31 - Village of Mamaroneck

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Village of Mamaroneck Microgrid Feasibility Assessment

Task 5 Report: Comprehensive Summary of Task 1-4

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Table of Contents

Acronyms and Abbreviations List

ATS	Automatic Transfer Switch
AHU	Air Handler Unit
BMS	Building Management System
CHP	Combined Heat and Power
CFL	Compact Fluorescent Bulb
CHW	Chilled Water
CHP	Combined Heat and Power
CIM	Common Information Model
CNG	Compressed Natural Gas
CPU	Central Processing Unit
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System
DMS	Distribution Management System
DRMS	Demand Response Management System
EPS	Electric Power System
ESS	Energy Storage System
ETL	Extract, Transform, Load
FAN	Field Area Network
FDA	Food and Drug Administration
GIS	Geographical Information System
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
HHW	Heating Hot Water
HVAC	Heating Ventilation and Air Conditioning
ISO	Independent Service Operator
JMS	Java Message Service
LMC-TV	Larchmont-Mamaroneck Community Television
LED	Light Emitting Diode
LLC	Limited Liability Corporation
LTE	Long-Term Evolution
O&M	Operations & Maintenance
OMS	Outage Management System
PCC	Point of Common Coupling
PCS	Power Conditioning System
PLC	Power Line Communications
PME	Pad Mount Equipment
PTAC	Packaged Terminal Air Conditioner
PV	Photovoltaic
REV	Reforming Energy Vision

RTU	Roof Top Unit
SAIFI	System Average Interruption Frequency index
SCADA	Supervisory Control and Data Acquisition
VRF	Variable Refrigerant Flow
VRV	Variable Refrigerant Volume
VOM	Village of Mamaroneck
WAN	Wide Area Network

Executive Summary

The following report details work performed in Task 1 through 4 of the NY Prize feasibility study for the Village of Mamaroneck community-shared microgrid. This report shows the design and evaluation path that was taken to arrive at the proposed Fenimore-Waverly microgrid design which includes a 750kW natural gas generator and 850kW of roof mounted PV aggregated capacity that can provide uninterruptable electricity for a group of buildings on Waverly Ave and Fenimore Rd. Critical facilities in the area include Arctic Glacier Ice (local ice manufacturer) and Mamaroneck self-storage (facility that can be used during emergencies as place of refuge and a reserve government command & communications center).

The Village of Mamaroneck is a flood prone area that has suffered damaging effects from several severe weather events dating back to spring of 2007 exacerbated by the burgeoning impervious surfacing due to development from White Plains down to Mamaroneck Village. The area surrounding Fenimore Rd and Waverly Ave is currently undergoing major redevelopment in an effort to control flooding issues and to spur economic growth. Through work with FEMA and the Army Corp of Engineers, a water risk mitigation study was completed and the local Village government is working to implement the proposed water management improvements. The "Industrial Area Redevelopment Plan" occurring in this area provides an ideal environment for a microgrid that can strengthen the grid and maintain critical services to the growing community.

During Task 1, the team was initially considering a wide array of buildings to include in the microgrid across several areas in the Village of Mamaroneck. Initial target buildings included Artic Glacier Ice, three gas stations, Mamaroneck self-storage facilities, LMC-TV, the town hall, the police station, and the fire station (Table 1). After discussion with Con Edison engineers about working all potential facilities into one grid system, the team eventually concluded that buildings needed to be grouped into smaller microgrid designs based on proximity and existing feeder layout.

Table 1. Critical Facilities Initially Considered for the Fenimore-Waverly Microgrid

Facility	Address
VOM Village Hall	123 Mamaroneck Ave
VOM Fire Dept. Headquarters	146 Palmer Ave
VOM Police Dept. Headquarters	169 Mt. Pleasant Ave
Artic Glacier Ice	500 Fenimore Rd
Vincent's Service Station	636 Fenimore Rd
Lebrini's Service Station	711 Fenimore Rd
Sunoco Service Station	245 Mamaroneck Ave
Mamaroneck Self Storage (Proposed microgrid site)	416 Waverly Ave
Larchmont-Mamaroneck Community Television (LMCTV)	740 West Boston Post Rd

As the team worked through the technical design analysis during Task 2, the target buildings had been broken into two separate potential microgrid areas: Waverly-Fenimore (Mamaroneck Self-Storage, Arctic Glacier Ice) and Mamaroneck Ave (village hall, residential at the Regatta, LMC-TV). A building level analysis was performed for each of the facilities based on available meter data. Generation and grid layout options were evaluated based on existing grid infrastructure. Based on grid interconnect capabilities, the team decided to concentrate efforts on the Fenimore-Waverly area and completed a technical design analysis that included creating preliminary schematics for distributed generation communications and control layout.

