steps from one minute to one hour.
- **Optimization:**
  HOMER examines all possible combinations of system types in a single run, and then sorts the systems according to the optimization variable of choice.
- **Sensitivity Analysis:**
  HOMER allows the user to run models using hypothetical scenarios. The user cannot control all aspects of a system and cannot know the importance of a particular variable or option without running hundreds or thousands of simulations and comparing the results. HOMER makes it easy to compare thousands of possibilities in a single run.

Load Description

The microgrid design team modeled and optimized each of the eight nodes separately. Table 5 presents an overview of the annual energy operations of the microgrid by node. The microgrid will have a maximum demand of 2,090 kW and an average demand of 533 kW. The microgrid will deliver approximately 4,670,000 kWh per year. The thermal loads in the microgrid will be approximately 22,500,000 kBTU per year, of which approximately 8,500,000 kBTU will be recovered from the CHP systems and reused to support on-site thermal loads.

Table 5 –Microgrid Energy Overview: Grid Connected Operation

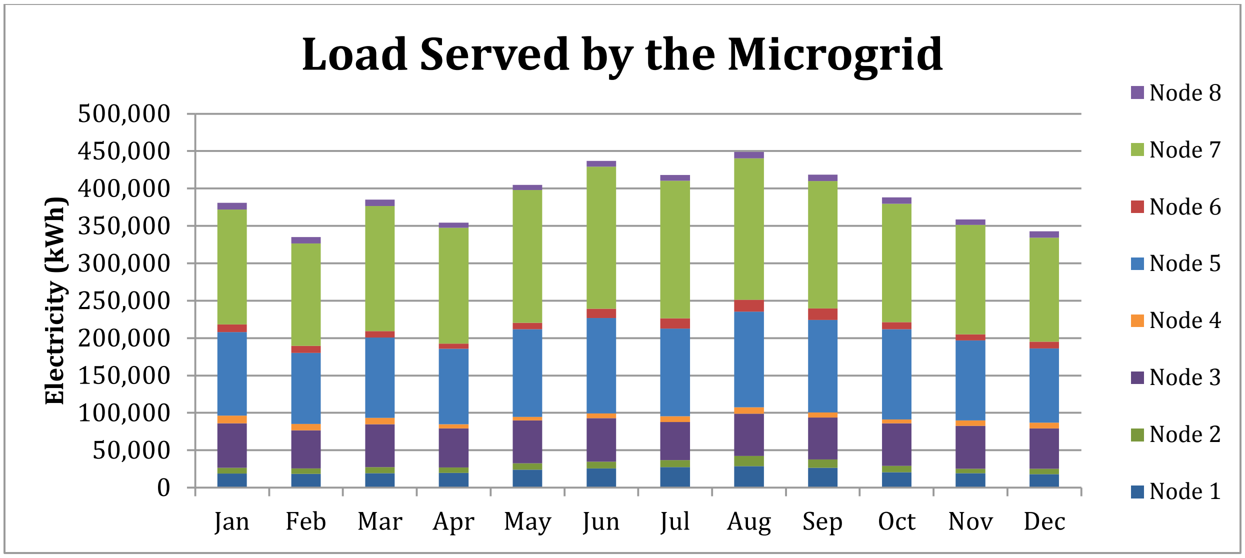
	Electric Demand		Electric Consumption		Thermal Load		Thermal Recovery	
Node	Max (kW)	Avg (kW)	kWh/year	kWh/month	kBTU/year	kBTU/month	kBTU/year	kBTU/month
1	126	30	266,901	22,242	1,398,064	116,505	608,100	50,675
2	73	12	104,727	8,727	530,479	44,207	99,209	8,267
3	254	76	666,731	55,561	5,792,913	482,743	1,079,487	89,957
4	42	10	87,319	7,277	732,871	61,073	137,244	11,437
5	620	155	1,356,397	113,033	8,842,167	736,847	2,669,165	222,430
6	80	14	126,127	10,511	732,871	61,073	164,436	13,703
7	860	225	1,967,349	163,946	4,470,702	372,558	3,745,253	312,104
8	35	11	96,306	8,026	19,341	1,612	19,336	1,611
Total	**2,090**	**533**	**4,671,858**	**389,321**	**22,519,408**	**1,876,617**	**8,522,230**	**710,186**

The monthly energy delivery by microgrid node is presented in Table 6 and presented graphically in Figure 6.

Table 6 –Monthly Grid Connected Operation by Node

Month	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Total
	(kWh)								
Jan	19,079	7,500	59,662	10,313	111,454	10,138	153,759	8,960	380,865
Feb	18,478	7,094	50,962	8,594	95,247	9,148	136,916	8,699	335,139
Mar	19,469	7,985	57,483	8,349	107,675	8,494	167,172	8,306	384,932
Apr	19,674	7,353	52,187	5,775	100,953	6,864	154,576	6,799	354,181
May	23,956	8,610	57,419	4,813	117,249	8,314	177,793	6,525	404,679
Jun	25,696	9,186	57,925	6,339	127,738	12,524	189,741	7,668	436,817
Jul	27,267	9,711	50,944	7,651	117,349	13,432	183,856	7,744	417,955
Aug	28,924	13,711	56,428	8,413	128,020	15,553	189,459	8,531	449,038
Sep	26,482	11,232	55,936	7,010	123,823	15,021	170,309	8,889	418,701
Oct	20,490	8,781	56,879	5,171	120,589	9,529	158,223	8,302	387,965
Nov	19,208	6,285	57,308	6,966	107,165	7,895	146,518	7,251	358,596
Dec	18,178	7,279	53,596	7,926	99,135	9,217	139,027	8,632	342,990
Total	**266,901**	**104,727**	**666,731**	**87,319**	**1,356,397**	**126,127**	**1,967,349**	**96,306**	**4,671,858**

Figure 6 - Monthly Grid Connected Operation by Node



The Croton microgrid is designed for a majority of the energy supply from on-site resources, with the remainder of the energy coming from the grid when the grid is operating. The microgrid treats the utility grid as an additional resource and incorporates it in the optimization of economics, emissions and reliability.

The reliability of the Croton Community Microgrid will be ensured with the following measures:

- The use of multiple, distributed, smaller unit sizes to help minimize generation loss and ensure that the microgrid can gracefully accommodate the failure
- The use of distributed energy storage systems that can accommodate short periods of high loading if the resource loss reason is known and quickly recoverable (15 minutes)
- Increasing the energy dispatch from the grid (in grid-connected mode - 99% of the time), to accommodate the loss of a resource until recovered
- The use of a combination of ESS and load modulation (up to 20% without curtailment) in island mode to accommodate the loss of a resource for a few hours. Beyond a few hours, non-critical loads will be shut down until the resource is recovered
- Much greater use of underground cabling and indoor infrastructure than is seen in the traditional utility grid.

These techniques are employed in the Croton Community Microgrid design so that equipment loss is mitigated or accommodated in the specific microgrid nodes for this community, under grid-connected and islanded modes of operation. Table 7 summarizes the microgrid resources in each node in terms of number of devices and the total installed capacity by technology.

Table 7 - Microgrid Resources Comparison

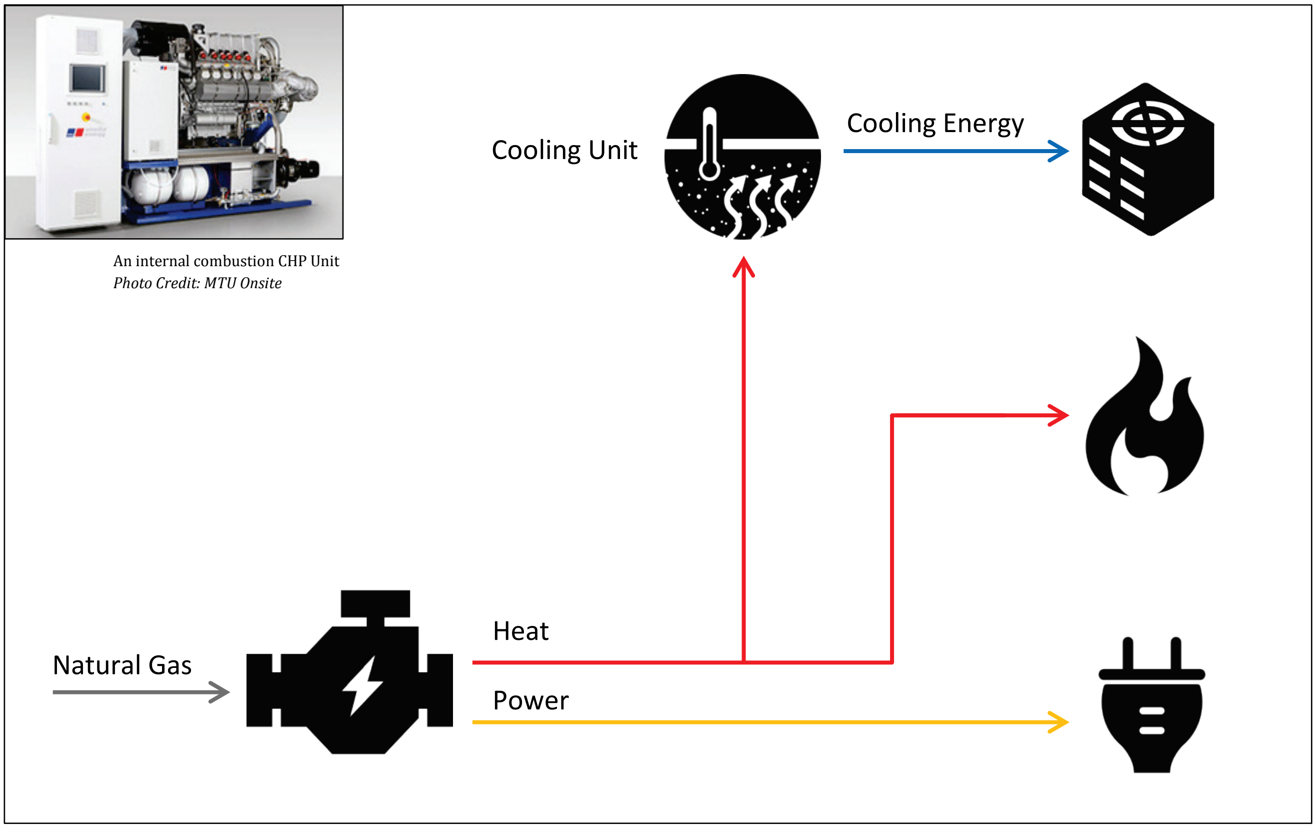
Node	Operation Scenario	Grid	PV		Battery Energy Storage		Natural Gas Engine or CHP		Backup Generators	
		Peak kW	# of Inverters	kW	Qty	kW / kWh	Qty	kW	Qty	kW
1	Business as Usual	126	-	-	-	-	-	-	1	200
	Microgrid	53	1	25	1	5/10	3	30	1	200
2	Business as Usual	73	-	-	-	-	-	-	-	-
	Microgrid	10	1	30	1	15/30	1	10	-	-
3	Business as Usual	254	-	-	-	-	-	-	1	200
	Microgrid	90	1	90	1	20/40	6	60	1	200
4	Business as Usual	42	1	5	-	-	-	-	1	125
	Microgrid	14	1	14	1	5/10	1	5	1	125
5	Business as Usual	620	-	-	-	-	-	-	2	700
	Microgrid	80	2	200	2	20/40	11	230	2	700
6	Business as Usual	80	-	-	-	-	-	-	2	220
	Microgrid	40	2	20	1	5/10	1	10	2	220
7	Business as Usual	860	1	15	-	-	-	-	1	60
	Microgrid	300	3	215	3	20/40	9	210	1	60
8	Business as Usual	35	-	-	-	-	-	-	-	-
	Microgrid	7	1	10	1	5/10	2	10	-	-

An overview of each technology, installation, operating strategy, and modeled operation are presented in this section.

CHP

CHP generators provide electrical and thermal energy from a single source. The use of fuel to generate both heat and power makes CHP systems more cost effective than traditional power generation. Most power generation produces heat as a byproduct, but because power is generated far from the end user, the heat is lost. CHP units take advantage of the fact that they are collocated with the end user and make use of thermal energy for heating and sometimes even cooling nearby buildings. For this microgrid application, internal combustion engine based CHP systems have been modeled. Internal combustion engines, also called reciprocating engines, use a reciprocating motion to move pistons inside cylinders that turn a shaft and produce power. Internal combustion engines typically range between 5 kW-7 MW and are best suited for load-following applications. An image of an internal combustion engine generator is presented in Figure 7.

Figure 7 – CHP System Overview



An internal combustion CHP Unit
Photo Credit: MTU Onsite

Benefits of CHP

- Reduces utility costs and improves economic competitiveness
- Increases power reliability and self-sufficiency
- Reduces GHG emissions and other pollutants

- Reduces demand for imported energy supplies
- Capable of operating on renewable or nonrenewable resources
- Suite of proven, commercially available technologies for various applications
- Additional financial incentives may be available through NYSERDA, and investment tax credits available are available for eligible customers

CHP Approach

- Co-locate generators near thermal loads on the customer-side of the meter
- Design for base load operation of ~8,500 hrs/yr, and to maximize heat recovery when grid connected
- Support microgrid operations when the electric grid is not available along with PV, energy storage, and building load control
- Design to serve specific winter Heat Recovery Loads, such as a boiler plant, space heating, DHW, and pool heating
- Design to serve specific summer Heat Recovery Loads, including space cooling, DHW, and pool heating

CHP in the Microgrid

The size and location of the planned CHP units is presented in the layout diagram and single-line diagram presented in the Appendix. Table 8 summarizes the CHP components by node of the microgrid.

Table 8 - Microgrid CHP Resources by Node

Node	Natural Gas Engine or CHP	
	Qty	**Total kW**
1	3	30
2	1	10
3	6	60
4	1	5
5	11	230
6	1	10
7	9	210
8	2	10
Total	**34**	**565**

The following tables and figures summarize the annual operation of the CHP fleet in the Croton microgrid on a monthly basis for each node.

Table 9 - Microgrid CHP Electric Production by Node

Month	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Total
	Electric Production (kWh)								
Jan	14,397	4,192	34,698	3,701	86,856	6,503	116,335	6,920	273,602
Feb	13,865	3,630	31,116	3,333	69,960	5,727	103,870	6,306	237,807
Mar	13,505	3,604	30,715	3,611	73,869	5,171	116,169	6,795	253,439
Apr	13,668	3,547	29,416	3,361	70,069	4,108	113,772	6,200	244,140
May	14,174	4,076	30,759	3,206	79,926	5,089	118,087	6,317	261,634
Jun	15,265	4,346	31,066	3,427	89,089	6,636	114,932	6,393	271,155
Jul	15,801	4,729	30,120	3,631	83,728	6,953	119,425	6,554	270,941
Aug	15,998	6,821	31,903	3,651	92,764	7,157	120,030	6,832	285,156
Sep	15,381	5,910	30,331	3,491	87,998	6,927	113,982	6,774	270,795
Oct	14,391	4,472	30,591	3,306	85,909	6,106	117,371	6,886	269,033
Nov	13,728	3,462	35,486	3,489	80,235	5,632	113,303	6,523	261,858
Dec	13,869	4,167	33,350	3,669	74,255	6,350	113,097	6,877	255,635
Total	**174,041**	**52,956**	**379,551**	**41,876**	**974,660**	**72,360**	**1,380,374**	**79,377**	**3,155,195**

Figure 8 – Microgrid CHP Electric Production

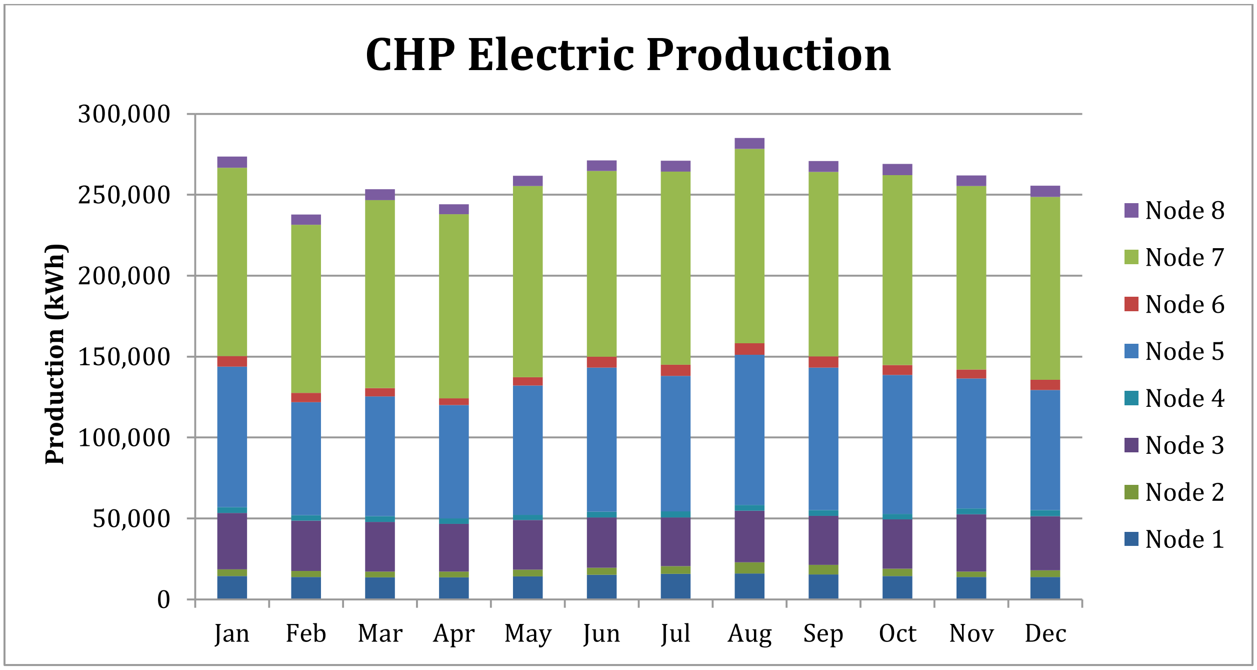


Table 10 – Microgrid CHP Heat Recovery by Node

Month	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Total
	Heat Recovery (kBTU)								
Jan	50,789	14,913	123,428	16,392	367,823	23,131	515,032	2,119	1,113,626
Feb	47,947	12,911	110,685	14,762	297,399	20,373	466,054	1,709	971,840
Mar	48,036	12,819	109,258	15,994	319,064	18,395	493,654	1,965	1,019,185
Apr	48,616	12,619	104,636	14,885	302,491	14,611	343,806	1,515	843,179
May	49,884	12,875	94,381	14,100	183,376	18,014	269,783	1,552	643,964
Jun	52,092	2,509	32,085	14,615	53,659	17,238	217,478	1,201	390,877
Jul	53,241	696	28,765	5,033	53,677	5,027	139,216	1,310	286,965
Aug	54,610	790	34,182	4,005	57,146	3,998	147,168	1,546	303,446
Sep	53,858	817	94,885	3,675	190,205	3,673	165,265	1,170	513,548
Oct	51,016	1,343	102,322	6,360	183,603	6,195	178,912	1,634	531,384
Nov	48,741	12,094	126,228	11,180	338,815	11,213	330,256	1,563	880,090
Dec	49,271	14,823	118,633	16,243	321,908	22,568	478,629	2,051	1,024,125
Total	**608,100**	**99,209**	**1,079,487**	**137,244**	**2,669,165**	**164,436**	**3,745,253**	**19,336**	**8,522,230**

Figure 9 – Microgrid CHP Heat Recovery

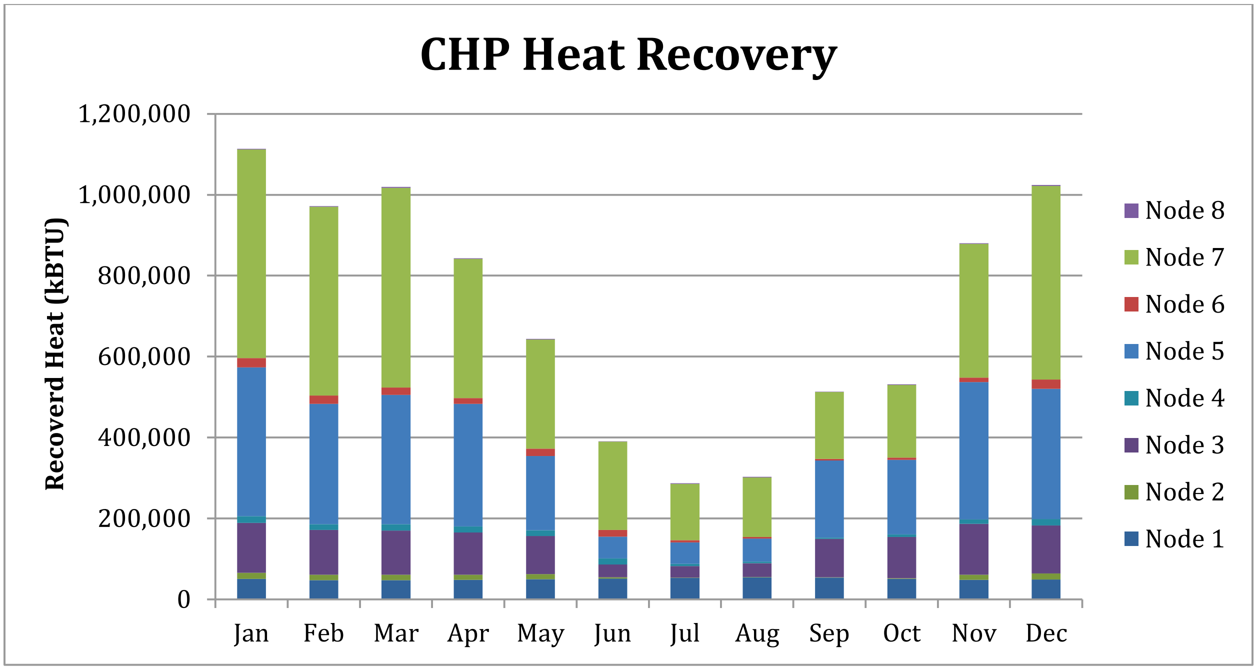
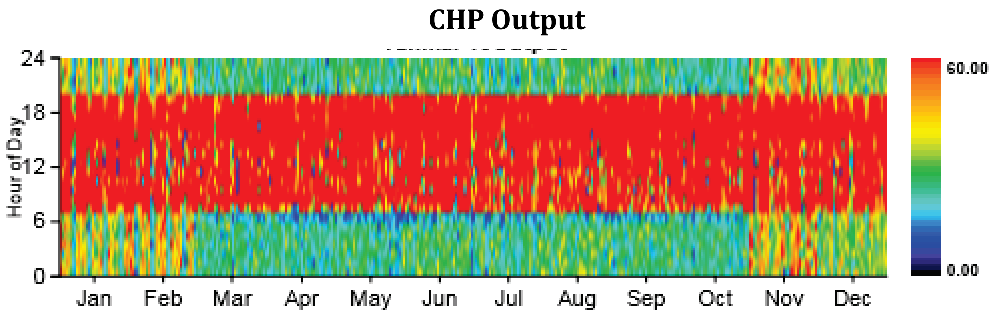


Figure 10 presents the hourly operation of the CHP in Node 3 in the form of a heat map. This representation demonstrates that the CHP unit is operating near full capacity for a majority of hours (red), then does some electric load following during the other hours (orange). There are a few hours where the unit is operating at approximately 50% capacity(green).