During Task 3, the team analyzed the commercial and financial feasibility of the Fenimore-Waverly design proposed during Task 2. Efforts included developing preliminary cost models and business operation plans. Working with Industrial Economics Corporation, a detailed financial analysis was completed; these results are presented in the Task 4 section of this report. The task 1-4 reports illustrate how the design evolved throughout the feasibility study and provide support for the proposed Fenimore-Waverly design.

The research team that was involved in developing content for this report includes members of: Steven Winter Associates, Murphy Brothers Contracting, the Village of Mamaroneck, Delta Group, Spirae, Robison & Cole LLP, and several additional community members and technical consultants. The outcome of this study is a preliminary technical and business design concept for a microgrid to be constructed on Waverly Ave and Fennimore Rd in Mamaroneck, NY, to be housed and operated by Murphy Brothers Contracting within Phase Two of the Mamaroneck Self-Storage master plan. Based on the results of the study, the team is currently pursuing additional funding to further develop the design and implementation plan.

1 Task 1 Development of Microgrid Requirements and Preferred Capabilities

During Task 1, the team discussed and analyzed the minimum required and preferred capabilities of the microgrid through a series of email and phone conversations, a cogeneration plant site visit, a meeting with the Village of Mamaroneck (VOM) critical facilities, and a meeting with technical design team members. The initial intent of the design team was to include critical facilities within ½ mile radius of Murphy Brother's self storage facility, the intended location of the microgrid equipment and controls. However, investigation into grid layout, costs to connect facilities, and existing infrastructure led the team to limit the size of the microgrid to facilities much closer to the self storage facility.

1.1 Minimum Required Capabilities

1.1.1 Critical Facilities

After deciding that the most practical grid integration opportunity was in the Fenimore-Waverly microgrid area, the critical facilities were reduced to Arctic Glacier Ice and Mamaroneck Self Storage – as summarized in Table 2. A map of the area with selected facilities indicated with a red dashed circle is shown in Figure 1.

Table 2. Critical Facilities in Fenimore-Waverly Microgrid

Facility	Address
VOM Village Hall	123 Mamaroneck Ave
Artic Glacier Ice	500 Fenimore Rd

Mamaroneck Self Storage (Proposed microgrid site)	416 Waverly Ave

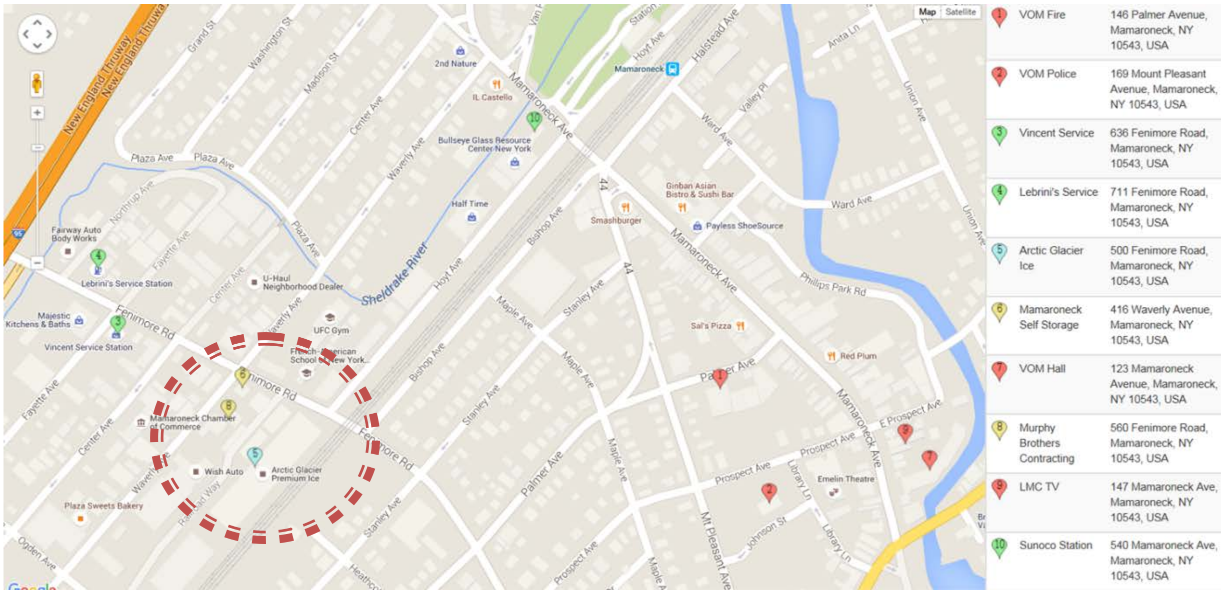

Figure 1. Map of Proposed Critical Facilities

During Task 1, the team worked with the VOM mayor to identify additional facilities that may need emergency power to keep the local government operational during grid power loss events. During the critical facility meeting held on August 18th, 2015, the group discussed several other buildings that may be beneficial to add into the grid. These include: the VOM public works building, VOM Emergency Medical Services building, and LMC TV (local community cable channel). Figure 1 displays a map of each of the critical facilities initially under consideration.

Table 3 summarizes the gas and electric utility information that SWA had access to at this stage of the study. All initial sites provided SWA with utility release forms, however, there were some challenges in obtaining full data sets. For buildings in the Fenimore-Waverly grid area, challenges included:

- The Murphy Brothers new construction buildings did not have past utility data. Energy use was estimated with energy modeling tools.
- Arctic Ice is the only facility that uses 500 kW of power and therefore is the only facility that has interval data available. SWA made estimates of power interval usage at other sites based on findings/ interviews at site visits.

A summary of the utility data collected and analyzed during Task 1 is shown in Table 3.

Table 3. Utility Data Access Summary

Building Information			Utility Information		
Account Name	Address	Account Number	Natural Gas	Electricity	Electricity Interval Data
East Coast North Properties, LLC	416 Waverly Avenue, Mamaroneck, NY	55-5716-0370-0003-1	Yes	Yes	No
East Coast North Properties, LLC	560 Fenimore Road, Mamaroneck, NY	55-5716-0367-0003-7	Yes	Yes	No
East Coast North Properties, LLC	560 Fenimore Road, Mamaroneck, NY	55-5716-0368-0003-5	No	Yes	No
East Coast North Properties, LLC	408 Waverly Avenue, Mamaroneck, NY	55-5716-0223-0305-1	No	Yes	No
Artic Glacier Ice	500 Fenimore Rd, Mamaroneck, NY	55-5716-0375-1102-9	No	Yes	No
Artic Glacier Ice	500 Fenimore Rd, Mamaroneck, NY	55-5716-0377-0402-0	Yes	Yes	No
Artic Glacier Ice	500 Fenimore Rd, Mamaroneck, NY	55-5716-0377-0603-3	No	Yes	No
Artic Glacier Ice	500 Fenimore Rd, Mamaroneck, NY	59-0013-4301-0000-7	Yes	Yes	Yes

1.1.2 **Generation**

During this phase, it was anticipated that the primary generation source capacity would be the photovoltaics (PV) located at the Murphy Brothers and Arctic Ice facilities. VOM town representatives also identified several other town buildings that have roof space available for PV (VOM garage roof, VOM pavilion), however these were located to far from the target are and were eventually removed from the design. In addition, natural gas fired combined heat and power (CHP) generation was investigated to determine if it could provide power and heat for both electrical and thermal loads. During Task II, the team evaluated the area available for PV and other existing generation resources. The team also considered options to keep the system running if natural gas supply is not available during an emergency. With this in mind, the feasibility of installing enough battery backup to outlast a short natural gas interruption was investigated; as will the possibility of adding compressed natural gas storage capability to the system.

A combination of generation resources will provide on-site power within a facility microgrid, and each facility microgrid can operate in both grid-connected and islanded mode. There may be several facility microgrids in a community forming in aggregate a community microgrid that can also operate in grid-connected and islanded mode. It may be possible that a particular facility may not have any resources itself but could be supplied by shared resources. Figure 2 displays a diagram illustrating the relationship between the facility and community microgrid. For the VOM microgrid, the primary facility microgrid generation will be located at the Mamaroneck Self Storage facility. Resources considered include PV and natural gas generation with a battery energy storage system (ESS). This grid will feed energy to several critical facilities within the community and can be designed to utilize generation/storage from existing sources. A point of common coupling will contain a switch that allows connection between the utility electric power system (EPS) and can break this connection for islanded mode. The generation sources will be controlled by a distributed energy resource management system (DERMS) that will have the ability to switch between various operating modes. The location of switches and the utility feeder layouts were discussed when the team met with Con Edison engineers in September 2015.