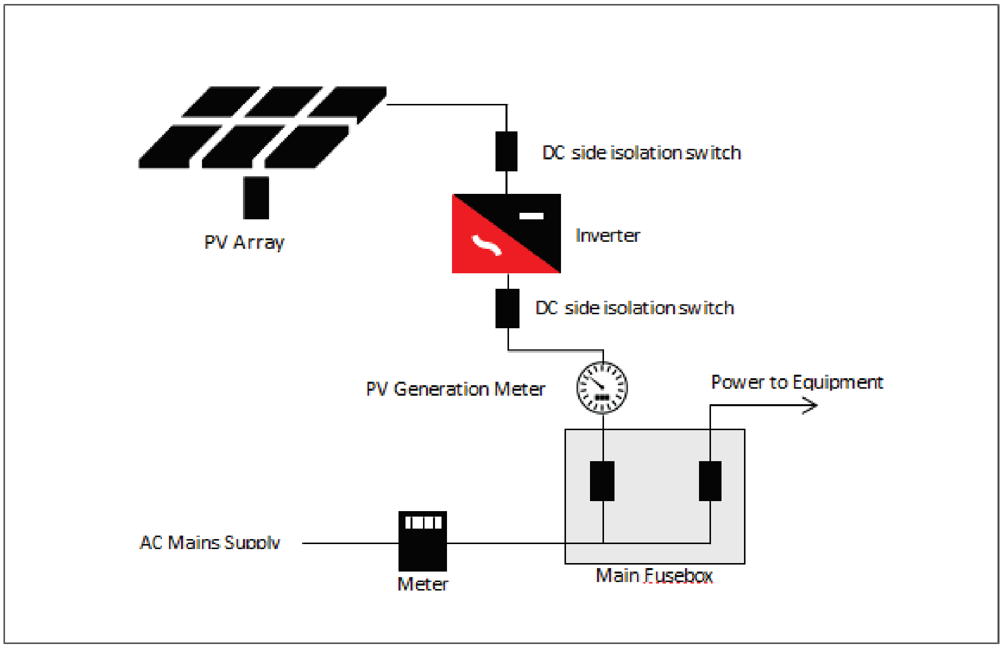
Figure 10 – Sample Node CHP Operational Summary



Solar Photovoltaics

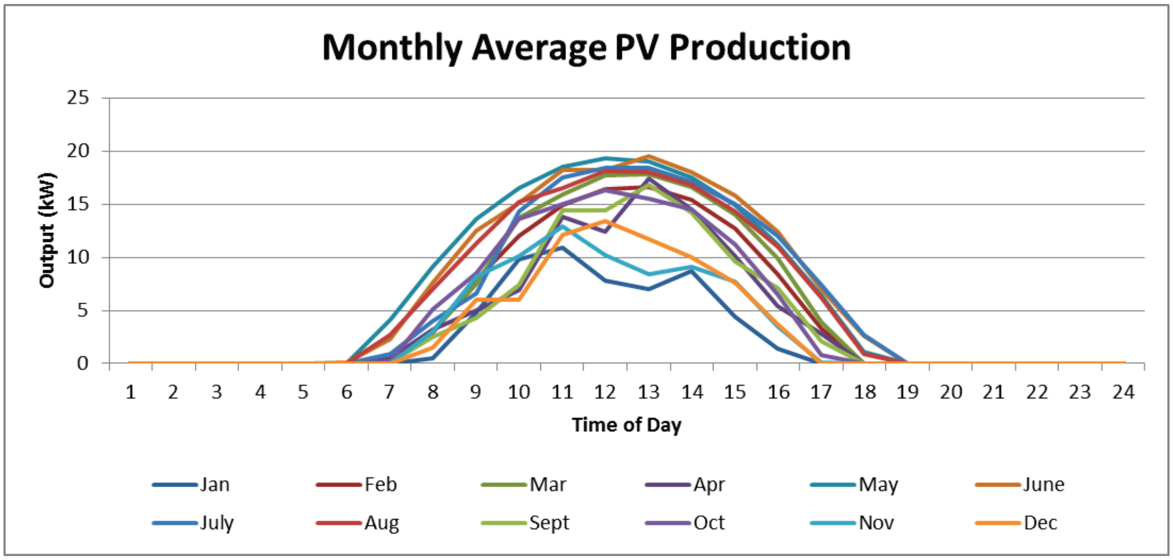
The solar PV will be rooftop, parking lot, or ground mounted using hail-rated solar panels. PV devices generate electricity directly from sunlight via an electronic process that occurs naturally in certain types of material, called semiconductors. Electrons in these materials are freed by photons and can be induced to travel through an electrical circuit, resulting in the flow of electrons to create energy in the form of direct current. The direct current is transformed into usable alternating current through the use of an inverter. A typical customer-side of the meter PV installation is presented in Figure 11.

Figure 11 – PV Installation Diagram (Customer Side of Meter)



Since the PV systems are driven by sunlight, the electric production profile varies with the position of the sun and is impacted by the level of cloud cover. Figure 12 presents the typical average daily PV generation profiles by month and demonstrates the seasonal variation of PV as a generation resource. The HOMER model takes this variability into account when simulating and optimizing the sizing of PV as a microgrid resource.

Figure 12 – Typical PV Daily Generation Profiles



PV systems are planned for rooftops, parking spaces, and ground-mount configurations. Figure 13 presents examples of each these types of installations

Figure 13 – PV Installation Options.

Benefits of PV

- Reduces utility costs and improves economic competitiveness
- Increases power reliability and self-sufficiency
- Reduces GHG emissions and other pollutants
- Reduces demand for imported energy supplies
- Fueled by a renewable resource
- Based on a suite of proven, commercially available technologies for a variety of applications
- Competitive market for hardware and installation services

PV Approach

- Co-locate PV systems on the customer-side of the meter to support resiliency
- Install on roofs, ground mount and covered parking
- Provide renewable energy resource (reduce site emissions and no fuel cost)
- Support day-time load requirements and annual energy loads (grid connected operation)
- Support microgrid operations when the electric grid is not available along with CHP, energy storage, and building load control

PV in the Microgrid

The size and locations of the planned PV systems is presented in the layout diagram and single-line diagram in the Appendix. Table 11 summarizes the PV components by node of the microgrid.

Table 11 - Microgrid PV Resources by Node

Node	PV	
	# of Inverters	Total kW
1	1	25
2	1	30
3	1	90
4	1	14
5	2	200
6	2	20
7	3	215
8	1	10
Total	**12**	**604**

The table and figures below present the monthly operation of the PV fleet by node.

Table 12 – Microgrid PV Fleet Electric Production

Month	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Total
Electric Production (kWh)									
Jan	2,200	2,640	7,919	1,232	17,598	1,760	18,918	880	53,147
Feb	2,445	2,934	8,803	1,369	19,561	1,956	21,028	978	59,075
Mar	3,408	4,090	12,269	1,908	27,264	2,726	29,309	1,363	82,336
Apr	3,071	3,686	11,057	1,720	24,570	2,457	26,413	1,229	74,202
May	3,260	3,912	11,736	1,826	26,081	2,608	28,037	1,304	78,764
Jun	3,107	3,728	11,185	1,740	24,856	2,486	26,720	1,243	75,066
Jul	3,108	3,729	11,188	1,740	24,862	2,486	26,727	1,243	75,084
Aug	3,050	3,660	10,979	1,708	24,398	2,440	26,227	1,220	73,681
Sep	3,002	3,602	10,805	1,681	24,012	2,401	25,813	1,201	72,517
Oct	2,783	3,339	10,018	1,558	22,262	2,226	23,932	1,113	67,232
Nov	2,138	2,565	7,696	1,197	17,102	1,710	18,385	855	51,648
Dec	2,007	2,409	7,226	1,124	16,058	1,606	17,262	803	48,495
Total	**33,604**	**40,294**	**120,881**	**18,804**	**268,625**	**26,862**	**288,771**	**13,432**	**811,273**

Figure 14 – Microgrid PV Fleet Electric Production

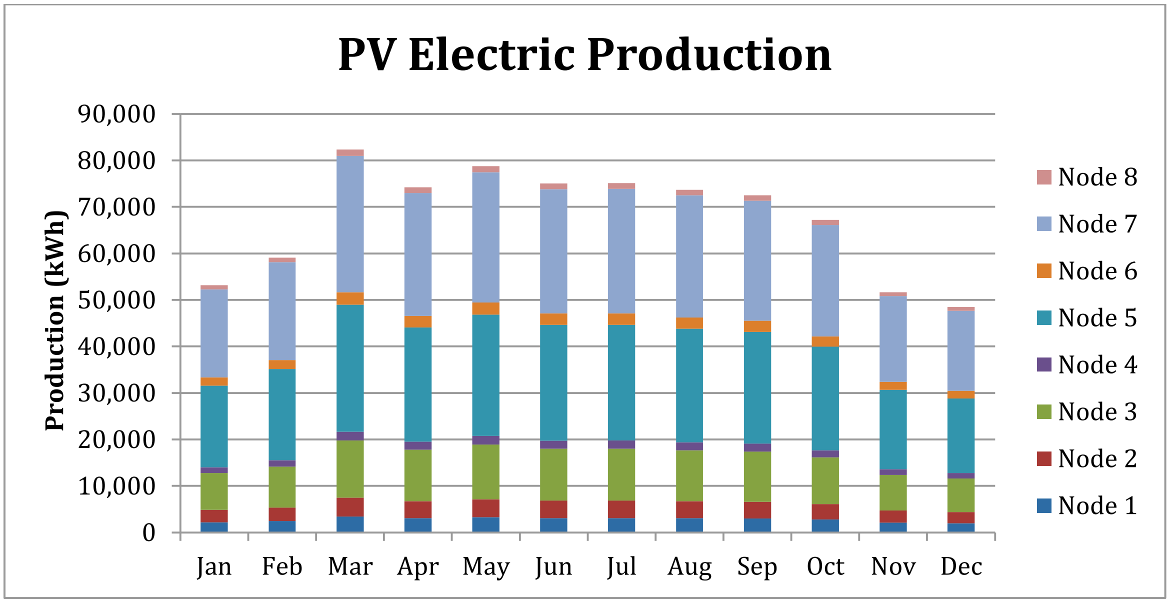
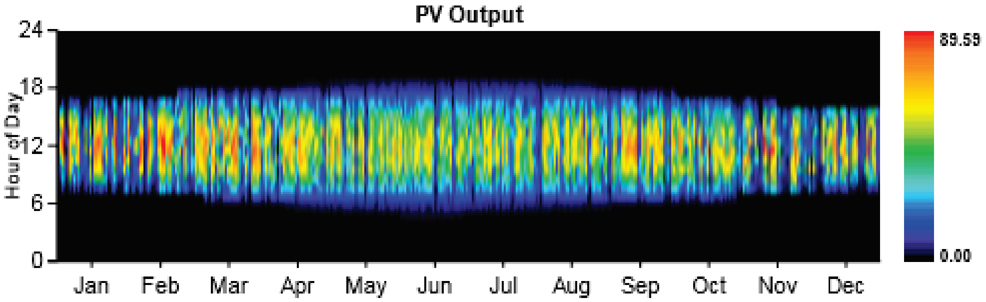


Figure 15 presents the hourly operation of the PV in Node 3 in the form of a heat map. This representation demonstrates how the PV units operate during hours of sunshine with maximum production in the middle of the day, ramping up in the mornings and ramping down in the afternoon hours. This also illustrates the trend of narrower daily bands of production in the winter and then expansion to maximum production in the summer.

Figure 15 – Sample Node PV Operational Summary



Energy Storage Systems

Energy storage in a microgrid can improve the payback period for the whole system by enabling an increase in the penetration of renewable energy sources, shifting the energy produced by PV, enabling peak load management, managing PV intermittency, providing volt/VAr support, and supporting island mode transitions. The technology specified for the Croton microgrid is Li-ion batteries, which have a fast reaction response to changes in load, a fairly small footprint, and a relatively high round trip efficiency. Li-ion batteries have some unique operational characteristics:

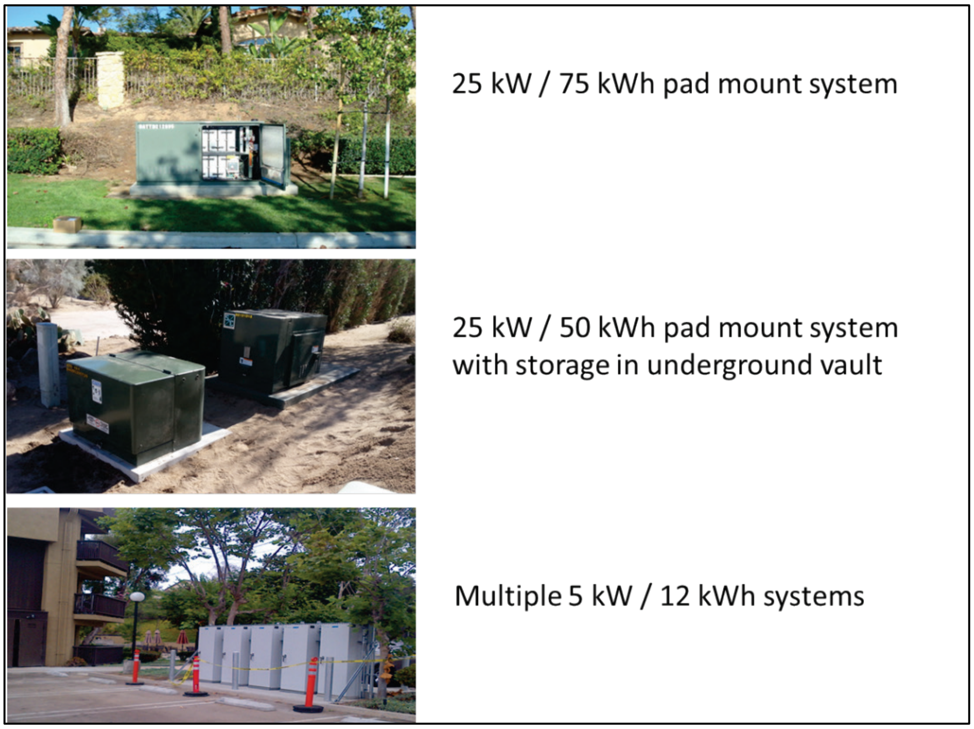
- The usable energy capacity is between a 15% and 95% state of charge (SOC)
- The life of the batteries are impacted by temperature and charge rate
- Most systems are capable of approximately 3,000 deep discharge cycles (+/- 80% SOC cycles)
- Most systems are capable of more than 100,000 shallow discharge cycles (+/- 15% SOC cycles)
- The batteries are at a high risk of failure if the system is discharged to a zero percent sate of charge
- The systems typically have different rates (kW) for charge and discharge
- Most Li-ion systems have accurate methods of determining the system SOC
- Typical power electronic systems provide multiple modes of operation
- Systems are typically capable of four quadrant operation

Benefits of Energy Storage

- Reduces utility costs and improves economic competitiveness
- Increases power reliability and self-sufficiency
- Reduces GHG emissions and other pollutants
- Reduces demand for imported energy supplies
- Supports system with a high level of renewable energy penetration
- Based on a suite of proven, commercially available technologies for a variety of applications
- Competitive market for hardware and installation services
- Provides multiple functions and benefits to the microgrid:
  - Peak Load Management
  - Load Shifting
  - Frequency Regulation
  - Reactive Power Support
  - PV Support
  - Demand Response
  - Energy Arbitrage
  - Backup Power

Figure 16 presents examples of energy storage installations for the technologies addressed for this microgrid design.

Figure 16 – Example ESS Installations



25 kW / 75 kWh pad mount system

25 kW / 50 kWh pad mount system with storage in underground vault

Multiple 5 kW / 12 kWh systems

Energy Storage Approach

- Co-locate with PV systems on the customer-side of the meter to support resiliency
- Install indoors or outdoors (indoor installation better for resiliency)
- Maximize functional benefits for the microgrid
- Support microgrid operations when the electric grid is not available along with CHP, PV, and building load control

ESS in the Microgrid

The size and location of the planned ESS systems is presented in the layout diagram and single-line diagram presented in the Appendix. Table 13 summarizes the ESS components by node of the microgrid.

Table 13 - Microgrid ESS Resources by Node

Node	Battery Energy Storage		
	Qty	kW	kWh
1	1	5	10
2	1	15	30
3	1	20	40
4	1	5	10
5	2	20	40
6	1	5	10
7	3	20	40
8	1	5	10
Total	**11**	**95**	**190**

Unlike the other microgrid resources, the ESS both consumes and produces energy. When properly used, the net energy consumed is very small. The annual operation of the ESS in Node 3 is presented in Table 14, which shows both the charge and discharge modes of operation. The net value is positive which takes into account the operational losses for the systems.

Table 14 – Microgrid ESS Operation Sample Node

Month	Charge	Discharge	Net
	(kWh)		
Jan	5,805	4,488	1,318
Feb	2,569	2,368	201
Mar	6,728	6,139	589
Apr	10,110	9,434	676
May	12,008	11,210	798
Jun	11,767	11,034	732
Jul	8,751	7,660	1,091
Aug	11,947	11,278	669
Sep	12,582	11,388	1,194
Oct	12,604	12,128	477
Nov	9,174	8,510	664
Dec	11,526	10,479	1,046
Total	**115,573**	**106,117**	**9,456**

Figure 17 – Microgrid ESS Operation

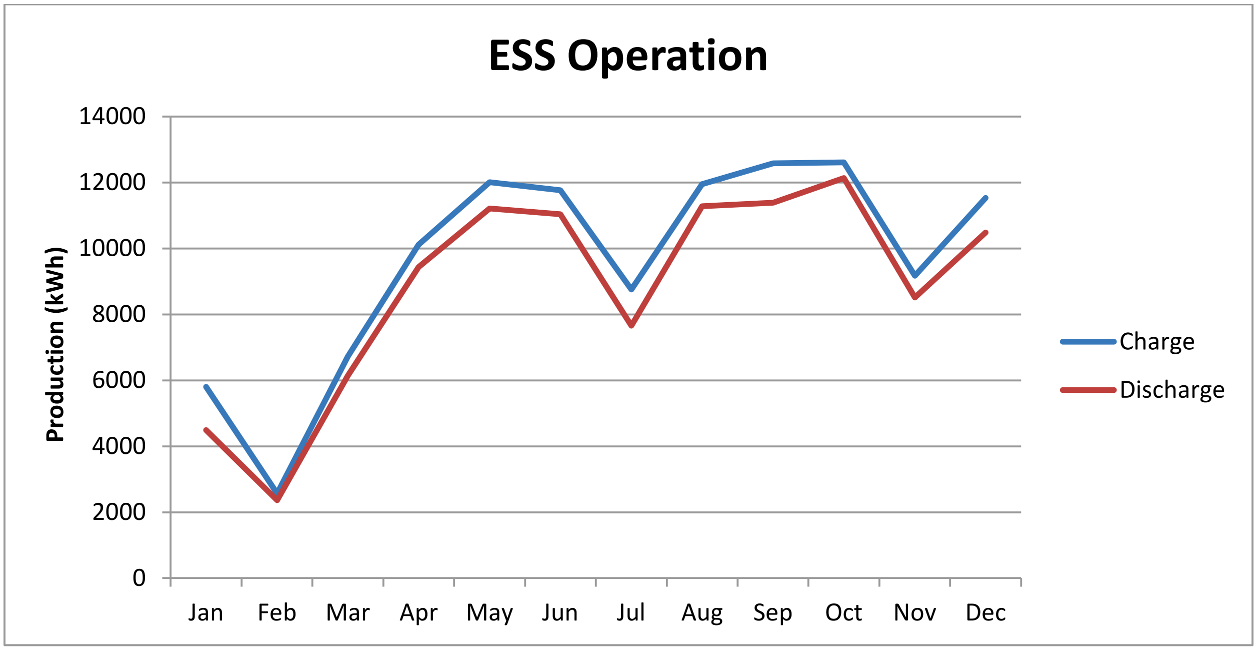
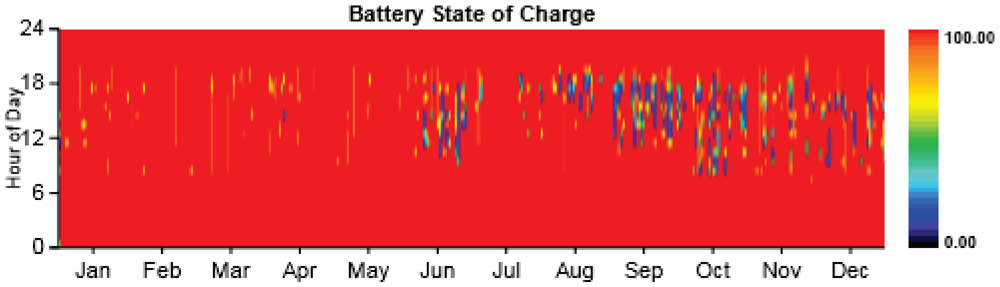


Figure 18 presents the hourly operation of the ESS in node 3 in the form of a heat map. This representation demonstrates how the ESS units operate. Typically, the units are charged to a high SOC in the middle of the day. The operations represent PV intermittency support, PV load shifting, peak shaving (to manage utility imports), and supporting CHP loading.

Figure 18 – Sample Node ESS Operational Summary



Island Mode Modeling Results

The resources included in the Croton Community Microgrid have been sized and operated to support island operation for a minimum period of seven days, with multi-week operation likely. During island mode operation, the microgrid control system will maintain system stability and ensure a balance of generation and load. The controller will forecast critical load and PV generation and then dispatch resources to match the load. We anticipate that the resources available to be controlled during island operations will include CHP, fossil fuel generators, PV systems, energy storage, and building load. We also expect that the utility will be able to provide an estimated time to restoration. This estimate will be used to help determine the remaining duration of island operation required, and will influence the dispatch of microgrid resources.

The design strategy for the Croton Community Microgrid is to supply the critical load at a level that enables the critical services that keep the community functioning at a sufficient level throughout the entire event duration. This provides full functionality for police, fire, and emergency services while also providing some level of heat and power to other facilities and residents. Each node was modeled for operation during an extended outage (one week) to evaluate and optimize microgrid resources operating in island mode. Two outage events were modeled to represent an outage during the winter and an outage during the summer. Energy flows during the outages are presented as weekly averages in Table 15.

Table 15 –Microgrid Energy Overview: Island Mode Operation

Node	Season	Electric Demand		Electric Consumption	Thermal Load	Thermal Recovery
		Max (kW)	Avg (kW)	kWh/week	kBTU/week	kBTU/week
1	Winter	65	27	4,555	37,116	13,675
	Summer	68	29	4,915	24,123	13,736
2	Winter	58	11	1,870	27,023	4,252
	Summer	32	14	2,327	177	177
3	Winter	209	94	15,711	364,223	38,470
	Summer	157	75	12,584	7,194	7,179
4	Winter	30	14	2,322	876,847	8,506
	Summer	23	11	1,925	10,826	1,277
5	Winter	437	174	29,241	480,214	95,738
	Summer	399	168	28,170	13,835	13,795
6	Winter	38	16	2,668	32,223	3,203
	Summer	44	20	3,384	1,278	904
7	Winter	538	222	37,259	187,721	136,511
	Summer	578	216	36,255	34,881	34,879
8	Winter	25	13	2,105	559	559
	Summer	21	11	1,931	369	369
Total	**Winter**	**1,400**	**570**	**95,730**	**2,005,927**	**300,914**
	Summer	**1,322**	**545**	**91,491**	**92,683**	**72,317**

Microgrid DERs Resiliency

An assessment was conducted to evaluate the resiliency risk profile for various forces of nature related to the microgrid design. This profile was evaluated in the following areas, with the associated design emphasis results:

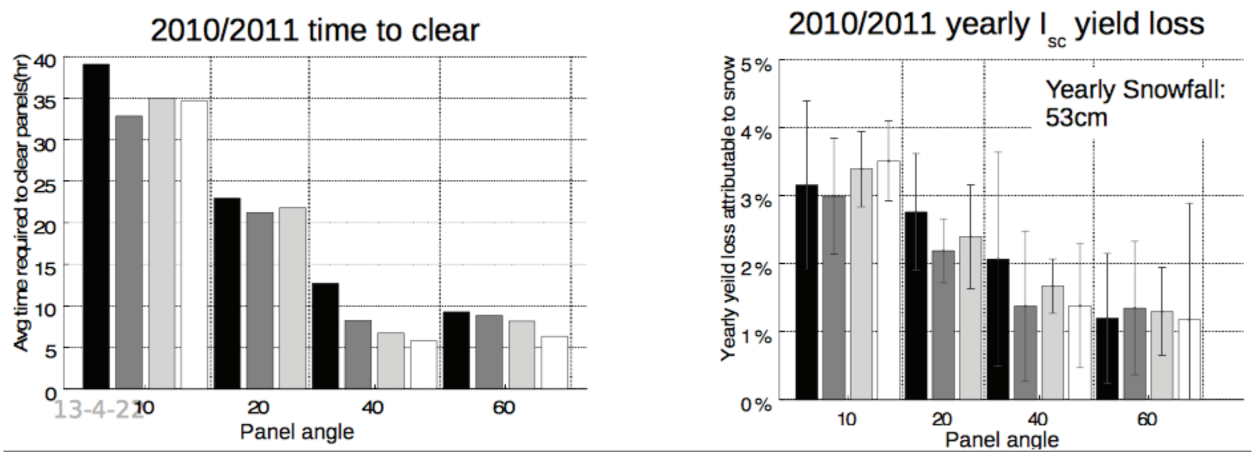
1. Wind / Tornado – the design of the DER structures (base foundations, enclosures, and connections) for distributed generators, fuel cells, CHP, outdoor energy storage, solar PV panels (hail rated) and racking, and electrical and thermal distribution equipment will withstand Category F2 wind speeds for this area. Installation of energy storage systems will be inside interior building electrical or mechanical rooms wherever possible.
2. Rain / Flooding / Hurricane – the design of the structures (base foundations, enclosures, and connections) for distributed generators, fuel cells, CHP, outdoor energy storage, solar PV panels (hail rated) and racking, and electrical and thermal distribution equipment will withstand Category 4 Hurricane (Staffer-Simpson scale, same maximum wind speed as the Category F2 tornado on the Fujita scale). In addition, the height of the base foundation for outdoor units is designed to assure the equipment is 1 to 1.5 feet above the 100-year flood plain level.

Installation of energy storage systems will be inside interior building electrical or mechanical rooms wherever possible.

3. Earthquake – the design of the structures (base foundations, enclosures, and connections) for distributed generators, fuel cells, CHP, outdoor energy storage, solar PV panels (hail rated) and racking, and electrical distribution equipment will withstand seismic event magnitude 6.9 (Richter scale), or 100-year local seismic event, whichever is lesser. Due consideration is given to the design to overhead risk from buildings and other structures located above the microgrid equipment.
4. Extreme Heat – the design the structures (base foundations, enclosures, and connections) for distributed generators, fuel cells, CHP, outdoor energy storage, solar PV panels (hail rated) and racking, and electrical distribution equipment will withstand 125°F (50°C) continuous operating temperatures. Where equipment enclosure temperatures are expected to exceed these temperatures for more than 10 minutes, space cooling is added.
5. Cold / Ice – the design of the structures (base foundations, enclosures, and connections) for distributed generators, fuel cells, CHP, outdoor energy storage, solar PV panels (hail rated) and racking, and electrical distribution equipment will withstand 15°F (-24°C) continuous operating temperatures. Where equipment enclosure temperatures are expected to exceed these temperatures for more than 10 minutes, space heating is added. Enclosure design includes mitigation of ice formations that block airflow.

While deep snow on PV arrays can affect production, the typical effects are not as severe as one might guess. The performance criteria for snow cover on PV panels are based on annual loss of energy generation. A study published at Sandia National Laboratory, conducted by Queens University and Calama Consulting in Canada, on a set of PV arrays totaling 8 MW in Kingston, Ontario, Canada using 2010-2012 data shows that snow affects about 1 to 3% annual production loss – similar to the annual production loss from sand and dust in San Diego, California.

Figure 19 – PV Impedance from Snowfall



The first graph shows the time required to clear the snow. The second graph shows the yield loss rate for having the snow in place for the duration of the first graph. Both are based on panel angle.

Reliability of Fuel Sources

Microgrid installations of natural-gas-fired generation systems at multiple locations provide opportunities to improve the quality and reliability of gas distribution that will benefit a wide range of customers throughout Croton.

The natural gas network is considered an uninterruptable fuel supply for the community in the face of major storms because:

(1) there are multiple network sources of natural gas

(2) the actual natural gas network load decreases in a major storm because the non-critical loads are not operating

(3) there is no history of loss of service in past major storms

In addition, interruptible service is a financial construct, not a technical limitation. Home heating is considered the highest priority for continuity of supply in the face of challenges to the natural gas network. Since this microgrid will use natural gas for CHP (heating of critical facilities), it will be given the highest priority for continuity of supply in the face of a major storm.

The operation of the microgrid will minimize the use of existing emergency diesel generators, and extend the typical three-day onsite fuel load for the emergency diesel generators to one week.

FINANCIAL FEASIBILITY

The outputs of the technical modeling process described above were used to evaluate the financial viability of the proposed microgrid from two perspectives. First, the project team analyzed the financial strength of the project when deployed using the proposed third-party ownership business model. Under this model, the project is funded through outside investment and debt which is recouped through a power purchase agreement (PPA) with each facility. In addition, NYSERDA contracted with Industrial Economics, Incorporated (IEc) to perform a benefit-cost analysis. The focus of this analysis is to evaluate the societal benefit of the microgrid, including benefits from emissions reductions, cost reductions, and resilience improvements.

Installed Cost

At this feasibility stage of the project, a high-level project budget for the Croton Community Microgrid project was developed and incorporated into the technical model to ensure that the design meets both the technical and economic requirements of the project. This budget includes costs for engineering, permitting, capital equipment, site preparation, construction, controls, start-up, commissioning, and training. The cost associated with “site preparation” includes the addition and modification of electrical infrastructure, PCC controls, monitoring, and protection equipment. Some of these infrastructure costs may be paid to the electric utility. The estimated installed cost for this project is $4,383,000 with an accuracy of +/- 25% (within the +/- 30% set by NYSERDA). The net cost with the federal investment tax credit (ITC) that was recently extended by the US Congress is $3,536,000. This cost does not include incentives that may be applicable to the project. The plan is to take advantage of all applicable incentives for the project.

The project team evaluated several available financial incentives when performing the financial analysis for the Croton Community Microgrid. The following programs[1] were evaluated:

- **Demand Response**: Con Edison's demand response programs pay customers who are able to temporarily reduce electric usage when requested. This capability will be improved by the existence of the microgrid.
- **Sales Tax Exemption**: Solar photovoltaic systems are 100% free from state and local taxes.
- **Business Energy Investment Tax Credit:** The ITC includes a 30% tax credit for solar or fuel cell systems on residential and commercial properties and 10% tax credit for CHP systems. In December, the ITC was extended for three years, with a ramp-down through 2022.
- **NYSERDA Incentives**: There are many incentive programs available from NYSERDA that are likely apply to the Croton Community Microgrid, including programs that support sub-metering, energy efficiency, and various distributed and clean energy resources. The details of these programs are likely to change by the time the Croton project is ready to take advantage of them, which is why no specifics are included here.
- **NY SUN initiative:** This program provides rebates and performance incentives for new residential and commercial solar PV installations.
- **New York Power Authority – Energy Services Program for Public Utilities**: This program provides various rebates on energy efficient equipment.
- **Federal Energy-Efficient Commercial Buildings Tax Deduction**: This deduction provides $0.30-$1.80 per square foot, depending on technology and amount of energy reduction for buildings that become certified as meeting specific energy reduction targets as a result of improvements in interior lighting; building envelope; or heating, cooling, ventilation, or hot water systems.
- **Con Edison (Gas) - Commercial and Industrial Energy Efficiency Program**: This program provides 50% of the cost of energy efficiency studies and various rebates for gas-saving efficiency measures.

Third Party Ownership

Under the proposed business model, a third party would fund all development and construction of the microgrid, own and operate the assets, and sell the energy generated from the microgrid to community customers through PPAs.

The SPE will engage the design team to finalize the construction drawings and utility interconnection agreements. The SPE will engage an engineering, procurement, and construction firm to build the

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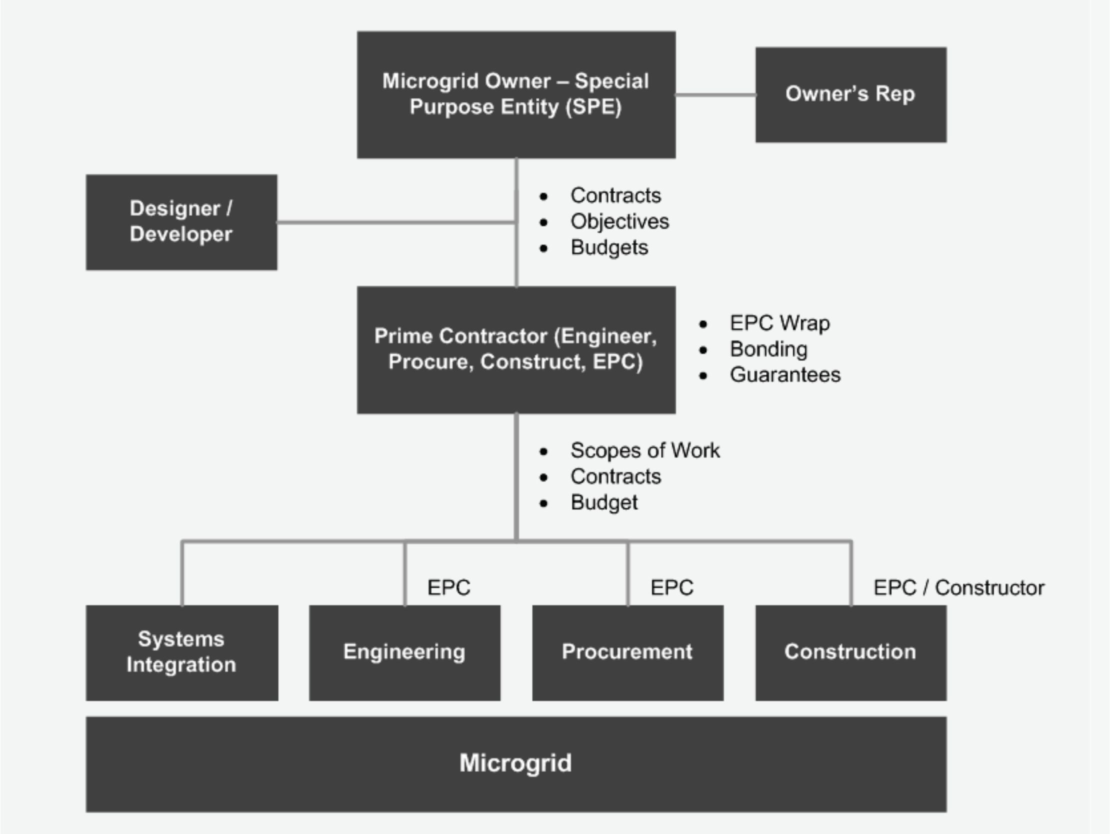
[1] Identified from the DSIRE database as of December 2015.
http://programs.dsireusa.org/system/program?state=NY

microgrid, and will be financially responsible for all engineering, procurement, and construction for the system. The SPE will also be financially responsible integrating the controls and communications systems. This process is presented in the Figure 20 below.

Figure 20: Microgrid Development Relationships



To ensure proper operation of individual microgrid resources, an energy performance contractor (selected through a partnership or solicitation, and hired by the SPE) will conduct site acceptance tests that validate the operation and performance of the new equipment. Once the system construction and integration are complete, the SPE will engage a third party commissioning agent that will test the microgrid as a system to ensure that the controls, communication and sequence of operation function to meet the requirements as defined in the specified use cases and the final design. After the fully commissioned system is accepted and transferred to the SPE, the SPE will own and operate the microgrid for a period of 25 years. If selected for Stage 2, the team would evaluate how shorter PPA periods would affect the per-kWh price and discuss those options with potential system participants.

The operation of the microgrid will leverage the autonomous functionality of the microgrid controller, and minimize the need for on site operators. The controller will operate the microgrid to maximize economic benefits, minimize emissions, and maximize reliability of service in the event of a fault on the grid. In addition, the microgrid controller will monitor the performance, operation and alarms of the distributed resources. In the event of an alarm, the SPE will be notified through the network operations center, and dispatch a service technician who will be engaged through a service contract. The microgrid controller will also track the hours of operation of each microgrid resource, and will employ a predictive maintenance strategy to schedule maintenance before any failure occurs, and at a time that will have the least impact on the overall operation of the microgrid. As the microgrid operates, a history of performance, trending and signature analyses will develop, adding to the microgrid's ability to anticipate failures.

The project team conducted a thorough econometric analysis of the proposed Croton Community Microgrid to determine the financial viability of the project. Hitachi has developed proprietary economic modelling software, known as EconoSCOPE^{TM}, that is specifically designed to support financial analysis for public infrastructure projects. The project team used this software to support the analysis of the financial viability of the Croton Community Microgrid project, and found that the financial case for this project is favorable. Financial institutions do not yet allow for recognition of incentives in their evaluations of project attractiveness. Therefore, the project team did not include them in the underlying economic analysis at this time. During the detailed design phase, financial incentives will be evaluated as part of the entire system costs.

The current weighted electric rate of the key critical facilities included in the proposed microgrid is approximately $0.1645/kWh. Based on the estimated energy savings, assumed project financing costs, and the 25 year contract term, the study supports a PPA electric rate with an electric cost that represents an average discount of approximately 2-5% for the facilities in this project.

Benefit Cost Analysis

NYSERDA contracted with IEc to conduct a benefit-cost analysis. The project team provided detailed information to IEc to support this analysis. IEc ran two scenarios for this proposed microgrid. The first scenario modeled no power outages, and evaluated the grid connected mode of operation. The second scenario modeled the number of days (or partial days) outage at which the costs of the microgrid would be equal to its various benefits, thus yielding a cost benefit ratio of 1. For the Croton Community Microgrid, the breakeven outage case is one outage per year for a duration 2.3 days. The cost benefit results are presented in table 16. The analyses 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 0.5 days per year (Scenario 2).

Table 16 – Cost Benefit Analysis Results

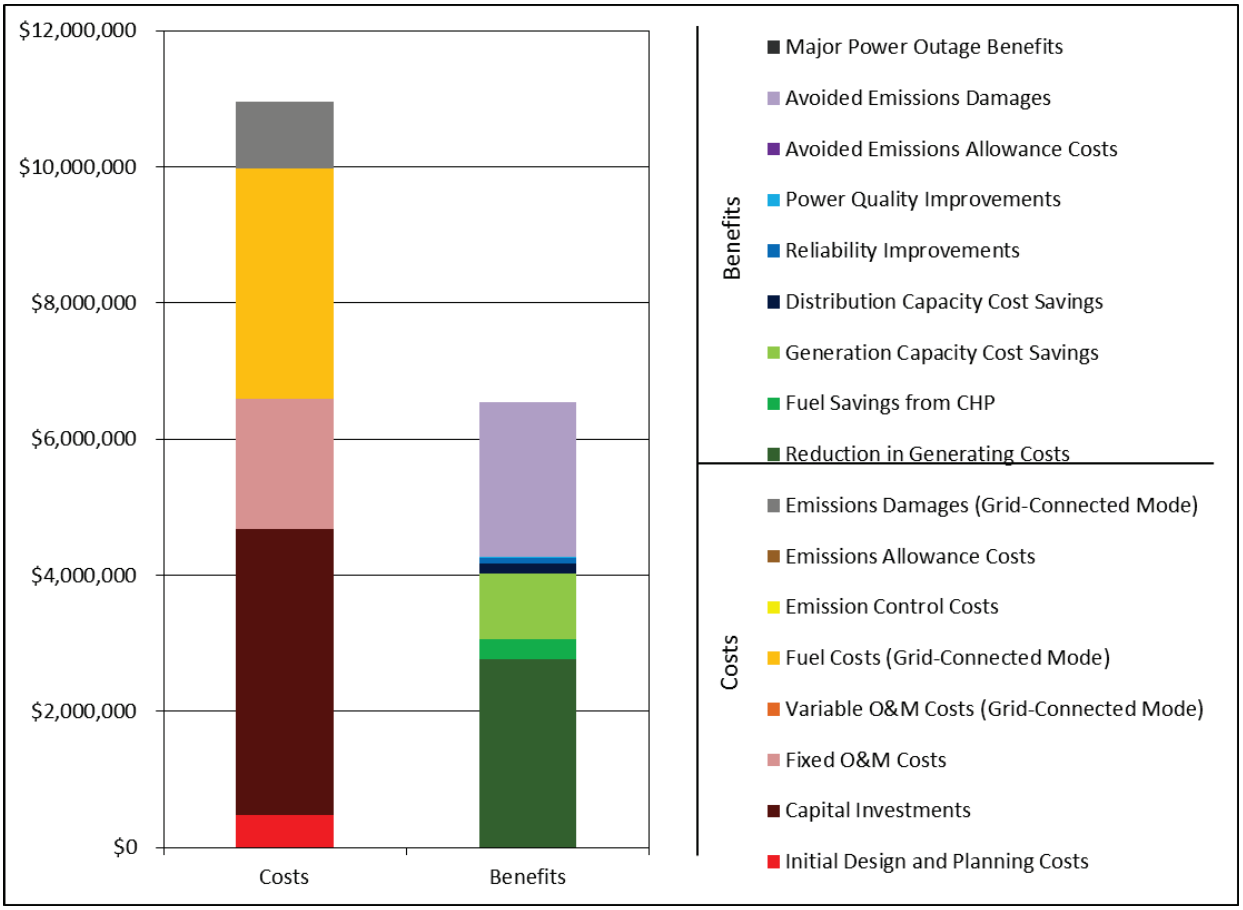
Economic Measure	Assumed average duration of major power outages	
	Scenario 1: 0 DAYS/YEAR	Scenario 2: 2.3 DAYS/YEAR
Net Benefits - Present Value	-$4,410,000	$193,000
Total Costs – Present Value	$10,900,000	$10,900,000
Benefit-Cost Ratio	0.6	1.0
Internal Rate of Return	-15.6%	6.5%

Table 17 and Figure 21 are from the IEc analysis outputs. They describe the costs and benefits associated with Scenario 1 (no power outages).

Table 17 – Cost Benefit Analysis 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	$475,000	$41,900
Capital Investments	$4,210,000	$344,000
Fixed O&M	$1,900,000	$168,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$3,390,000	$299,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$978,000	$63,900
Total Costs	**$10,900,000**	
Benefits		
Reduction in Generating Costs	$2,770,000	$244,000
Fuel Savings from CHP	$290,000	$25,600
Generation Capacity Cost Savings	$970,000	$85,600
Distribution Capacity Cost Savings	$142,000	$12,600
Reliability Improvements	$82,600	$7,290
Power Quality Improvements	$17,600	$1,550
Avoided Emissions Allowance Costs	$1,360	$120
Avoided Emissions Damages	$2,270,000	$148,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$6,530,000**	
Net Benefits	**-$4,410,000**	
Benefit/Cost Ratio	**0.6**	
Internal Rate of Return	**-15.6%**	

Figure 21 – Cost Benefit Analysis Scenario 1
(No Major Power Outages; 7 Percent Discount Rate)

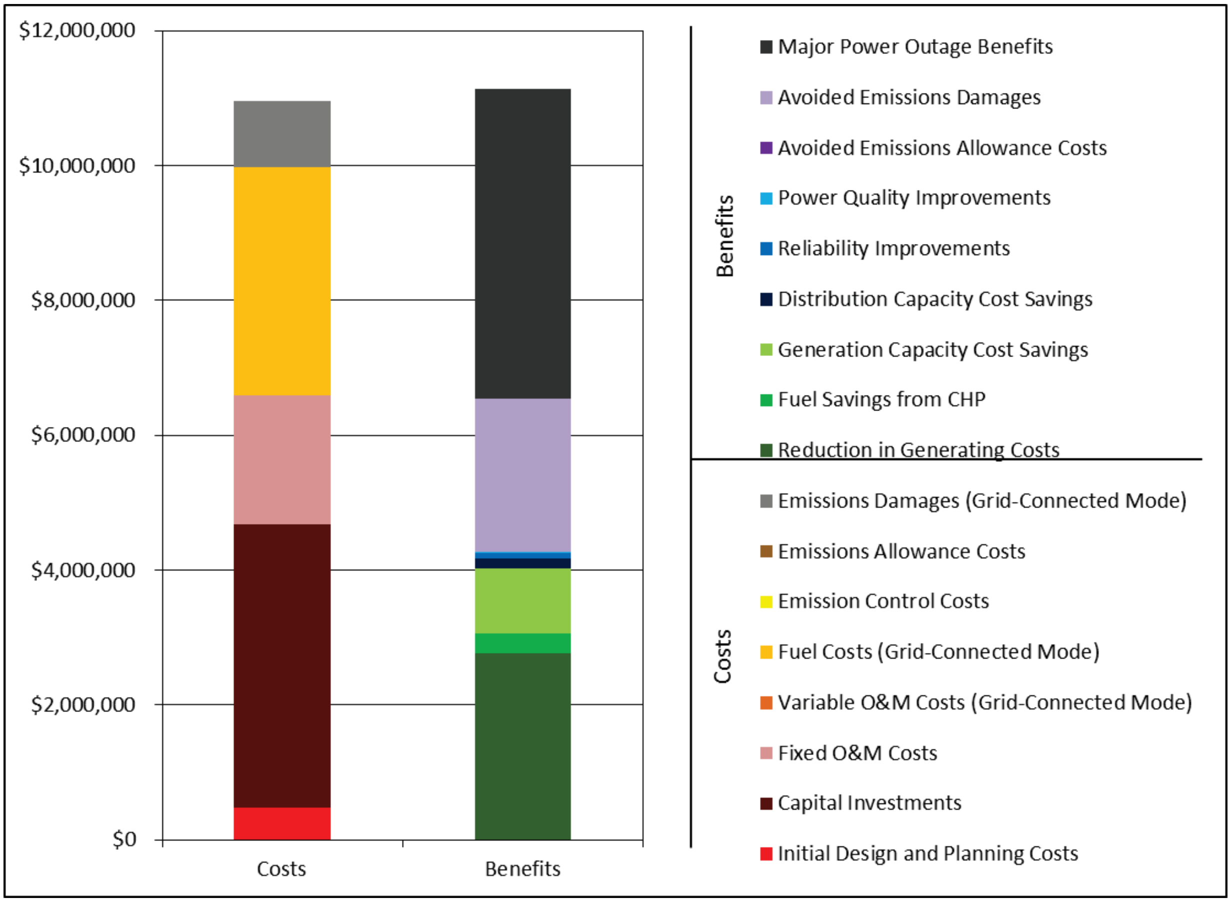


The major drivers of costs are the capital investments and fuel, where the major benefits are reduction in generation costs and avoided emissions damages.

Table 18 – Cost Benefit Analysis Scenario 2
(Major Power Outages Averaging 2.3 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$4,210,000	$344,000
Fixed O&M	$1,900,000	$168,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$3,390,000	$299,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$978,000	$63,900
Total Costs	**$10,900,000**	
Benefits		
Reduction in Generating Costs	$2,770,000	$244,000
Fuel Savings from CHP	$290,000	$25,600
Generation Capacity Cost Savings	$970,000	$85,600
Distribution Capacity Cost Savings	$142,000	$12,600
Reliability Improvements	$82,600	$7,290
Power Quality Improvements	$17,600	$1,550
Avoided Emissions Allowance Costs	$1,360	$120
Avoided Emissions Damages	$2,270,000	$148,000
Major Power Outage Benefits	$4,610,000	$406,000
Total Benefits	**$11,100,000**	
Net Benefits	**$193,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.5%**	

Figure 22 – Cost Benefit Analysis Scenario 2
(Major Power Outages Averaging 2.3 Days/Year; 7 Percent Discount Rate)



The benefits from the half day outages result in $4,610,000 during the life of the microgrid. The entirety of the IEc analysis can be found in Appendix D of this report.

Model Comparisons

This benefit-cost analysis differs from the financial feasibility analysis performed by the project team in several ways. In addition to the differing objectives of these two analyses, the underlying assumptions used in each also differed. A few of these differences affected the results of these analyses in significant ways, including:

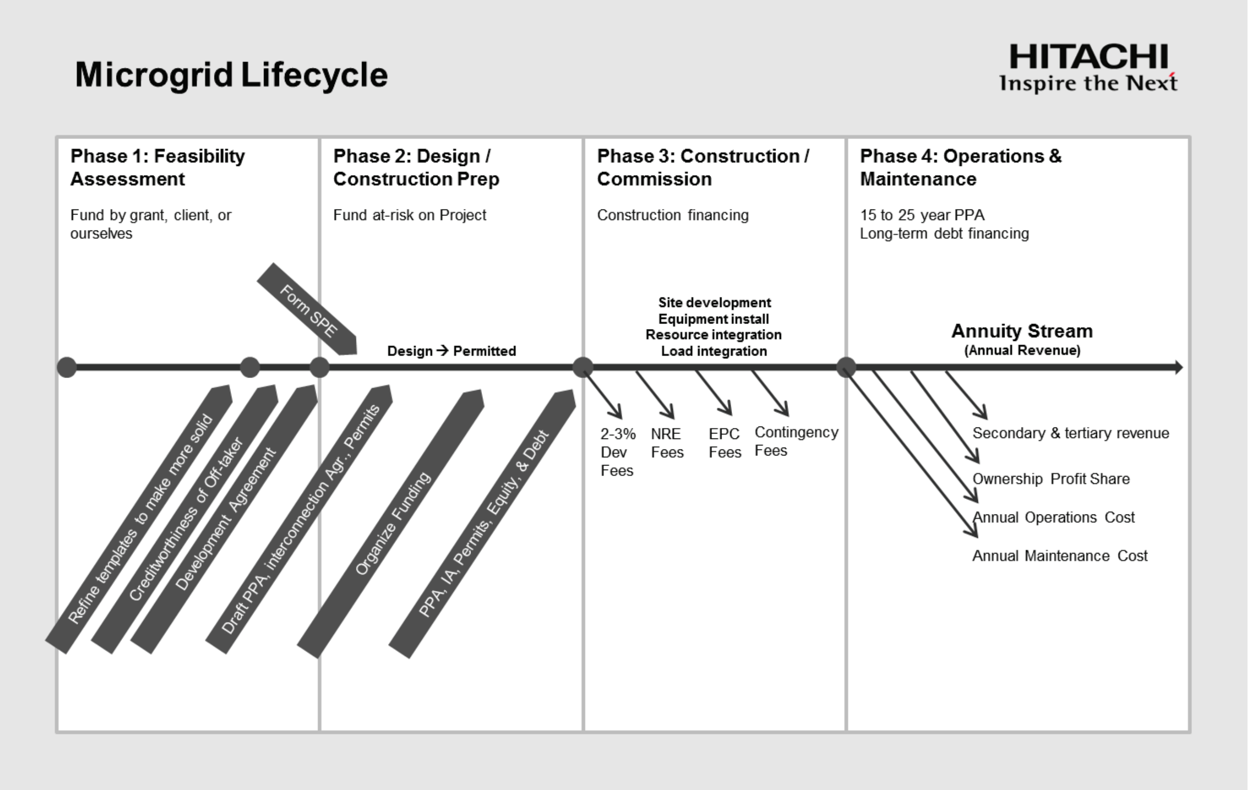
- Gas rates used in IEc's benefit-cost analysis were based on a state-wide average for commercial end-use customers. The rates used in Croton's financial feasibility analysis are based on the Con Edison's distributed generation rate. This resulted in year 1 gas rates of $6.34 and $5.84, for the benefit-cost analysis and the financial feasibility analysis, respectively. If Con Edison's distributed generation rate were applied to the benefit-cost analysis, net benefits would be increased by $70,000.

- The financial feasibility assessment incorporates the tax benefits of the Federal Investment Tax Credit, whereas the benefit-cost analysis does not. This benefit reduces the capital cost of the project by $847,000.
- Capital replacement costs used in the BCA were calculated as a full replacement costs, whereas the project team assumed a ‘rebuild’ cost that is not equal to the full cost of replacement. The rebuild cost for the Croton Community Microgrid is $268,000 less than the full cost of replacement.
- The benefit-cost analysis derives a price for electricity based on average wholesale energy costs, whereas the financial feasibility assessment evaluates the savings to the community based on actual costs paid by community participants.
- The period of analysis in the benefit cost analysis is 20 years and the third party ownership model is based on a period of analysis of 25 years.

Development, Construction, and Operating Approach

Once the design phase of a microgrid project is complete, the project must be brought to life by a well-designed and effectively supported development approach. The Hitachi Microgrid Lifecycle process closely matches the NY Prize process shown in Figure 23:

Figure 23: Hitachi Microgrid Lifecycle



In addition to the elements included in NY Prize Stage 1, the Hitachi Microgrid Lifecycle includes an evaluation of the off-taker creditworthiness.

In addition to the elements included in NY Prize Stage 2, the Hitachi Microgrid Lifecycle includes establishing a SPE early in the process to formulate the business model negotiation.

Prior to construction, it is important to clearly define the manner in which O&M will be managed once the microgrid is operational. There are multiple options for handling microgrid O&M:

- System owner O&M – The system owner, or SPE, hires staff to operate and maintain the microgrid.
- O&M Contractor – The SPE hires an O&M contractor under a long term service-level agreement.
- Separate O&M Contractors – The SPE hires separate operations and maintenance contractors under long term service-level agreements because each has its own skills advantages and cost savings advantages.

For the long term benefit of all stakeholders, it is important to structure a deal in which all parties benefit from optimal operations of the microgrid. Therefore, the SPE revenue and profitability must be in balance with savings to the community off-takers. The appropriate O&M approach for the Croton Community Microgrid has not yet been determined.

System development will involve a complex permitting process. In Stage 2, the team will conduct an environmental assessment that includes CHP air emissions, PV and ESS recycle potential, inverter recycle potential, and visual pollution. The CHP systems will require air quality operating permits, but all proposed systems will qualify for permitting.

The local utility will need to approve of the design of the switching that provides disconnect, islanding, and restoration functions in case of power disruption. The utility will also need to approve plans to use sections of utility distribution equipment while in island mode.

The utility will coordinate protection and switching schemes for the points of common coupling and the distribution system. Hitachi will address these needs in the interconnection agreement and the studies that support it. The Hitachi approach to points of common coupling simplifies the interconnection agreement and studies for the utility. This is due to the straight-forward approach taken to isolate the microgrid from the distribution grid with control by the utility in accordance with the Institute of Electrical and Electronics Engineers (IEEE) 1547 interconnection standard. This gives the utility more control and makes the interconnection agreement easier to approve.

Hitachi will use only underground cabling to connect loads in the Croton Community Microgrid. Overhead distribution lines do not provide the resiliency or reliability required to meet the specified uptime requirements. Ownership of new purchased and installed underground cabling could be retained by the SPE or gifted to the utility, based on the objectives of community stakeholders. The REV proceedings include a consideration of such arrangements.

If the utility owns the underground cable, then the utility may charge full delivery charges, or “freight,” to the customers. This will likely not be the case if the microgrid project paid for the underground cable. A full freight policy, based on past practice and not true value, eliminates nearly all the community’s financial benefit associated with the microgrid. This may become an issue for consideration under REV, and is policy recommendation that Hitachi supports.

Operation of the microgrid will include several key components:

Metering: The SPE will require the state of New York to allow sub-metering that can be applied to the microgrid. The Hitachi team will add new sub-metering as necessary.

Technical Operations: The microgrid controls and microgrid design are based on the ten Oak Ridge National Laboratory Microgrid Use Cases. The most important use cases address transition to an island mode (planned and unplanned) and return to grid-connected operations. If desired, Hitachi can provide a very detailed sequence of operations for transitioning to island and back to grid-connected mode.

Under normal conditions, the microgrid will operate under one of two regimes to accommodate its nodal structure. The first regime is local (within each node) where optimization is primarily focused on assurance of reliable and resilient operations. The second regime is global – across the entire microgrid – where optimization includes economic and emissions reduction objectives. At the global microgrid level, operations are focused on savings to the community and reduction of emissions.

Financial Operations: The SPE will bill system off-takers monthly for energy from system resources. Hitachi's approach to the PPA simplifies this process, billing consumed $/kWh monthly instead of the 18+ billing determinants in a typical utility electric bill. Depending on how the SPE is established with the community, the customer may still be billed by the utility. To simplify bill management for the customers of the microgrid, the utility bill may become a pass-through within the microgrid billing.

Transactional: Any additional revenue to customers from shared utility program participation (demand response, ancillary services) will be accounted for in the monthly bill that the customer receives from the SPE.

SWOT Analysis

The third party ownership approach offers the community many advantages and few risks, as the following SWOT analysis demonstrates. The specific terms of the PPA will affect (amplify or mitigate) the impacts of the various characteristics described below.

Strengths

- This model is associated with no or low up-front cost to the customers. The SPE arranges all financing, which enables Croton-on-Hudson resources to be used for other village needs.
- The PPA establishes predictable energy prices for the customers at or below utility rates during the course of the PPA term – typically 25 years. (Limited allowances for fluctuations in rates are included for fuel pricing adjustments).
- The PPA secures the electricity output from the microgrid for critical community facilities.
- The PPA clearly defines the annual energy delivered and the associated costs.
- A tax-exempt entity (e.g., local government) can receive reduced electricity prices due to savings passed on from federal and state tax incentives available to the SPE.
- A third-party SPE can take advantage of the Federal Investment Tax Credits for qualified costs to essentially reduce the total project cost.
- The SPE, rather than the municipality, handles billing for each facility on the microgrid (lower overhead expense for Croton-on-Hudson).

- The SPE handles regular operation, maintenance, and equipment replacement.
- Additional distributed energy resources can easily be added to the microgrid as energy requirements increase.

Weaknesses

- At the end of the PPA term, the PPA must be renegotiated. Alternatively, the assets can be transferred to the facility owner(s). This can also occur before the end of the PPA termination period, subject to "fair market value" terms defined in the agreement.
- If the buyers' demand for energy significantly decreases, the PPA requires the buyer to continue to purchase the guaranteed amount of kilowatt-hours at the price agreed upon in the PPA.
- Savings from new, more cost-effective solutions that are integrated into the microgrid over the life of the PPA are captured by the SPE rather than the community.
- Additional coordination is required for maintenance and replacement of facility infrastructure (e.g., roofs) for facilities housing microgrid components (e.g., PV panels).

Opportunities

- The PPA approach allows the community to direct their capital to pursue other village resilience projects or other priorities.
- Croton-on-Hudson may be able to integrate existing distributed generation resources into the microgrid (and receive fair market value for these assets), optimizing return on investment for these existing assets.
- Croton-on-Hudson has a set of resources at specific critical facilities to include in a comprehensive emergency preparedness plan.

Threats

- Municipal ordinances, public utility rules and requirements, and state regulations may cause constraints, including:
    - Debt limitations in state and local codes and ordinances
    - Limits on contracting authority in city codes and state statutes
    - Budgeting, public purpose, and credit-lending issues
    - Limits on authority to grant site interests and buy electricity
- The PPA will be dependent on the long-term viability of the SPE. During the 15-25 year term of the PPA, the SPE could face difficulties and dissolve, requiring a change in ownership.
- The microgrid arrangement may trigger interconnection agreements and fees from the electrical distribution utility.
- Regulatory changes may burden the PPA arrangement.
- Price adjustments due to fuel cost fluctuations may threaten the value proposition for the SPE.

PROJECT TEAM

The success of this project relies on a strong team to take it from a feasibility study to an operational system. This Croton Community Microgrid team has engaged with nearly all of the major community stakeholders. Local government representatives from Croton have led this project from the beginning, and have signaled Croton's clear interest in participating in a microgrid that can deliver resilient, cost effective energy. The community has not stated interest in any kind of public-private partnership at this time, but the project team will continue to consider the potential benefits of such an approach as the project is designed. This may take the form of partial ownership of the SPE by one or more local government agencies.

Other stakeholders have been kept informed throughout the process and have assisted the study by supporting site audits, providing facility information, and participation in regular status calls. As this project enters the next phase, the project team will hold face-to-face meetings with participants to review the results of the feasibility study and touch base on their interest in participating in the microgrid once it becomes live.

Con Edison is aware of this project and provided a letter of support for the initial feasibility study and participated in the project kick-off meeting. Throughout the process, the project team has engaged the utility in design discussions. As of this date, Con Edison has not yet weighed in on the value of this project based on the results of the feasibility study.

Project Leader: Hitachi Microgrid Solutions has expressed a desire to support the full-system design of the proposed microgrid as the project moves to the next stage. This group has extensive experience in microgrid design and operation. Hitachi also has access to the capital, at a competitive rate, needed to finance the system and set up an SPE to operate the equipment and manage PPAs. The team has designed over 50 microgrids and overseen the construction of several microgrids. The Hitachi Microgrid Solutions Business will also leverage its close partnership with other Hitachi Companies to support faster microgrid development and deployment. These include:

- Hitachi America, Ltd. – Established in 1959 and headquartered in Tarrytown, NY, Hitachi America, Ltd. is a major infrastructure and technology services company in North America with offerings in electronics, power and industrial equipment and services, and infrastructural systems.

- Hitachi Capital Corporation – Established in 1969, Hitachi Capital provides financing to various Hitachi Group Companies and the commercial business sector worldwide. Hitachi Capital's Energy Projects Division is one of its largest and fastest growing groups and it currently owns and finances projects through PPAs all over the world.

Together, this team has the financial strength to ensure that this project can be completed and sustained over time. Hitachi has more than 100 years of experience in product and service innovation and quality engineering. In 2012, the company had $96.2 billion in revenue and spent $3.7 billion on research and development. The company's 326,240 employees are all directed toward advancing Social Innovation – the idea that Hitachi's technological innovation should be leveraged for environmental and social good. . This goal is directly supported by Hitachi's expanding Microgrid Solutions Business. Hitachi Capital, a potential financier of the Croton Community Microgrid, has over 5,000 employees and has made investments exceeding $17 billion to support Hitachi's Social Innovation projects.

Hitachi's expertise alone will not be enough to ensure project success. There are several critical roles that must be filled when designing a complex community scale microgrid. These include:

Project Financiers: Hitachi Capital has indicated interest in serving as an equity investor in the SPE, and could arrange for the related project financing. Hitachi Capital has a division dedicated specifically to energy project finance, and has financed more than 200 renewable and distributed energy projects at highly competitive rates. Other project investors have also contacted the team about the opportunity to invest in this project.

Microgrid Control Provider: Effective control and optimization are critical features in any microgrid. The Hitachi Microgrid Team is currently reviewing the results of their industry-wide RFI for microgrid control technologies. The team will utilize this ongoing analysis to determine the best system for the Croton Community Microgrid during the detailed design phase. The team will develop a competitive RFP process to identify and select the controller partner with the most attractive combination of experience, skillsets, and price.

EPC Contractor: The EPC will be responsible for detailed engineering drawings of the system, purchasing the equipment specified in the design, and overseeing construction and commissioning of the microgrid system itself. The Hitachi Microgrid Solutions Business has long-term and strong relationships with many EPCs and is in discussions with several regarding Croton's microgrid project. A final evaluation and selection will be made during the proposal process for Stage 2.

CHP Design Firm: To ensure optimal design and placement of the generation and heat sources in the microgrid, the Hitachi Microgrid Team will leverage a firm that specializes in CHP applications. For this role, Hitachi anticipates partnering with GI Energy. GI Energy was established in 2001 and is recognized as a leader in the analysis, engineering, construction, and maintenance of CHP and geothermal heat pump applications for buildings and campuses. GI Energy is CHP vendor agnostic and works to find the best-fit solution for the specific application. Since 2001, GI Energy has been deploying CHP and geothermal heating and cooling technologies in the US and Europe.

PV System Design Firm: To ensure that PV generation systems in the microgrid are designed and placed for optimal performance, the Team will partner with a firm that specializes in PV applications. The Team is currently in discussions with multiple PV design firms to identify potential partners for the Croton project. The team will develop a competitive RFP process to identify and select the PV firm with the most attractive combination of experience, skillsets, and price.

O&M Firm: Once a system is installed, operations and maintenance on the equipment will be critical to ensure both the resilience and profitability of the system. The SPE that owns the system will need to retain the services of an O&M firm with qualified team members close to the Croton. The team will again develop a competitive RFP process to identify and select the team with the most attractive combination of experience, skillsets, and price. All microgrid resources will be monitored on an ongoing basis to ensure efficient operation, plan maintenance activities, troubleshoot issues, and respond to equipment alarms.

Legal and Regulatory Advisors: Hitachi's Microgrid Business is served by Crowell & Moring outside counsel. Crowell & Morning has a dedicated energy practice with more than 50 attorneys and a significant presence in New York. Further credentials can be provided on request.

LEGAL VIABILITY

The project team has developed a model for the legal organization of the Croton Community Microgrid based on ownership by a dedicated SPE. The project team has proven the legal viability of this model through numerous existing microgrid projects. This ownership structure maximizes opportunity for low-cost financing, and helps to ensure that final customer rates are kept as low as possible. The ultimate owner of the microgrid system has not been finalized at this point.

Other team members or community stakeholders may decide to take an ownership stake in the system. However, at this time, no community customers or stakeholders have expressed interest in an ownership role. As the lead developer of the Stage 1 feasibility study, Hitachi is in a unique position to understand the commercial proposition and opportunity of the Croton Community Microgrid and how to make the project a success.

The SPE will not own the real estate or facilities in which microgrid systems and equipment will be installed. In each case these sites are owned by customers included in the microgrid. These customers have been included in the planning process throughout the feasibility study. Representatives for each accompanied the project team as they walked through the sites following the kick-off meeting, they have worked with the project team to gather data necessary to construct the model, and they will be included in the project close-out meeting. In each step of the process the project team has discussed plans for locating microgrid equipment at each site with the customers who own that site, and have received their provisional approval.

Market Barriers

There are a number of variables which could impact the viability of the project, even if the technical and economic fundamentals look strong. They include:

<u>Financing:</u> There may be aspects of the current market that make securing financing at a competitive cost of capital more difficult. The primary barrier is the education level and familiarity with microgrids within the finance sector. While solar PPA's are now a well-established financing opportunity, only ten years ago, they were little understood by financiers. Today, microgrids are not as well understood in the financial sector. The financial industry has not yet created standardized financing products for microgrids, and each new project has required a custom deal. This tends to drive up the cost of capital. Hitachi Capital and its partners understand Hitachi's Microgrid Solutions Business and the market, and the project team is therefore optimistic that this barrier will be avoided.

<u>Stage 2 NY Prize Funding:</u> Stage 1 funding was not sufficient to cover the costs of a comprehensive feasibility study. This was anticipated, and many organizations involved in the delivery engaged in cost sharing and were prepared to make significant investments to deliver a high quality and reliable study

for the Croton feasibility study. However, given the levels of investment required of vendors in Stage 1, there will be little appetite or ability to incur additional cost share or risk in Stage 2. This is exacerbated by the inherent risks and known and unknown costs associated with the next phase of development, many of which are specific to community microgrids. Stage 2 funding is critical to moving forward to the next stage of project development.

Customer Commitments: The project economics are highly sensitive to the microgrid design. The design is dependent on customer sites and loads, and the distributed energy resources planned for those locations. A major risk is posed by the possibility of customers withdrawing before final contracts are signed. This would affect the overall microgrid design and fundamental project economics.

Utility Cooperation: The negotiation of interconnection agreements with local utilities can cause significant delays and lead to new costs when the proposed microgrid concepts are unfamiliar to the utility's staff and engineering contractors. To date, Con Edison has offered support and cooperation with the feasibility study phase. Should this trend continue, Croton can expect this risk to be fairly small in the next phase.

Regulatory Issues

The ownership model of the Croton Community Microgrid will influence the type of regulatory status it has under Public Service Law. This report assumes that the system will be owned by a third-party SPE. Privately-owned microgrids are legal in New York.

The system will not be considered an electric distribution company by the public services commission because it utilizes qualifying forms of generation,[1] is under 80 MW,[2] serves a qualifying number of users, and its related facilities (including any private distribution infrastructure) are located "at or near" its generating facilities. This saves the system from a raft of burdensome regulatory requirements.

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[1] Qualifying generation facilities are defined in PSL § 2 as those falling under the definitions of "Co-generation facilities," "Small hydro facilities," or "Alternate energy production facilities." A qualifying co-generation [1]
[2]Qualifying generation facilities are defined in PSL § 2 as those falling under the definitions of "Co-generation facilities," "Small hydro facilities," or "Alternate energy production facilities." A qualifying co-generation facility is defined as "Any facility with an electric generating capacity of up to eighty megawatts…. together with any related facilities located at the same project site, which is fueled by coal, gas, wood, alcohol, solid waste refuse-derived fuel, water or oil, …. and which simultaneously or sequentially produces either electricity or shaft horsepower and useful thermal energy that is used solely for industrial and/or commercial purposes." NY PSL § 2-a. A qualifying small hydro facility is defined as "Any hydroelectric facility, together with any related facilities located at the same project site, with an electric generating capacity of up to eighty megawatts." NY PSL § 2-c. A qualifying "alternate energy production facility is defined as "Any solar, wind turbine, fuel cell, tidal, wave energy, waste management resource recovery, refuse-derived fuel or wood burning facility, together with any related facilities located at the same project site, with an electric generating capacity of up to eighty megawatts, which produces electricity, gas or useful thermal energy." NY PSL Ser § 2-b.

[2] Id.

Placing distribution wires or leveraging the existing utility distribution system for energy sharing between facilities will be subject to state-wide electric utility regulations, local franchise and rights of way statutes, and the willingness of the local utility.

A revocable consent can be granted by the local government only up to 2,500 feet of wire,[3] (combining all separate revocable consents held by the applicant) which may or may not exclude granting a revocable consent for the full length of distribution required to connect the properties in this project. Separated by up to two miles at different points, the distribution required to connect the properties in question at either node may measure over 2,500 feet. Otherwise, a revocable consent may apply to a portion of the distribution required for this project if the rest were owned by the utility. The additional wiring needed to connect buildings within nodes for this project is estimated to be less than 2,500 feet, making this approach an option if Con Edison is not willing to provide access to their distribution system for those purposes.

Privacy

Ensuring the privacy of the microgrid clients will be of paramount importance for both customer satisfaction and project replicability. The Project Team has taken steps to improve the privacy of all stakeholder data, including all utility data, plans, diagrams and site specific and sensitive information. The project team has done this by setting up a secure data site which allows our team to minimize access of this data to only those directly involved in the modeling and design process. This tightened data control will ensure the project stakeholder's data meets all privacy requirements.

CONCLUSIONS AND NEXT STEPS

The NY Prize feasibility assessment indicates that the Croton Community Microgrid is both technically and economically viable. In addition to protecting the city's ability to respond to emergencies, the microgrid will provide direct benefit to the entire population within Croton by protecting critical services in an area that is particularly vulnerable to storm damage. The microgrid will result in lower energy costs and lower carbon footprint for the microgrid customers. The project team believes that the proposed microgrid design will serve as a leading example for New York, and will be beneficial and replicable to other communities across the state and beyond. Key findings from the feasibility assessment include the following:

1. ***Engaged Stakeholders***: The Community Microgrid is built around a set of facilities and institutions that are well established, and committed to the project. Most of these are public facilities managed by the village government, but the three private institutions included in the study all contributed to the project in various ways .
2. ***Many Small Distributed Systems***: The small size and large number of nodes drove up the total installed cost of the systems. However, this design will allow the microgrid to cover all of the

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[3] Village of Croton Code Chapter 205(3)(G).

facilities that village stakeholders identified as most critical, maximizing the resilience benefit of the system.

3. ***Natural Gas Costs***: One of the other cost drivers for the project is natural gas. Increasing costs for natural gas will have a negative impact on the PPA rates for each of the facilities, but overall electricity cost savings should increase year over year for microgrid customers compared to the cost of electricity from the grid.
4. ***Community Microgrid Financing Costs***: The cost of project financing is high for community microgrids. This is due to the fact that there are numerous stakeholders and potential customers, and that each stakeholder has its own procurement requirements. The project team will need to seek out a financier that is knowledgeable about these projects, and can help keep transaction costs to a minimum.
5. ***Financial Prospects:*** The feasibility analysis indicates that the Croton Community Microgrid project meets the financial requirements for third party financing and ownership.

The next steps that the Croton community will need to undertake are to finalize the ownership structure to be proposed, and identify a team of partners to engage in the detailed design phase of the project. Once these decisions are made, the project team will draft a proposal to NYSERDA to compete in Stage 2 of NY Prize. This Stage 2 funding will help defray the additional cost and risk associated with a multi-stakeholder community microgrid . Stage 2 of the NY Prize program will require additional cost share, and a determination will need to be made about which parties will take this on.

Regulatory and Policy Recommendations

In the process of performing this feasibility analysis, the project team identified several key regulatory and policy recommendations that will help control the costs associated with community microgrid development, and help to maximize the benefits these systems can yield:

1. ***Franchises and Rights-of-Way***: Community microgrids almost always include critical facilities that are not co-located on the same parcel of land. To interconnect these facilities requires the crossing of one or more public right of ways. The installation of electrical distribution lines (above or below ground) or thermal distribution infrastructure across a public right of way will usually infringe on an existing franchise, or require a new one to be issued. In New York State, each municipality (town, village, city, etc.) has the statutory authority to grant franchise rights or similar permissions. In many cases, these franchise rights have already been granted to the distribution utility, and the installation of microgrid infrastructure by a third party may represent an infringement of that franchise.

   At the state level, a program to standardize and expedite the issuance of franchise rights to microgrid developers would significantly reduce associated development costs for community microgrids. For instance, the State Supreme Court in Connecticut ruled that installing a distribution wire from one parcel to another and selling power across that line cannot encroach on a utility franchise (and won't trigger PUC jurisdiction).[4]

2. ***Utility Ownership***: The rules governing utility ownership of microgrids in New York State, and specifically DER within the microgrid, are not clearly defined. After ruling in 1996 that distribution utilities must end all investments in generation assets, the Public Service Commission (PSC) carved out a general criterion for exceptions in a 1998 ruling known as the Vertical Market Power Policy. This policy stated that distribution utilities could own DER if they could demonstrate "substantial ratepayer benefits, together with [market power] mitigation measures."[5] In February, 2015, the PSC published the "Order Adopting Regulatory Policy Framework and Implementation Plan"[6] which described several circumstances when utility ownership of DER would be allowed. One of these circumstances is for a project that is "sponsored for demonstration purposes." This may be applicable to some NY Prize projects, but it is unclear what the criteria would be for an acceptable demonstration project. Also, this does not help drive the broader market for microgrids as this limits the number of systems that will be implemented in the near term.

   Greater clarity from the state on the circumstances under which utility ownership of microgrid assets would help communities interested in microgrid development assess utility ownership as an option, and evaluate the costs and benefits of this ownership model.

3. ***CHP Natural Gas Tariffs:*** The resilience of natural gas infrastructure to storm damage and other disruption makes it an attractive fuel source for powering microgrid energy resources (such as combined heat and power plants). The economic health of microgrids that use natural gas plants to meet base loads is subject to favorable natural gas tariffs. The application of natural gas generators create benefits in the form of a base natural gas load (including in the summer months when natural gas demand is lowest), and improved system efficiency (through generation located at the load, efficient operation on the power curve, and recovery of heat to offset other heating loads). Most utilities offer specific tariffs for the operation of distributed generation equipment. State support for attractive natural gas tariffs helps to assure viable business models for both CHP and microgrid development.

4. ***Multiple Customer Contracting:*** Multiple customers within the community microgrid create challenges of financing, procurement, and operations across the stakeholders in the community. Continued state support for the NY Green Bank mission of implementing structures that address gaps and overcome barriers in current and clean energy financing markets, particularly as related to community microgrids with multiple customers and customer types, may lead the industry toward sustainable solutions for addressing these issues.

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[4] See *Texas Ohio Power v. Connecticut Light and Power*, 243 Conn. 635, 651 (1998).

[5] New York Public Service Commission. 1998. "Vertical Market Power Policy (VMPP) Statement."

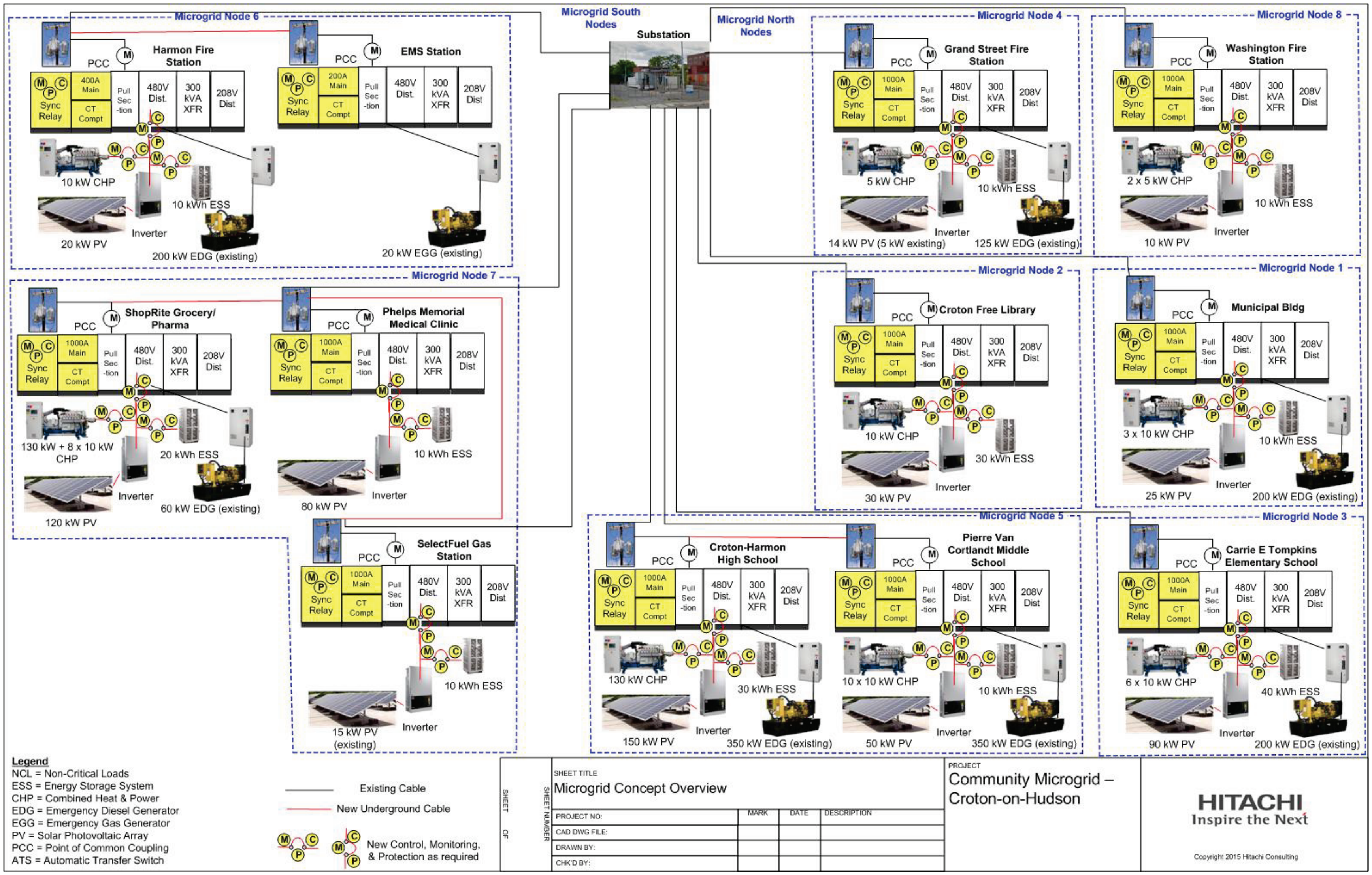
[6] New York Public Service Commission. 2015. "Order Adopting Regulatory Policy Framework and Implementation Plan."

5. ***Stage 2 and Stage 3 Funding Structure:*** Stage 2 funding should focus on advancing the project towards the construction phase, and less on reporting deliverables. Stage 3 funding sends a poor market signal, indicating that microgrids need subsidies in order to be cost effective, which is often not the case.
6. ***Municipal Lowest Rate Requirement:*** Regulations that require that municipal customers pay the lowest available rate for electricity and gas may prevent investment in microgrid infrastructure and resilience benefits through a PPA in certain cases. Projects that provide other societal benefits (support critical loads, serve the community at times of natural disaster, reduce emissions, etc.) should be eligible for consideration as projects that municipalities may execute.
7. ***Competitive Procurement Requirements*:** Given cost share requirements in Stage 2, development firms are going to hesitate to invest unless they are assured work in Stage 3. This could potentially be mitigated by state-issued guidance for special exemptions for the NY Prize program, or by encouraging a single procurement process for Stage 2 and 3.

[End of Report]

APPENDIX A: CROTON MICROGRID LAYOUT DIAGRAM

APPENDIX B: CROTON MICROGRID ONE-LINE DIAGRAM



APPENDIX C: LEGAL AND REGULATORY REVIEW

I. Ownership and Public Service Law Regulatory Treatment

The ownership model that the Croton microgrid undertakes will influence the type of regulatory status it has under Public Service Law. Three basic potential ownership models are identified below, with relevant regulatory implications noted.

1. Utility Ownership of Microgrid Assets, Inclusive

Utility ownership of microgrid assets can have the potential benefits of lowering the technical and administrative burdens on project participants, easing the interconnection process, and providing a ready source of capital, among others. If Con Edison ownership of various DER assets within the microgrid is proposed, it will be necessary to address how generation assets will be treated, considering ongoing discussions in REV proceedings and potential demonstration project status.

The Public Service Commission (Commission) has considered utility ownership of distributed energy resources (DERs), which would include *inter alia* microgrid generation and storage assets. The Commission's stated policy from its February 26th "Order Adopting Regulatory Policy Framework and Implementation Plan" can be summarized as follows:

> "A basic tenet underlying REV is to use competitive markets and risk based capital as opposed to ratepayer funding as the source of asset development. On an ex ante basis, utility ownership of DER conflicts with this objective and for that reason alone is problematic….As a general rule, utility ownership of DER will not be allowed unless markets have had an opportunity to provide a service and have failed to do so in a cost-effective manner…. [U]tility ownership of DER will only be allowed under the following circumstances: 1) procurement of DER has been solicited to meet a system need, and a utility has demonstrated that competitive alternatives proposed by nonutility parties are clearly inadequate or more costly than a traditional utility infrastructure alternative; 2) a project consists of energy storage integrated into distribution system architecture; 3) a project will enable low or moderate income residential customers to benefit from DER where markets are not likely to satisfy the need; or 4) a project is being sponsored for demonstration purposes."[7]

Of these four qualifying scenarios, most likely only the fourth would apply here.

Speaking to the first scenario, the utility may always appeal to the Commission to own DERs if it first conducts an open solicitation process for private owners. In the context of this feasibility study, such a solicitation process will not be undertaken, so for now we ignore this condition. If other ownership models proposed by this study prove untenable following the appropriate solicitations, this condition may become relevant.

Speaking to the second scenario, while a microgrid may incidentally incorporate storage devices into utility infrastructure, it is clear from the context surrounding these comments that the Commission intends for projects qualifying under this condition to be primarily geared towards expanding the

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[7] Case 14-M-0101, Order Adopting Regulatory Policy Framework and Implementation Plan, Feb. 26, 2015, at 67-70.

utility's understanding of how storage assets can provide benefit to the distribution grid, and specifically noted that "[w]ith respect to resources at the customer location, utility ownership should not be necessary."[8] Storage integrated into a microgrid would not seem to qualify under this condition.

Speaking to the third scenario, the proposed project does not target low/moderate income customers who would otherwise not be likely to receive microgrid service from the market. As such it may not target utility ownership as a potential DER ownership structure under this condition.

Speaking to the fourth scenario, there remains substantial uncertainty regarding what will be determined a satisfactory "demonstration project" by the Commission. The only criteria for demonstration projects promulgated by the Commission to date is its December 12, 2014 "Memorandum and Resolution on Demonstration Projects," which states that:

> 1. REV demonstrations should include partnership between utility and third party service providers.
>
> 2. The utility should identify questions it hopes to answer or problems or situations on the grid and the market should respond with solutions. Hence, third party participation through a traditional RFP/RFI method where the utility has pre-diagnosed the solution(s) does not meet this requirement.
>
> …
>
> 4. The market for grid services should be competitive. *The regulated utility should only own distributed energy resources if market participants are unwilling to address the need and the utility is acting as the service provider of last resort (in this instance, "provider of last resort" and "needed" means that no one in the market is providing the solution and the distributed solution is less costly than alternatives for the problem)* (emphasis added).[9]

The fourth principle for demonstration projects articulated by the Commission leaves some uncertainty regarding what conditions utility ownership will be permitted under in the context of a demonstration project. The Commission elsewhere notes that "proponents of demonstration projects should strive for third party ownership of DER, keeping in mind that any regime of third party ownership must be done in a manner that ensures safety, reliability and consumer protection."[10]

In practice, the Commission has approved demonstration projects that involve utility ownership of DERs. Consolidated Edison's Virtual Power Plant demonstration project, for example, allows Consolidated Edison to own storage assets that are marketed as a package with PV provided by a third party to customers as, when taken together, a resilient power system.[11]

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[8] Id. at 69.

[9] Case 14-M-0101, "Memorandum and Resolution on Demonstration Projects," Dec. 12, 2014, at Appendix A.

[10] Id. at 9.

[11] See Case 14-M-0101, "REV Demonstration Project Outline: Clean Virtual Power Plant," Consolidated Edison, July 1, 2015, and Case 14-M-0101, Letter from Scott Weiner, Deputy for Markets and Innovation, NYS Public Service Commission, to Consolidated Edison, August 3, 2015.

The Commission has noted that "[d]emonstration projects will be a continuing effort as the implementation of REV develops….The need for demonstrations will continue, and we will examine methods for utilities to develop a common platform for sharing of information regarding needs and potential offerings by third parties."[12] The Commission has not yet issued a formal deadline for the proposal of new demonstration projects at this time.

In the Croton microgrid, it is plausible that Con Edison would be allowed to act as the owner/operator of a substantial set of DERs if such an arrangement were pursued: (a) as a demonstration project; (b) for the purpose of testing a hypothesis of how to provide REV-related benefits to customers, perhaps through a novel tariff or third party partnership; and (c) where there is not a ready market provider for the same service. This model may be pursued further through a demonstration project filing if there is an appetite among project stakeholders for utility ownership of microgrid assets.

2. Utility Ownership of Non-Generation Microgrid Assets Only

Even if Con Edison does not own any of the DER assets within the Croton microgrid, it may still be beneficial for the project to rely on existing distribution service to carry power between microgrid customers and avoid the investment and regulatory burden associated with private distribution. If Con Edison ownership of only distribution microgrid assets is proposed, it will be necessary to address the method under which the microgrid will export to the utility grid. There are several potential regimes under which individual customers within the microgrid may export power onto the utility grid.

A) Net metering

New York's net metering rules allow customers with eligible distributed generation sources to export power onto the utility grid. This mechanism may be relevant for facilities exporting power onto utility-owned wires for distribution to other microgrid customers. Net metering allows onsite generators to offset grid electricity purchases (when onsite demand exceeds onsite generation) with power exported to the grid (when onsite generation exceeds onsite demand). Under this mechanism, qualifying generators can effectively receive retail rates for their excess generation. Net metering is available in New York to residential and nonresidential solar, wind, fuel cells, microhydroelectric, agricultural biogas, and residential micro-CHP.

The size of the eligible generator is capped depending on the kind of generation (e.g., solar, wind, etc.) and customer type (e.g., residential, nonresidential, farm). The cap for residential solar, wind, and micro-hydroelectric is 25 kW. The cap for nonresidential solar, wind and micro-hydroelectric is 2 MW. The cap for farm-based wind is 500 kW, and the cap for farm-based biogas is 1 MW. The cap for residential fuel cells and micro-CHP is 10 kW, while the cap for nonresidential fuel cells is 1.5 MW.[13]

New York's net metering policies may be revisited through the REV proceeding, and the Microgrid Working Group has particularly flagged for resolution the issue of how eligible and non-eligible net metering resources at a given site will be accounted for.

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[12] Case 14-M-0101, Order Adopting Regulatory Policy Framework and Implementation Plan, Feb. 26, 2015, at 117.

[13] NY PSL § 66-j.

In the Croton microgrid project, proposed PV generation assets may be eligible to receive net metering credit. Con Edison's net metering tariff may be found at Rider R: Tariff for Net-Metered Customers.[14]

B) Buyback Tariffs

For generation that is not eligible for net metering, microgrid owners may also sell energy services through applicable "buy back" tariffs that require utilities to purchase excess generation from qualifying facilities. Con Edison's buyback tariff can be found at Service Classification SC-11.[15]

The buyback tariff will typically provide highly variable rates to the microgrid owner for energy services. The utility typically buys generation from the participating customer at the Locational Based Marginal Price (LBMP), which reflects the wholesale price of energy through NYISO's bulk power markets at the transmission level. From the standpoint of the nonutility microgrid owner, selling relatively large amounts of energy produced via a buy back tariff would likely not be a preferred arrangement due to the uncertainty of the revenue stream resulting from the fluctuating wholesale price of energy.

Selling energy back to the utility via a buy back tariff may be a viable option for Croton if used as a secondary means of receiving compensation for energy services. This may be particularly salient if the system is designed to provide thermal energy through CHP operated to follow thermal demand. In these instances, there will be times where electric generation exceeds electric demand. When this occurs, the grid can serve as a destination for the surplus power produced.

The ability to sell surplus energy via the buyback tariff also provides the option for microgrids to export intentionally to the grid when the LBMP is at favorable rates. For example, while the Burrstone Microgrid has established a PPA with each microgrid user that covers most of the energy produced, the microgrid sells surplus power to National Grid at the LBMP. To operationalize the microgrid's interaction with the wholesale power market, Burrstone developed an algorithm that governs the microgrid control system. Using market prices fed into the algorithm, the microgrid control system provides signals to the units indicating when to run and when not to run. Burrstone's algorithm makes hourly operational decisions that are automatically implemented by the Energy Management System.

C) Application of the Offset Tariff

Con Edison's offset tariff can supplant the traditional standby tariff to allow customers connecting an efficient CHP system[16] between 2 and 20 MW on the high tension (utility) side of the meter to distribute power between a campus of proximate buildings all registered to a single customer account.[17] This tariff might currently apply to serving a series of buildings within the same microgrid that are all registered to the same customer account, such as the Croton Middle and High Schools.

Con Edison has agreed recently to convene a collaborative discussing removal of the single-customer limitation from the offset tariff. If this collaborative leads to an expansion of the offset tariff to multiple

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[14] Available at http://www.coned.com/documents/elecPSC10/GR24.pdf#nameddest=riderr.

[15] Available at http://www.coned.com/documents/elecPSC10/SCs.pdf#nameddest=sc11.

[16] As designated pursuant to the order of the Public Service Commission, dated January 23, 2004, in Case 02-E-0781.

[17] General Rule 20.2.1(B)(7), Leaf 157 (covering single-account offset arrangements), and General Rule 20.2.1(B)(8), Leaves 157.1-157.5

customer accounts, a wider group of customers within the Croton project may benefit from the offset tariff.

D) Creation of New Tariff for Microgrid Service

Specially designed tariffs or service agreements may be adopted to support microgrids that rely on the utility distribution system to wheel power between microgrid users. Such a "wheeling charge," specialized tariff or other form of service agreement may be agreed to by the parties, and may potentially be approved by the Commission as a REV demonstration project. As articulated by the Commission:

> "Demonstrations should inform pricing and rate design modifications….Demonstrations should include opportunities for third parties to demonstrate how various rate designs, information sharing, adjusted standby tariffs, and other technologies can be used to benefit consumers, encourage customer participation, and achieve REV's efficiency and bill management objectives."[18]

This criteria may open the door for Con Edison to propose novel methods of billing microgrid customers for their use of the distribution system. In other settings, utilities have already considered or proposed REV-related projects that include reaching unique service agreements with microgrid customers.[19]

3. Privately-Owned Microgrid Distribution

Croton may pursue a privately-owned microgrid in a variety of flavors: a third-party energy services company, a special purpose entity or LLC owned and controlled by microgrid customers, or some combination of the two as relates to different assets. The important legal question across all varieties of this model will be whether the microgrid is an electric distribution company under Public Service Law, and if so, what level of regulation it will fall under at the Public Service Commission. Discussion of the State-level regulatory landscape, Section 2 of the Public Service Law, and various cases applying its standards will inform this discussion. New models of regulatory treatment, currently under discussion in the REV proceeding, may also apply if adopted in the future.

A) Currently Existing Regimes of Regulating Privately-Owned Microgrid Distribution Under Public Service Law

Under existing law and Commission guidance, the Croton microgrid will be treated as an electric corporation under Public Service Law unless it is deemed a qualifying facility under the terms of PSL §§ 2(2-d) or otherwise qualifies for lightened regulation.

If subject to the full spectrum of regulation that the Commission may exercise over an electric corporation, the microgrid may be regulated for general supervision[20] (investigating the manufacture, distribution, and transmission of electricity; ordering improvements; and performing audits), rates,[21]

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[18] Case 14-M-0101, "Memorandum and Resolution on Demonstration Projects," Dec. 12, 2014, at Appendix A.

[19] See, e.g., Case 14-E-0318, "Testimony of the Reforming the Energy Vision Panel," July 15, 2014, at 14.

[20] PSL § 66.

[21] PSL § 65.

safe and adequate service,[22] all aspects of the billing process, financial, record-keeping, and accounting requirements,[23] corporate finance and structure,[24] and more. This expansive purview of regulation may prove too administratively onerous for a small project like the Croton microgrid to comply with. It is therefore important that, if the microgrid utilizes private distribution infrastructure, it be designated a qualifying facility, be subject to lightened regulation, or be granted some alternate regulatory status, as discussed in part (B) of this section.

i. Qualifying Facility

Croton's microgrid may be exempted from much of the PSL regulation applying to electric distribution companies if it is deemed a qualifying facility under the terms of PSL §2. A microgrid will be deemed a qualifying facility if it utilizes qualifying forms of generation,[25] is under 80 MW,[26] serves a qualifying number of users, and its related facilities (including any private distribution infrastructure) are located "at or near" its generating facilities.

Type of generation facilities: In the Croton project, PV generation facilities have been proposed that will qualify. CHP facilities have also been proposed that will likely qualify if its electricity, shaft horsepower, or useful thermal energy is used solely for industrial and/or commercial purposes.

Size of generation facilities: In the Croton project, generation facilities will likely fall under the statutorily imposed 80 MW limit.

Qualifying number of users: It is difficult to apply the requirement that a microgrid serve a qualifying number of users in the abstract. This requirement has not been explicitly spoken to by the Commission, but has been contested in Case 07-E-0802, regarding the Burrstone Energy Center.[27] There, petitioners raised the question of whether a qualifying facility may distribute power to three different institutional users – a hospital, college, and nursing home. The Commission found that "furnishing electric service to multiple users" is specifically contemplated in PSL §2(2-d) "by providing that electricity may be

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[22] PSL § 66.

[23] PSL § 66, 68(a).

[24] PSL § 69.

[25] Qualifying generation facilities are defined in PSL § 2 as those falling under the definitions of "Co-generation facilities," "Small hydro facilities," or "Alternate energy production facilities." A qualifying co-generation facility is defined as "Any facility with an electric generating capacity of up to eighty megawatts…. together with any related facilities located at the same project site, which is fueled by coal, gas, wood, alcohol, solid waste refuse-derived fuel, water or oil, …. and which simultaneously or sequentially produces either electricity or shaft horsepower and useful thermal energy that is used solely for industrial and/or commercial purposes." NY PSL § 2-a. A qualifying small hydro facility is defined as "Any hydroelectric facility, together with any related facilities located at the same project site, with an electric generating capacity of up to eighty megawatts." NY PSL § 2-c. A qualifying "alternate energy production facility is defined as "Any solar, wind turbine, fuel cell, tidal, wave energy, waste management resource recovery, refuse-derived fuel or wood burning facility, together with any related facilities located at the same project site, with an electric generating capacity of up to eighty megawatts, which produces electricity, gas or useful thermal energy." NY PSL Ser § 2-b.

[26] Id.

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

distributed to 'users,' in the plural."[28] The Burrstone Energy Project was held to qualify for regulatory exemption.

The *Burrstone* case is the only existing precedent of the Commission applying the "qualifying facility" standard to more than one user. One interpretation of this precedent might conclude that no upper bound exists on the number of users that may be served by a qualifying facility. This interpretation, however, may prove unwisely speculative. In the case of the Croton microgrid, it would be wise, as the petitioners in *Burrstone* did, to petition the Commission for a declaratory ruling that the multiple users anticipated in this microgrid do not run counter to the Commission's interpretation of PSL §2.

Distribution facilities at or near generation: The physical distance that distribution facilities may extend from generation facilities has been questioned in several Commission decisions applying the qualifying facility standard.[29] A limited review of prior cases interpreting the "at or near" requirement could suggest that a project will be deemed a qualifying facility if its distribution network is under two miles. However, this range might expand (or contract) depending on several types of variables, which the Commission has cited in previous precedent, including: whether the project site is in a densely or sparsely developed location; what type of technologies it uses (e.g., wind farm will naturally require a broader distribution network due to the acreage it takes up); and whether those facilities stay on private property or cross public rights of way.[30]

In the Croton microgrid, the geographic footprint of private distribution facilities may or may not satisfy the "at or near" test developed by the Commission, depending on where distribution facilities are required. The proposed properties in the Northern node appear to be within approximately two miles of each other. Private distribution facilities would have to cross property lines, and several rights of way. Declaratory rulings addressing facilities in comparable environments have met or exceeded this distance, such as *Burrstone* (approximately half a mile),[31] *Nissoquogue Cogen Partners* (1.5 miles),[32] and *Nassau District Energy Corporation* (1.7 miles).[33] Of these, the closest precedent may be the Burrstone case, because the Commission in Burrstone considered whether crossing multiple property lines complicated the "at or near" analysis (while Nissoquogue and NDEC involved distribution passing almost entirely over a single property). If private distribution across the entire Northern node were proposed, it would exceed the length for which the Commission has provided positive precedent, albeit by a small amount. If a smaller circuit of private distribution were proposed, it may better compare to precedent.

In light of the above factors, the Croton microgrid project may or may not satisfy the "at or near" requirement to achieve qualifying facility status. If the project wishes to secure its qualifying status, it must petition the Commission for a declaratory ruling to this effect.

ii. Lightened Regulation

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[28] Id.

[29] See NYSERDA, "Microgrids for Critical Infrastructure Resiliency in New York," (Dec. 2014), at 31.

[30] Id.

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

[32] Case 93-M-0564, In re Nissoquogue Cogen Partners, Declaratory Ruling (1993)

[33] Case 89-E-148, Nassau District Energy Association, Petition for a Declaratory Ruling (Sept. 27, 1989).

If the Croton project does not otherwise qualify for regulatory exemption, it may petition the Commission for a lightened regulatory burden. The Commission may consider a "realistic appraisal" of the need to regulate the microgrid based on a three-prong analysis: 1) whether a particular section of the PSL is inapplicable on its face; 2) if a provision is facially applicable, whether it is possible for an entity to comply with its requirements; and 3) whether imposing the requirements on an entity is necessary to protect the public interest, or whether doing so would adversely affect the public interest.[34] A realistic appraisal yields different results depending upon the microgrid's characteristics. The PSC recently applied the "realistic appraisal" test to the Eastman Park facility, which resembles a microgrid.[35] The precedent of microgrids receiving lightened regulatory burden under this standard is very thin, however, and it is difficult to prognosticate how this standard would be applied to the Croton project.

B) Future Regimes of Regulating Privately-Owned Microgrid Distribution Under Public Service Law

In its February 26th "Order Adopting Regulatory Framework and Implementation Plan,"[36] the Commission considered that a third model for regulating "community microgrids" with respect to the PSL might be appropriate. The Commission did not fully articulate how this model would function or make specific proposals. Parties were invited to comment on this matter on May 1st, 2015. The Croton microgrid project may be impacted by any future regulatory developments issued by the Commission pursuant to these comments or otherwise in REV.

II. Contractual Considerations for Various Ownership Models

The regulatory implications addressed in Section I make some distinction regarding who owns various types of microgrid infrastructure. As previously discussed, whether the utility or private parties own different types of microgrid assets may impact how they are treated by the Commission and under Public Service Law. However, setting aside State regulatory issues, there remain various contractual considerations that may impact how rights and responsibilities are aligned between microgrid parties. This section will consider those contractual questions.

Croton's microgrid proposal has not yet addressed which parties may have the appetite for ownership, the access to capital, expertise, or what the preferred ownership structure would be for other participants. This section therefore addresses the potential ownership models introduced in Section I in the abstract and notes the areas of contractual tension that may arise for these parties.

1. Contracting between Utility and Customer/Project Developer in a Utility-Owned DER/Generation Model

Wholly utility-owned microgrids may have several advantages over privately-owned microgrids, including ease of the interconnection process, the utility's superior access to capital, and ease of customer solicitation, given the utility's existing relationship with its customers. Examples of microgrids

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[34] Case 98-E-1670, In re Carr St. generating Station, Order Providing for Lightened Regulation, at 4–5 (Apr. 23, 1999).

[35] Case 13-M-0028, RED-Rochester LLC and Eastman Kodak Company, Order Approving Transfer Subject to Conditions, Providing For Lightened Ratemaking Regulation, and Making Other Findings (issued May 30, 2013).

[36] Case 14-M-0101, Order Adopting Regulatory Framework and Implementation Plan, Feb. 26, 2015, at 110.

where the utility owns at least some of the generation assets are the Consortium for Electric Reliability Technology Solutions (CERTS) demonstration project in Ohio, owned by American Electric Power,[37] and the Borrego Springs microgrid owned by San Diego Gas & Electric.[38] These projects, which take place in jurisdictions where rules regarding utility ownership of generation are more permissive, face lower regulatory burdens than utility-owned microgrids in New York may face. However, at least one New York project has proceeded under a utility-owned model, and others have been proposed in rate case settings.

In the Town of Denning, NY, Central Hudson Gas & Electric (Central Hudson) developed a microgrid system to serve an electric load center located more than 14 miles from the distribution substation after an evaluation of the electric service reliability of the area found service to be unacceptable. The microgrid's internal DER consists of a 1,000-kVA diesel engine—owned and operated by Central Hudson—which is capable of serving the total peak load of the feeder. After the utility evaluated electric service reliability in the area of concern and determined it was below acceptable standards, Central Hudson developed a comprehensive corrective action plan to improve reliability that evaluated four different options with their respective costs. One option evaluated was the microgrid proposal and the other three options involved more traditional measures that included rebuilding miles of electric distribution lines. Due to its rugged and remote terrain, additional transmission and distribution investments were not comparably cost effective, as well as being an environmentally inferior option.[39]

In other settings, utilities have proposed microgrid ownership as part of pilot projects. Consolidated Edison, for example, agreed as part of its 2013 rate case to convene a collaborative geared towards developing a microgrid pilot. Central Hudson, in its 2014 rate filing, proposed a utility-owned microgrid pilot that has not moved forward yet.

Given the general prohibition on utility-owned generation, Con Edison would have to show that a microgrid is the cheapest alternative to distribution upgrades required to maintain adequate service, as in Denning, or propose a utility-owned microgrid as a demonstration or pilot, possibly in the REV proceeding. In the present case, Croton does not appear to suffer service adequacy issues that would invoke the need to build a utility-owned microgrid purely for reliability purposes. It is likely that, if this project were to proceed as a utility-owned microgrid, it would need to seek a PSC approval as a demonstration project or pilot.

From a contracting perspective, utilities may have broad latitude to develop unique contracting arrangements directly with customers in a pilot or demonstration project. There do not exist model contract templates for microgrid service. In Central Hudson's microgrid proposal, for example, it proposed developing "a service agreement for a specified term under which the cost for [microgrid]

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[37] See "CERTS Microgrid Test Bed with American Electric Power," CERTS, available at. http://energy.lbl.gov/ea/certs/certs-derkey-mgtb.html.

[38] See "Microgrids: Benefits, Models, Barriers and Suggested Policy Initiatives for the Commonwealth of Massachusetts," DNV KEMA, at 6-3; and "Microgrids: An Assessment of Values, Opportunities, and Barriers to Deployment in New York State," NYSERDA, at A-2.

[39] Central Hudson Gas & Electric EPTD 1208 Program Proposal. See also NYSERDA, Microgrids for Critical Infrastructure Resiliency in New York (2015) at 122.

facilities would be recovered,"[40] but left open for collaborative discussions how this agreement would be structured. Customers will want to be concerned with the following aspects of contracting for microgrid service:

- Price of power
    - Potentially variable depending on customer class, demand level, and time of use
    - Potentially variable as linked to fluctuating operating costs, such as fuel prices
    - Value of tax credits, incentives, accelerated depreciation incorporated into rates or otherwise passed onto customers
- Customer obligation to take specific quantities of power or total system output over a given period
- Utility's obligation to produce certain quantities of project power over a given period
- Load shedding protocols
    - Price for varying levels of continued service in outage situation
- Penalties for non-performance or lateness in developing the project
- Ownership of RECs generated
- Any applicable terms relating to leasing customer land or facilities to microgrid owner
    - Insurance to cover damages to property
- Level of exit fees
- Allocation of interconnection costs
- Transferring service obligation to future property owners / encumbering property
- Potential joint-financing schemes (i.e., a municipal customer with a higher credit rating than utility may take lead on securing financing for some portion of project)

2. <u>Contracting between Utility and Customer/Project Developer in a Privately-Owned DER/Generation Model</u>

There does not presently exist a model tariff for utilities to provide islanding service to a group of customers served by privately-owned DERs. However, different microgrids have proposed to move forward under existing or novel tariffs with the incumbent utility to use utility distribution and rely on the utility to integrate with private microgrid controllers to support islanding functionality.[41]

In the Croton project, existing utility distribution infrastructure may be employed, where the project exports power under a community net metering tariff, a combination of standard net metering and buyback tariffs, or any novel microgrid tariff proposed and approved for REV demonstration purposes. In this case, key considerations would include:

- Applicable tariff under which different levels of power export will occur

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[40] Case 114-E-0318, Testimony of Reforming the Energy Vision Panel (July 25, 2014) at 14.

[41] See, e.g., discussion of the Parkville microgrid in NYSERDA's 2014 report, "Microgrids for Critical Infrastructure Resiliency in New York State," at 129, which states that "The Parkville Microgrid will also employ a buy/sell arrangement for the hybrid utility microgrid in addition to utilizing virtual net metering. The net excess energy produced by the reciprocating engine in the school that is not credited to another municipal account via virtual net metering will be purchased by the utility at applicable buy-back rates. The other microgrid users (i.e., the supermarket and gas station) will continue to buy their energy from the utility at their normal tariffs."

    - Any novel “microgrid wheeling charge” framework that compensates the utility for delivering power from one microgrid customer to the next and islanding the project during an outage.
- Rights of utility to access or control equipment and facilities to ensure operational safety (easements, fee for access, etc.)

3. Contracting between Customer and Private Developer

Privately-owned microgrids are permissible in New York, subject to the regulatory concerns around PSL regulation discussed in the previous section. See the Burrstone Energy Center case study in NYSERDA’s 2010 microgrid report.[42] A privately developed microgrid may be owned by a third-party developer with no pre-existing contractual relationship with the parties, or microgrid customers may collectively form a limited liability corporation for the purpose of owning and operating the microgrid on its customers’ behalf. In either case, contractual concerns for customers may include:

- Price of power
    - Potentially variable depending on demand, time of use
    - Potentially variable as linked to fluctuating operating costs, such as fuel prices.
    - Value of tax credits, incentives, accelerated depreciation incorporated into rates or otherwise passed onto customers
- Customer obligation to take specific quantities of power or total system output over a given period
- Developer’s obligation to produce certain quantities of power over a given period
- Load shedding protocols
    - Price for varying levels of continued service in outage situation
- Penalties for non-performance or lateness in developing the project
- Ownership of RECs generated
- Any applicable terms relating to leasing customer land or facilities to microgrid owner
    - Insurance to cover damages to property
- Fair exit fees
- Allocation of interconnection costs
- Transferring obligation to future property owners / encumbering property
- Potential joint-financing schemes (i.e., a municipal customer with a higher credit rating than developer may take lead on securing financing for some portion of project)
- Privacy of customer usage data
- Division of operational responsibilities
- Allocation of potential liabilities / indemnification of customers or developer
- Access rights to equipment/facilities (easements, fee for access, etc.)
- Purchase option at end of service term
- Division of interconnection costs between developer and customers

It is premature at this time to make a recommendation on ownership structure for the Croton project.

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[42] NYSERDA, “Microgrids: An Assessment of the Value, Opportunities, and Barriers to Deployment in New York State,” (Sept. 2010) at A-45.

Regulatory Issues and Tariffs

I. Franchises and Rights-Of-Way

All entities that require the use of public ways (i.e., for transmission or distribution facilities) must be granted permission by the presiding municipal authority in the form of a franchise or some lesser consent, depending on the scope of the usage. The cities, towns, and villages of New York have specific statutory authority to grant franchises: as provided by N.Y. Vil. Law § 4-412, every Village Board of Trustees is empowered to grant franchises or rights to use the streets, waters, waterfront, public ways, and public places of the city.[43] "Use" encompasses occupying public rights-of-way and operation of the provider's built infrastructure to provide the public service.[44]

In the village of Croton, the process for granting a franchise for electric distribution wires is governed by the village's Telecommunications Franchising and Licensing Provisions,[45] which applies to franchises for telecommunications as well as "other right of way authorizations."[46] The Telecom Code provides two avenues for securing rights to lay wire: a franchise or a revocable consent.

A revocable consent can be granted only up to 2,500 feet of wire,[47] (combining all separate revocable consents held by the applicant) which may or may not exclude granting a revocable consent for the full length of distribution required to connect the properties in this project. Separated by up to two miles at different points, the distribution required to connect the properties in question at either node may measure over 2,500 feet. Otherwise, a revocable consent may apply to a portion of the distribution required for this project if the rest were owned by the utility.

A franchise is not inhibited by the same length limits, but the Code suggests more expansive terms and conditions be applied to it, including: the Village's right to inspect; insurance and indemnification; compensation paid to the Village; provisions restricting assignment or transfer; and any other provisions the Village determines is appropriate in furtherance of the public interest.[48] The content of these terms and conditions is not specified in the Code, but is expected to be the subject of negotiations.

The factors and process for Village's review of the application either for a franchise or a revocable consent are the same. An application is submitted to the Village Manager and Village Attorney. Thereafter, the Board of Trustees is given broad latitude to make any investigations or take any steps it

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[43] N.Y. Vil. Law § 4-412.

[44] See, e.g., "Contract of April 7, 1887 between Hess et al. Commissioners & Consolidated Telegraph & Electrical Subway Co." (Con Tel and Electrical Subway Company Agreements 1886-1891.pdf)

[45] See Chapter 205 of Village of Croton-on-Hudson Code, available at http://ecode360.com/9144000.

[46] In its definitions, Chapter 205 appears to limit its application to franchises and revocable consents for the provision of telecommunications. However, an editor's note to the adoption of Chapter 205 notes that "The local law adopting the Chapter provided that to the extent permitted by law, the village may determine to apply all or certain provisions of the chapter to Telecommunications providers and franchises and other right-of-way authorizations existing on the effective date of this chapter." In any event, NY Vil. Law §4-412 provides the Village Board of Trustees similar authority to issue franchises, regardless of whether Chapter 205 applies specifically or not.

[47] Village of Croton-on-Hudson Code Chapter 205(3)(G).

[48] Village of Croton-on-Hudson Code Chapter 205(10).

deems appropriate to act on the application, including seeking additional information from the applicant or other advisory bodies. In doing so, the Board of Trustees is to consider:

1) The adequacy of the proposed compensation to be paid to the village, including the value of any facilities and telecommunications services offered by the applicant to the village.
2) The legal, financial, technical and other appropriate qualifications of the applicant.
3) The ability of the applicant to maintain the property of the village in good condition through the term of the franchise or the revocable license.
4) Any services or uses of the streets that may be precluded by the grant of the franchise or revocable license; and the adverse impact of the proposed franchise or revocable license on the efficient use of the streets or utilities at present and in the future.
5) The willingness and ability of the applicant to meet construction and physical requirements and to abide by all lawful conditions, limitations, requirements and policies with respect to the franchise or the revocable license.
6) The adequacy of the terms and conditions of the proposed franchise or revocable license agreement to protect the public interest, consistent with applicable law.
7) Any other public interest factors or considerations that the City has a lawful right to consider and that are deemed pertinent by the City for safeguarding the interests of the City and the public.[49]

The Board of Trustees has wide discretion to grant or deny the application after it has completed this review.

II. Application of Other Local Codes

1. Zoning

The candidates to receive microgrid service in Croton are zoned as follows:

- Municipal Building, 1 Van Wyck St., Croton-on-Hudson, NY 10520: O-1 Limited Office District
- Croton-Harmon High School, 36 Old Post Rd. South, Croton-on-Hudson, NY 10520: RA-5 One Family Residence District
- Pierre Van Cortlandt Middle School, 3 Glen Place, Croton-on-Hudson, NY 10520: RA-5 One Family Residence District
- Carrie E. Tompkins School, 5 Hughes St., Croton-on-Hudson, NY 10520: RA-25 One Family Residence District
- Croton Free Library, 175 Cleveland Dr., Croton-on-Hudson, NY 10520: RA-25 One Family Residence District
- Grand St. Fire Station, 154 Grand St., Croton-on-Hudson, NY 10520: RB Two Family Residence District
- Washington Fire Station, 82 North Riverside Ave., Croton-on-Hudson, NY 10520: C-1 Central Commercial District
- Harmon Fire House, 30 Wayne St., Croton-on-Hudson, NY 10520: C-2 General Commercial District

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[49] Village of Croton-on-Hudson Code Chapter 205(8).

- Phelps Memorial Medical Clinic, 440 South Riverside Ave., Croton-on-Hudson, NY 10520: C-2 General Commercial District
- Croton-on-Hudson Gulf, 67 Croton Point Ave., Croton-on-Hudson, NY 10520: C-2 General Commercial District (Gateway Overlay Zoning District)
- ShopRite Grocery and Pharmacy, 460 South Riverside Ave, Croton-on-Hudson, NY 10520: C-2 General Commercial District

Generation as Permitted Use in Croton

No zone in Croton lists electric generation as an expressly permitted use.[50] Generation must be approved either as an accessory use, a specially permitted use, or as a variance. Due to the identical relevant terms of each of the zones in question, this analysis will discuss how these three pathways function across all relevant zones.

Uses accessory to expressly permitted uses are allowed in all zones in Croton. "Accessory" in Croton's zoning code is defined as "A building or use clearly incidental or subordinate to and customarily in connection with the principal building or use on the same lot."[51] Accessory use is defined as "A use customarily incidental and subordinate to the main use on a lot, whether such accessory use is conducted in a principal or accessory building."[52] While in some jurisdictions, backup electric generation is considered an accessory use, it is uncertain that electric generation of a scale to be sold back to the grid or a microgrid operator in large quantities would be considered accessory to the principal uses of the districts in question. Whether power export is "customarily incidental" to other permitted uses of the properties in question poses, at least, some regulatory uncertainty.

Each zone also allows for "public utility structures" to be permitted by a special permit process requiring application, public hearing, and approval by the Board of Trustees. "Public utility structures" are not defined in the Code. Such structures would likely be limited to those owned by Con Edison, if the utility company were to engage in ownership of microgrid assets. Applications for special permit uses in Croton require a showing of cost-benefit analysis from the municipality's perspective and consistency with the Village Master Plan before being reviewed by the Planning Board and subjected to a public hearing. The Board of Trustees will ultimately issue the permit.[53]

If microgrid generation is not deemed accessory to the permitted uses of the district and is not granted a special use permit, the project would have to seek a variance. Croton's Code specifies that each variance applicant should meet four criteria:

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[50] Croton-on-Hudson Code §230. Of the zones in which proposed microgrid participants are situated, C-2 zones incorporate all of the permitted uses of C-1 zones, which do not permit generation, but do allow "public utility structures" by a special permitting process. O-1, RB, RA-25, and RA-5 zones each incorporate all of the permitted uses found in RA-60 zones, which also do not allow for electric generation, but which similarly offer a special permitting path for public utility structures. RA-60 zones also lend permitted "municipal uses" to each of the zones that incorporate its contents. "Municipal uses" is not defined, although there is little to suggest in the Code that it extends to electric generation at the scale contemplated for this microgrid.

[51] Croton-on-Hudson Code § 230-4.

[52] Id.

[53] Croton-on-Hudson Code § 230-57, 58, 59, 60.

(a) The applicant cannot realize a reasonable return, provided that lack of return is substantial as demonstrated by competent financial evidence;
(b) That the alleged hardship relating to the property in question is unique and does not apply to a substantial portion of the district or neighborhood;
(c) That the requested variance, if granted, will not alter the essential character of the neighborhood; and
(d) That the alleged hardship has not been self-created.[54]

These provisions are consistent with New York State precedent,[55] as well as State law incorporating that precedent. These requirements are unlikely to be satisfied for microgrid facilities, which may add value to the properties in question, but are not indispensable to the value of the properties in general.

<u>Zoning Solutions</u>: If electric generation for were added as a specially permitted use in each of the districts in which microgrid customers have been proposed, it would create a regulatory path forward while allowing the Zoning Board of Appeals to maintain some essential controls over the character and uses of affected neighborhoods. Some relevant considerations for policymakers and model language has been attached.

2. Fire Code

The Croton Fire Protection Code incorporates Subchapter C of the NYS Uniform Fire Prevention and Building Code, with no substantive additions.[56]

3. Building Code

The Croton Building Construction Code incorporates the NYS Uniform Fire Prevention and Building Code, the State Energy Conservation Construction Code and all other applicable laws, ordinances and regulations without any substantive addition that would affect distributed generation or local distribution facilities.[57]

4. Electric Code

Croton's Electrical Standards adopt the latest edition of the National Electrical Code (NFPA No. 70), as adopted by the National Fire Protection Association and as approved and adopted by the American Standards Association, with no substantive additions.[58]

5. Energy Conservation Code

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[54] Croton-on-Hudson Code §230-162(C).

[55] *See* Otto v. Steinhilber, 282 N.Y. 71 (1939). In that case, the owner of a parcel of property which was located in both a residential and commercial zone applied for a variance enabling him to use the entire parcel for a skating rink, which was a permitted commercial use. The lower court upheld the granting of the use variance, which ruling was affirmed by the Appellate Division. The Court of Appeals, the highest court in the State, reversed these holdings and in doing so, set forth the definitive rules that are still followed today.

[56] Croton-on-Hudson Code §125.

[57] Croton-on-Hudson Code §86-6.

[58] Croton-on-Hudson Code §113-4.

Croton's Energy Conservation Code establishes a property-assessed clean energy financing program (PACE)[59] as well as a Community Choice Aggregation Program. PACE financing is offered through the Village's Energy Improvement Corporation, is limited to 10% of the appraised property value, and requires the submission of an energy audit or renewable energy feasibility study. This opportunity may be of interest to microgrid customers pursuing on-site renewable generation or energy efficiency improvements.

The Village's CCA program is less developed. Adopted in July of 2015, the Village has designated Sustainable Westchester to solicit and review bids from ESCOs to act as power supplier for the Village's customers on an opt-out basis.[60] As this proposal moves forward, it may inform the value proposition for microgrid customers, as it poses a new potential "base case" for Croton's power cost and quality.

III. Applicable Tariffs

Distributed generation may be eligible for new tariffs for each of the customers at which DG is sited. This section outlines the various tariff structures one or several customers within the microgrid may fall under. This section builds on the discussion in Section I(2), which discussed tariffs under which power could be exported onto the utility grid, including net metering, buyback, offset, and potential future microgrid regimes.

1. Standby Tariff

Customers operating private generating facilities to cover part of their load while receiving backup or supplementary power from the utility will be subject to Con Edison's standby tariff[61] unless they are otherwise exempt.[62] Under current standby rate design, Con Edison recovers the cost of supplying supplemental power through three distinct charges: customer charges, contract demand charges, and daily as used demand charges. The customer charge is designed to recover certain fixed costs, such as metering expenses and administrative costs that do not vary with energy use. The customer charge shows up on the customer's bill as a fixed monthly charge.

The standby contract demand charge is intended to recover variable costs associated with distribution infrastructure dedicated to the customer (e.g. nearby infrastructure that only serves the single customer). The contract demand charge is based on the customer's maximum metered demand during some previous 12 month period of time. The charge is levied regardless of whether the customer's actual maximum peak demand approaches the level at which the charge is set. In 2015, Con Edison and Staff came to a rate case settlement that will establishment a performance incentive, lowering the contract demand charge, for customers running generation reliably. Con Edison was authorized to file

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[59] Croton-on-Hudson Code §114-1.

[60] Croton-on-Hudson Code §114-10.

[61] Located at http://www.coned.com/documents/elecPSC10/GR1-23.pdf#nameddest=gr20.

[62] In April 2015, the Commission expanded exemptions to standby rates, notably by permitting exemption for CHP system up to 15 MW. Exemptions also apply to fuel cells, wind, solar thermal, photovoltaic, biomass, tidal, geothermal, and methane waste-powered generation. See Case 14-E-0488, "Order continuing and Expanding the Standby Rate Exemption," (Apr. 20, 215).

amendments to its electric tariff schedules designed to implement the Standby Service provisions effective on a temporary basis July 1, 2015.[63]

The actual level at which the contract demand charge is set can be established by the customer or Con Edison. If the customer opts to set their own contract demand charge, penalties can be levied if the charge is exceeded, while a charge set by the utility is not subject to penalties. Exceedance penalties will result in a surcharge equal to between 12 to 24 times (depending on the level of exceedance) the sum of the monthly demand charges for the demand in excess of the contract demand.

The daily as-used demand charge is designed to recover the costs of distribution infrastructure needed to meet the entire system's demand peaks. Therefore, the charge is assessed based upon the customer's daily maximum metered demand during peak-hour periods on the macrosystem.

Standby rates are under reexamination as part of the REV proceeding. Staff has noted that "the methodology for allocating costs that determine the contract demand and as-used demand components of standby rates should be reviewed in this new [REV] context."[64] The manner in which these rates change cannot be forecast at this time.

2. Community Net Metering

In July 2015, the Public Service Commission established a community net metering regime[65] that is currently pending implementation through tariff revisions in Con Edison's territory. Qualifying generation assets include those that would be eligible under net metering (See Section I(2)(A) above). Under community net metering, a project sponsor could size eligible generators far beyond the demand of a host utility account and distribute retail-value net metering credit to a set of "subscribing" customers in the same utility service territory. This may be a substantial value-added to the rate paid on qualifying generation assets for power exported to the utility.

Note that the Commission's Order required at least 10 subscribing customers in a qualifying community net metering project, which threshold is currently met by the project's proposed microgrid customers.

3. Residential/Non-Residential DG Gas Rate

A distributed generation rate is established in Con Edison's territory, applying where "separately metered gas service is used solely for the purpose of the operation of a Distributed Generation Facility with a name plate rating less than 50 MegaWatts and having an Annual Load Factor equal to or greater than 50 percent."[66] This rate may be economically advantageous for CHP components of the microgrid, although customers should compare costs against a Transportation Rate or the price offered by a third-party gas marketer, as these may also propose a cost-effective solution.

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[63] Case 15-E-0050, "Order Adopting Terms of Joint Proposal to Extend Electric Rate Plan," (June 19, 2015).

[64] Case 14-M-0101, "Staff Whitepaper on Ratemaking and Utility Business Models," (July 28, 2015).

[65] Case 15-E-0082, "Order Establishing a Community Distributed Generation Program and Making Other Findings," (July 17, 2015).

[66] *See* Consolidated Edison's Rider H tariff, available at http://www.coned.com/documents/gas_tariff/pdf/0003(06)-General_Information.pdf#page=37.

3.1 Cost of Gas Service Upgrades

Microgrids that incorporate new natural gas-fired generators or CHP systems may require the delivery of substantially more natural gas to the site than was previously provided by the utility. If the additional natural gas demand exceeds the current infrastructure's capacity, the relevant natural gas mains, service piping and related facilities will need to be upgraded for the project to succeed. The requirements of utilities and gas upgrade applicants regarding gas service upgrades are governed by 16 NYCRR §230. Prior to any upgrades, the applicant must sign an agreement to assure the Con Edison that he/she will be a reasonably permanent customer, pay the utility for any installation and materials costs beyond the costs the utility is required to bear, and pay a rate for future gas delivery charged to similarly situated customers.[67] Section §230.2 outlines the "100 foot rule," which requires gas utilities to install up to 100 feet of main and service line extensions and related facilities at no cost to the applicants.[68] Utilities can bear the cost of extensions and additional facilities beyond 100 feet if the utility deems the expansion to be cost justified.[69] This situation, however, is relatively rare, and utilities will often require the applicant to pay for any installation and material costs beyond 100 feet.

Distributed generation that is designed to receive gas at high inlet pressures may be more economical in cases where it can receive gas service directly from the utility company's high pressure transmission lines, rather than the comparatively lower pressure distribution lines that service most customers.[70] This might save a customer-generator the cost of buying and maintaining gas compressors that raise the gas pressure to appropriate inlet levels. In such a case, the customer must typically apply to the utility company for a dedicated service line at high pressure connecting to the transmission line, which would be built and paid for under the same set of rules the govern gas service upgrades, described above.

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[67] 16 NYCRR § 230.2(b).

[68] 16 NYCRR § 230.2 (c), (d), and (e).

[69] 16 NYCRR § 230.2 (f). Methods for determining cost-justified upgrades are set forth in each utility's tariff. For example, Con Edison analyzes whether the projected net revenue derived from the potential customer will cover the cost to install the service line beyond the 100 ft. maximum. If so, Con Edison will provide line upgrades beyond 100 feet at no cost to the customer.

[70] Different types of natural-gas powered DG may or may not require higher pressure gas service. E.g., small scale reciprocating engines do not require high pressure gas lines to operate. A sub 500kwe unit may require 0.3(min)-0.8(max) PSIG input pressure. Small scale microturbines may require higher gas input pressure of about 75-80PSIG.

Relevant Considerations for Revising Zoning Codes to Establish a Special Permit for Microgrid Distributed Generation

A common barrier for microgrid development are zoning codes which are silent on siting distributed generation as either a permitted use, an accessory use, or a special permit use. While in many jurisdictions, on-site generation has been deemed an accessory use where it is used for back-up, particularly for critical infrastructure such as hospitals and municipal services, there is typically greater regulatory uncertainty where distributed generation is planned at a scale to provide significant export to other customers, as in a microgrid. Clarifying the type, size, and review process to site distributed generation through the zoning code may greatly expand opportunities for microgrid development.

Policymakers will be concerned to adjust zoning codes broadly enough to permit microgrids of appropriate technical configurations, and narrowly enough to preserve the essential character of the districts in question. To balance these concerns, we recommend:

1. The definition of a microgrid be incorporated into the definitions section of the zoning code. This will allow the code to later limit the circumstances in which an applicant can site distributed generation substantially larger than their on-site load to circumstances where that power will support other local customers.
2. Permitted microgrid generation technologies should be incorporated into the definitions section of the zoning code, and fashioned broadly enough to support appropriate technical configurations. For example, the code should explicitly permit natural gas fired combined heat and power systems, but may wish to restrict diesel generation.
3. The siting of qualified microgrid generation should be added as a specially permitted use to each of the districts in question, subject to a comparable review by the Zoning Board of Appeals as other specially permitted uses. The standard for permitting microgrid generation by the Zoning Board of Appeals should be more lenient than granting a variance. For example, the granting of a special permit for microgrid generation may be contingent on a showing that the generation will:
    a. Be sited on a lot of a certain size and not occupy over a certain percentage of the square footage of that lot. For certain technologies, such as solar, the code may place other appropriate restrictions on siting, explored further below.
    b. Be designed, enclosed, painted or colored and screened so that it is harmonious with the area in which it is located.
    c. Be landscaped and maintained in conformity with the standards of property maintenance of the area.
    d. Be surrounded by protective fencing and gates.
    e. Comply with appropriate limitations on capacity, noise, or emissions for the district in which sited.

    The special permit process should not, however, require a showing of economic hardship in the absence of the permit, as is typically required for a variance.

It is beyond the scope of this feasibility study to prescribe exactly how policymakers may wish to restrict the siting of microgrid generation in their zoning codes in each district. We offer model language addressing several of the points identified above from other jurisdictions for consideration.

Defining Microgrids

New York State has adopted the US Department of Energy's definition of microgrids, which is "A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and that connects and disconnects from such grid to enable it to operate in both grid-connected or island mode."

We recommend this definition be applied in the zoning context.

Defining Permitted Microgrid Generation Technologies

Zoning codes should at least permit the breadth of technologies identified, e.g., in the definition of "Renewable Energy Systems" from the Portland, Oregon zoning code,[71] although we recommend a broader scope of permitted generation, including all CHP systems, and diesel generation designed to run solely in back-up scenarios. While Portland's code specifies maximum sizes of certain types of generation, we recommend that such restrictions be determined on a district-by-district basis. A hospital with a 5 MW load, e.g., may be a more appropriate site for a large CHP generator than a residential area, where smaller renewables may play a role.

Portland's definition of "Renewable Energy System" follows:

> **Renewable Energy System**. Energy production where the energy is derived from the following:
>
> 1. Solar;
> 2. Small wind energy turbines;
> 3. Geothermal;
> 4. Hydroelectric systems that produce up to 100 kW;
> 5. Waste heat capture, heat exchange or co-generation of energy as a byproduct of another manufacturing process;
> 6. The following systems that use only biological material or byproducts produced, harvested or collected on-site. Up to 10 tons a week of biological material or byproducts from other sites may be used where the base zone regulations specifically allow it:
>
> - Biogas. Generation of energy by breaking down biological material in anaerobic conditions to produce gas that can be used to generate electricity or heat. The process generally occurs inside a closed system such as a tank or container.
> - Biomass. Generation of energy through the combustion of biological material to produce heat, steam, or electricity.
>
> 7. Any of the methods listed here or natural gas used to produce steam, heat or cooling, with an output up to 1 megawatt.

Special Permitting Restrictions on Siting

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[71] Portland Oregon Code section 33.910, available at https://www.portlandoregon.gov/bps/article/53500.

Different sizes and types of microgrid generation may be subject to different restrictions on where and how they can be sited. Butte County, California, for example, has developed a tiered set of siting restrictions for solar installations of different sizes and types. A similar exercise may be helpful for other types of generation.[72]

Developing sophisticated restrictions tailored to each type of generation and each district in which it may be sited may be time-intensive and unnecessarily delay projects, however. We recommend it as a long-term regulatory goal. In the short term, many microgrids may benefit from simply being permitted to site generation within existing facilities in such a way that they will not be noticeable to the public. As an immediate measure, we recommend the zoning code permit generation that can be entirely contained within existing buildings and structures on the property.

Butte County's Solar Zoning Ordinance follows:

> **Tier 1.** A roof-mounted Solar Electric System used to power on-site primary or accessory uses located on structures or placed over parking lots or a ground mounted Solar Electric System up to one-half acre in size. Tier 1 includes building-integrated photovoltaic systems where the Solar Electric System is part of the building materials used in the construction of on-site primary or accessory structures.
>
> **Tier 2.** A ground-mounted Solar Electric System used to power on-site primary or accessory uses, limited to less than 15 percent of the parcel's size up to 5-acres, whichever is less, with less than 50 percent of the power generated being used off-site.
>
> **Tier 3.** A ground-mounted Solar Energy System, limited in Agriculture zones to "Grazing Land" and "Other Land" as defined under the latest mapping under the California Department of Conservation Division of Land Resource Protection Farmland Mapping and Monitoring Program, not subject to a Williamson Act Contract, and limited to less than 30 percent of a parcel's size up to 20 acres maximum with 50 percent or more of the power generated for on-site primary and accessory uses, with the remainder of the power delivered off-site.
>
> **Tier 4.** A ground-mounted Solar Energy System limited in Agriculture zones to "Grazing Land" and "Other Land" as defined under the latest mapping under the California Department of Conservation Division of Land Resource Protection Farmland Mapping and Monitoring Program, and not subject to a Williamson Act Contract, where most or all power generated is delivered off- site with little or no on-site use.

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[72] Butte County Zoning Code, Chapter 24-157, available at https://www.buttecounty.net/Portals/10/Docs/Zoning/ButteZoningOrdinance2015-06.pdf.

Site 30 – Village of Croton-on-Hudson

PROJECT OVERVIEW

As part of NYSERDA's NY Prize community microgrid competition, the Village of Croton-on-Hudson has proposed development of a microgrid that would enhance the resiliency of electric service for the following facilities in this Westchester County community:

- The Municipal Building (which houses the community's Police Department in addition to other offices);
- The Croton Free Library;
- The Carrie E. Tompkins Elementary School, the Croton-Harmon High School, and the Pierre Van Cortlandt Middle School, all of which are designated as community shelters in the event of an emergency;
- The Emergency Medical Services (EMS) Station;
- The Grand Street Fire Station, the Harmon Fire Station, and the Washington Fire Station;
- The Phelps Memorial Medical Clinic;
- ShopRite Grocery and Pharmacy; and
- The SelectFuel Gas Station.

The microgrid would incorporate combined heat and power CHP and solar capabilities to provide base load power. Ten CHP units would be distributed among the participating facilities, and would range in capacity from 0.005 to 0.13 MW; of these, eight would burn natural gas and two would burn diesel. Solar capability would supplement the microgrid, with PV equipment distributed among the facilities. The solar installations would add 0.589 MW of capacity to the microgrid. In addition, a battery storage system and energy efficiency measures would be incorporated in each node of the microgrid; the total battery capacity included in the microgrid is 190 kWh.[73] The operating scenario submitted by the project's consultants indicates that these new resources together would produce approximately 3,970 MWh of electricity per year, roughly 85 percent of the amount required to meet the average annual demand of the facilities listed above. During a major outage, the project's consultants indicate that the microgrid system would supply 100 percent of average electricity use at the facilities served by the

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[73] In addition to these resources, the microgrid will incorporate the emergency generators that currently serve the facilities listed above. These units, however, would only be relied upon in extreme circumstances, would not operate on a regular basis, and are not considered integral to the design of Croton's microgrid. Also, an existing PV solar array at the SelectFuel gas station with .015 MW of capacity would be integrated into the microgrid; the operating profile of the existing PV would not be expected to change with the implementation of the microgrid.

microgrid.[74] They also indicate that the system would be capable of providing ancillary services to the grid.

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.

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.[75] It also

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[74] As noted previously, the capacity of the new resources appears sufficient to supply 85 percent of average daily electricity use at facilities within the microgrid's island; the remainder would presumably come from the existing PV and the emergency generators incorporated in the microgrid.

[75] 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

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.[76]

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 2.3 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

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.]

[76] 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.

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: 2.3 DAYS/YEAR
Net Benefits - Present Value	-$4,410,000	$193,000
Benefit-Cost Ratio	0.6	1.0
Internal Rate of Return	-15.6%	6.5%

Scenario 1

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

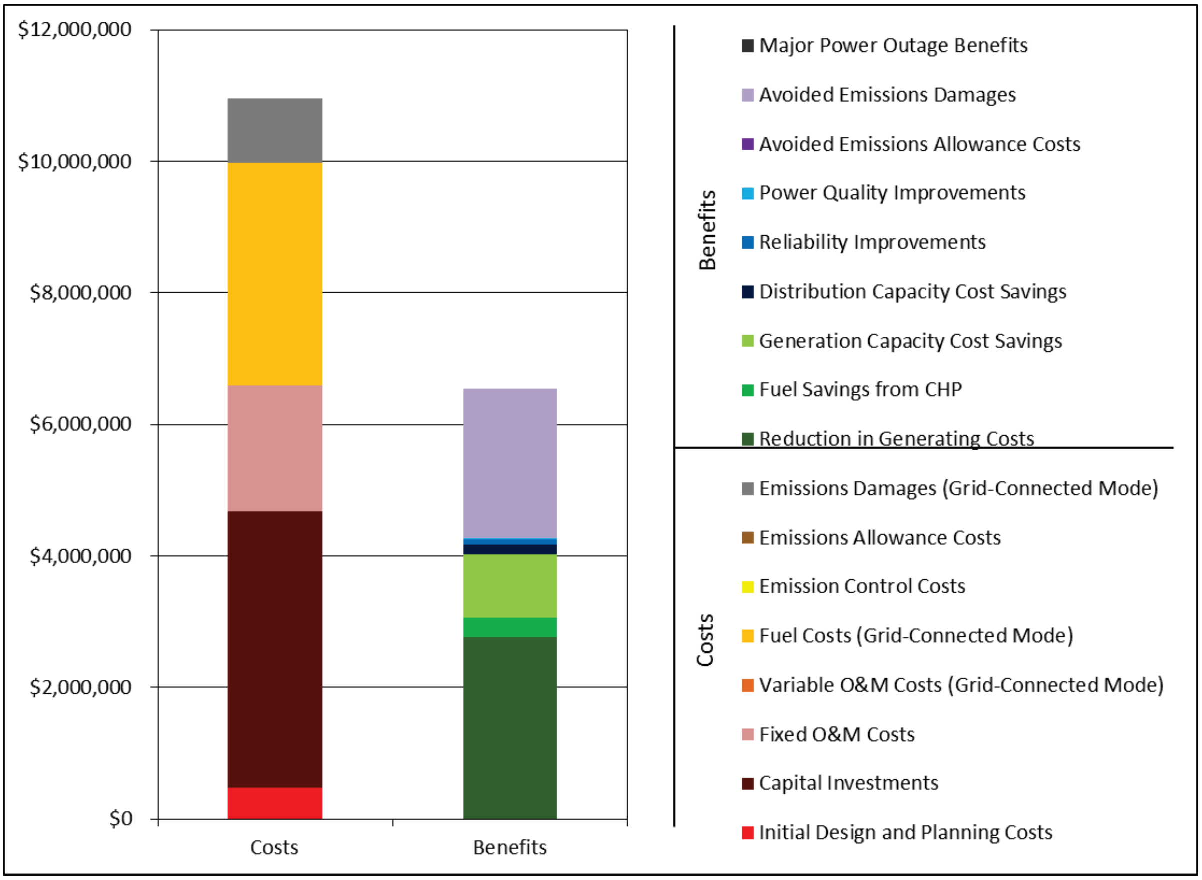

Figure 1. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

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	$475,000	$41,900
Capital Investments	$4,210,000	$344,000
Fixed O&M	$1,900,000	$168,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$3,390,000	$299,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$978,000	$63,900
Total Costs	**$10,900,000**	
Benefits		
Reduction in Generating Costs	$2,770,000	$244,000
Fuel Savings from CHP	$290,000	$25,600
Generation Capacity Cost Savings	$970,000	$85,600
Distribution Capacity Cost Savings	$142,000	$12,600
Reliability Improvements	$82,600	$7,290
Power Quality Improvements	$17,600	$1,550
Avoided Emissions Allowance Costs	$1,360	$120
Avoided Emissions Damages	$2,270,000	$148,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$6,530,000**	
Net Benefits	**-$4,410,000**	
Benefit/Cost Ratio	**0.6**	
Internal Rate of Return	**-15.6%**	

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

$475,000.[77] The present value of the project's capital costs is estimated at approximately $4.21 million, including costs associated with installing the new CHP units, PV arrays, battery storage, and associated microgrid infrastructure (controls, communication systems, information technology, etc.). 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 $1.90 million, based on an annual cost of $168,000.

Variable Costs

A significant variable cost associated with the proposed project is the cost of natural gas and diesel to fuel operation of the system's 10 CHP units. 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.[78] Based on these figures, the present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $3.39 million.

In addition, the analysis of variable costs considers the environmental damages associated with pollutant emissions from the distributed energy resources that serve the microgrid, based on the operating scenario and emissions rates provided by the project team and the understanding that none of the system's generators would be subject to emissions allowance requirements. In this case, the damages attributable to emissions from the microgrid's CHP units are estimated at approximately $63,900 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 $978,000.

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 $2.77 million; this estimate takes into account both the electricity that the microgrid's CHP units and PV arrays would produce and an anticipated reduction in annual electricity use at the facilities the microgrid would serve.[79] In addition, the new CHP systems would cut consumption of natural gas for heating purposes; the present value of these savings over the 20-year period analyzed is approximately $290,000. The reduction in demand for electricity from bulk energy suppliers would also reduce the emissions of air pollutants from these facilities, yielding

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[77] The project consultants note that this estimate is based on the costs of developing the power purchase agreement (PPA), negotiating other contracts, and arranging financing and insurance. It represents an average cost estimate; the actual costs ultimately incurred may be higher or lower, depending on the complexity of the site.

[78] 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.

[79] The project's consultants anticipate an annual reduction in electricity consumption of four percent due to energy efficiency upgrades included with the microgrid.

emissions allowance cost savings with a present value of approximately $1,360 and avoided emissions damages with a present value of approximately $2.27 million.[80]

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.[81] Based on application of standard capacity factors for the CHP units, as well as the capacity of the battery storage systems, the analysis estimates the present value of the project's generating capacity benefits to be approximately $970,000 over a 20-year operating period. Similarly, the project team estimates that the microgrid project would reduce the need for local distribution capacity by approximately 0.34 MW/year, yielding annual benefits of approximately $12,600. Over a 20-year period, the present value of these benefits is approximately $142,000.

The project team has indicated that the proposed microgrid would be designed to provide ancillary services to the New York Independent System Operator (NYISO). Whether NYISO would select the project to provide these services depends on NYISO's requirements and the ability of the project to provide support at a cost lower than that of alternative sources. Based on discussions with NYISO, it is our understanding that the markets for ancillary services are highly competitive, and that projects of this type would have a relatively small chance of being selected to provide support to the grid. In light of this consideration, the analysis does not attempt to quantify the potential benefits of providing this service.

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 $7,290 per year, with a present value of $82,600 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:[82]

- System Average Interruption Frequency Index (SAIFI) – 0.11 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 181.2 minutes.[83]

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[80] 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.

[81] 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.

[82] www.icecalculator.com.

[83] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for Consolidated Edison.

The estimate takes into account the number of small and large commercial or industrial customers the project would serve; the distribution of these customers by economic sector; average annual electricity usage per customer, as provided by the project team; and the prevalence of backup generation among these customers. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.[84] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

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

Power Quality Benefits

The power quality benefits of a microgrid may include reductions in the frequency of voltage sags and swells or reductions in the frequency of momentary outages (i.e., outages of less than five minutes, which are not captured in the reliability indices described above). The analysis of power quality benefits relies on the project team's best estimate of the number of power quality events that development of the microgrid would avoid each year. The [Croton] team estimates that the facilities served by the microgrid would avoid an average of 0.156 such events annually. The model estimates the present value of this benefit to be approximately $17,600 over a 20-year operating period.

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. It calculates the economic damages that development of a microgrid would avoid based on

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

(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.[85,86]

As noted above, the Village of Croton-on-Hudson's proposed microgrid project would serve 12 facilities, including the Municipal Building, the Croton Free Library, three public schools, three fire stations, the EMS station, a medical clinic and two commercial facilities. In the event of an extended outage, the Croton Free Library and the Washington Fire Station would be expected to close. The project's consultants indicate that at present, all three public schools, two of the fire stations, the EMS station, the Municipal Building and the ShopRite Grocery and Pharmacy are equipped with backup generators. If an extended outage occurred, the Phelps Memorial Medical Clinic and the SelectFuel gas station would rent backup diesel generators (assuming rental units were available). If these generators failed or if rental units were unavailable, all supported facilities would experience a complete loss in operating capabilities.

The information provided above serves as a baseline for evaluating the benefits of developing a microgrid. Specifically, the assessment of Scenario 2 makes the following assumptions to characterize the impacts of a major power outage in the absence of a microgrid:

- The Municipal Building, Harmon Fire Station, Grand Street Fire Station and the EMS Station would rely on their existing backup generators, experiencing no loss in service capabilities while these generators operate. If the backup generators fail, EMS staff and operations in the municipal building would relocate to the Harmon Fire Station at a one-time cost of $500, while the fire stations would experience a 30 percent loss of service while operating on rental generators.

- The three public schools would experience a 20 percent loss in service capability and the ShopRite Grocery and Pharmacy would experience a 40 percent loss in service capability while operating on their backup generators. In addition, during heating season (four months per year), the project's consultants estimate additional costs of $5,000/day per facility to run diesel generators to heat the school buildings, which would be used as emergency shelters.

- During a major outage, Phelps Memorial Medical Clinic and the SelectFuel Gas station would experience a 50 percent loss in service capability while operating with rental generators.

- The Croton Free Library and the Washington Fire Station would close, experiencing a total loss of service.

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[85] 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.

[86] 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.

- The Police department (located in the Municipal Building) would not be expected to experience a loss in service; the project consultants indicate that additional officers would be working during a major outage and the effectiveness of police services would not decline.

- In all cases, the supply of fuel necessary to operate the backup generators would be maintained indefinitely.

- In all cases, there is a 15 percent chance that the backup generator would fail.

The consequences of a major power outage also depend on the economic costs of a sustained interruption of service at the facilities of interest. The analysis calculates the impact of a loss in the village's fire and emergency medical services using standard FEMA methodologies. The impact of a loss in service at the remaining facilities is based on the following value of service estimates:

- For the Municipal Building, Phelps Memorial Medical Clinic, the Croton Free Library, ShopRite Grocery and Pharmacy, and SelectFuel gas station, a total value of approximately $279,000 per day. This figure was estimated using the ICE Calculator, assuming 24 hours of microgrid demand per day during an outage.[87]

- For the three schools, which will act as emergency shelters during an extended outage, a total value of approximately $165,000 per day. This figure is based on an estimate of the facilities' shelter capacity (3,300 people across all three facilities) and a standard value from the Red Cross of $50 per person per day for food and shelter.[88,89]

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 2.3 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.

Figure 2. Present Value Results, Scenario 2 (Major Power Outages Averaging 2.3 Days/Year; 7 Percent Discount Rate)

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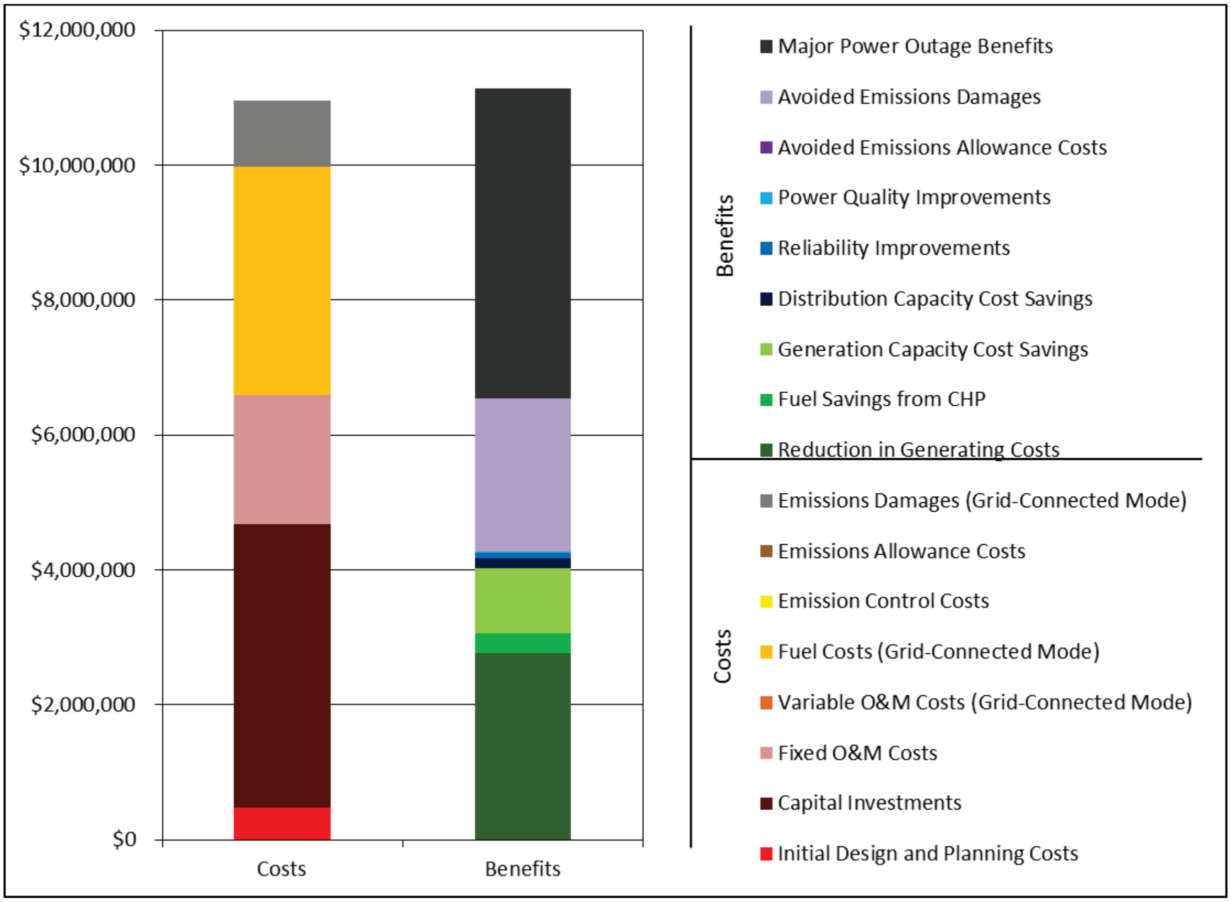
[87] http://icecalculator.com/.

[88] We estimate the shelter's capacity based on the project team's estimate of square footage available and a standard value of 40 square feet per person for shelter (for more than 72 hours). The 40 square feet per person assumption is from: FEMA. 2010. Guidance on Planning for Integration of Functional Needs Support Services in General Population Shelters. Accessed March 17, 2016 at https://www.fema.gov/pdf/about/odic/fnss_guidance.pdf.

[89] The standard value from the Red Cross of $50 per person per day for food and shelter is from: American Red Cross. 2014. Fundraising Dollar Handles for Disaster Relief Operations. Revised March 2014 based on FY14 figures. Accessed March 17, 2016 at http://www.redcross.org/images/MEDIA_CustomProductCatalog/m30240126_FY14FundraisingDollarHandles.pdf.


$12,000,000
$10,000,000
$8,000,000
$6,000,000
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$0
Costs
Benefits
Benefits
Major Power Outage Benefits
Avoided Emissions Damages
Avoided Emissions Allowance Costs
Power Quality Improvements
Reliability Improvements
Distribution Capacity Cost Savings
Generation Capacity Cost Savings
Fuel Savings from CHP
Reduction in Generating Costs
Costs
Emissions Damages (Grid-Connected Mode)
Emissions Allowance Costs
Emission Control Costs
Fuel Costs (Grid-Connected Mode)
Variable O&M Costs (Grid-Connected Mode)
Fixed O&M Costs
Capital Investments
Initial Design and Planning Costs

Table 4. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 2.3 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$4,210,000	$344,000
Fixed O&M	$1,900,000	$168,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$3,390,000	$299,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$978,000	$63,900
Total Costs	**$10,900,000**	
Benefits		
Reduction in Generating Costs	$2,770,000	$244,000
Fuel Savings from CHP	$290,000	$25,600
Generation Capacity Cost Savings	$970,000	$85,600
Distribution Capacity Cost Savings	$142,000	$12,600
Reliability Improvements	$82,600	$7,290
Power Quality Improvements	$17,600	$1,550
Avoided Emissions Allowance Costs	$1,360	$120
Avoided Emissions Damages	$2,270,000	$148,000
Major Power Outage Benefits	$4,610,000	$406,000
Total Benefits	**$11,100,000**	
Net Benefits	**$193,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.5%**	

APPENDIX E: CONSOLIDATED EDISON COMMENTS AND RESPONSES

Following the completion of the feasibility analysis, the project team received additional comments from Consolidated Edison upon their full review. The Consolidated Edison comments, and the project team's responses are below.

Metrics and Characteristics

Characteristics	ConEd Observation	Community Response/Comment
Number of PCC	12 PCC	There are only eight PCC – we removed the pumping station nodes with EDG/EGG
CHP capacity	565 kW	-
PV capacity	279 kW	Actually 604 kW
Storage capacity	140 kWh	Actually 190 kWh
Existing Load	2,090 kW peak	2,090 kW is the peak demand, however the load is actually 4,671,857 kWh/yr or 533 kW average demand
Load support by Microgrid (%)	56% (1,169 kW, without storage), ?% with storage	Actual annual production from resources is 3,968,552 kWh, or 85% of the load. The battery is a grid resource with capacity support, but should not be considered a production device for load.
Control system details	Wireless microgrid controller	-
Black-Start Capability	Yes	-
Ownership model/suggestions	Third-party owner	-
New Feeders/distribution lines	No	-
Site geographical distribution	Disbursed throughout Croton	-

Utility Comments and Project Team Responses

Category	ConEd Comment	Community Response/Comment
Relative ease of interconnection?	Very difficult, 12 PCC	The number of PCC's is large, but the technical approach is identical in each. Interconnection study on one is highly replicable to the other seven.
Adhere to guidance of utility?	No. Did not consider the interconnection difficulties with Con Edison.	We considered the Interconnection difficulties. But, each of the PCC technical solutions is identical, and we have all the protection ConEd requires including Reverse Power Trip on all PCC's.
Working within existing tariffs/rates/specs?	Wants a new wheeling charge tariff (similar to offset or net-metering)	We will not be sending energy to the ConEd grid. We see no need for special tariff.
Area station benefits?	No	We would suggest there are area station benefits, because a 0.4 MW reducing in load on the substation would extend its lifetime – T&D deferment. In addition, microgrid resources can help reduce peak demand, variability from other PV within the substation area, and support CVR, voltage, VAR, and frequency.
Local area benefits?	No	We would suggest that there are local area benefits because the microgrid cuts emissions as a benefit to society.
Additional comments?	- No equipment in this project qualifies for SC-11 or offset tariff since everything is low voltage. - No daily load analysis shown.	The project team developed full 8760 hour load analysis for the Croton Community Microgrid, and it is available upon request.

APPENDIX F: ACRONYM GLOSSARY

- ATS- automatic transfer switch
- BCA – benefit cost analysis
- CCA- community choice aggregation
- CHP- combined heat and power plants
- CRCC- Central Regional Control Center
- DER- Distributed Energy Resources
- DHW- domestic hot water
- DMS- distribution management system
- EDG- emergency diesel generator
- EEM- energy efficiency measures
- EGG- emergency gas generator
- EPC- Engineering Procurement Contractor
- EPRI- Electric Power Research Institute
- ESS- energy storage systems
- GHG- greenhouse gases
- IEEE- Institute of Electrical and Electronics Engineers
- ISO- independent system operators
- ITC- Investment Tax Credit
- kW- kilowatt
- kWh- kilowatt hour
- LAN- local area network
- Li-ion- lithium ion
- NOC - Network Operations Center
- NREL- National Renewable Energy Laboratory
- NYSERDA- New York State Energy Research and Development Authority
- O&M- operations and maintenance
- ORNL- Oak Ridge National Laboratory
- PCC - point of common coupling
- PLC- programmable logic controller
- PME- pad mounted enclosures
- PPA- power purchase agreement
- PV- solar photovoltaics
- REV- Reforming the Energy Vision
- RFI- request for information
- RFP- request for proposals
- RTO- Regional Transmission Organizations
- SGIP- Smart Grid Interoperability Panel
- SOC- state of charge
- SPE- special purpose entity