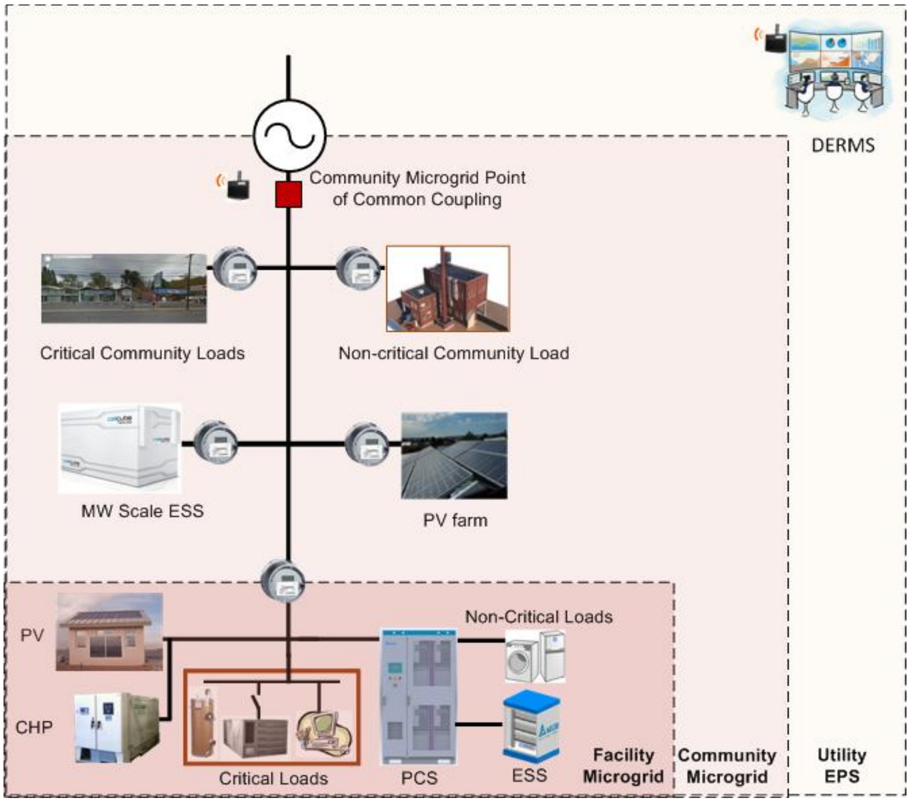

Figure 2 Facility microgrid and community microgrid

1.1.3 Operation and Maintenance

Spirae's Wave control platform, running the On-grid Microgrid Application, forms an intentional island upon operator command by adjusting the settings of the participating assets. The island is then created when the operator selects to activate the "island controls". Wave's Spinning Reserves Manager then achieves the zero active and zero reactive power at the point of common coupling (PCC) by using an optimization framework to determine asset allocation to meet the required PCC set points. Simultaneously, Wave oversees all system, resource, and operational constraints. As soon as the island is formed, Wave sends the frequency, and voltage set points and appropriate mode selections to the islanded assets. The island frequency and voltage set points are maintained by the Wave controls once island control is activated.

Spirae's Wave island controls monitor the state of the utility grid and continuously update a load shedding pre-load and generation curtailment plan in anticipation of the loss of utility. Upon the loss of utility power the Wave controls select the appropriate assets to be frequency and voltage leads. Wave will also shed any load or curtail generation as required to maintain the island frequency with the available microgrid assets. Each facility microgrid will automatically separate from the grid in accordance with 1741 and/or Rule 21. There may also be solar farms or energy storage resources that will also separate and restore themselves automatically.

IntelliGen (or equivalent vendor), as the manufacturer of the generators, will perform all maintenance of the generators and will comply with recommended maintenance intervals and record keeping. For 75kW, 150kW, and 250kW CHP units, the prescribed maintenance schedule is listed below:

- *Annual Maintenance, once per year:* Pump seal change on engine coolant pump. 4 hours on site. Glycol check and richen concentration to minimum 40% at start of cold season. 4 hours on site. Valve maintenance as necessary.
- *Every 1000 Hours* – Perform 1000 hour service which includes oil and filter change, oil sample, and valve adjustment to 0.5mm, visual inspection of engine/generator, pumps, battery, air cleaner, heat exchangers, exhaust system, spark plugs, and control panel. 3-4 hours on site average. Note change spark plugs as needed.
- *Every 20,000 Hours* – Top End Overhaul – Replace Heads
- *Every 24,000 Hours* – CAT Element Replacement
- *Every 50,000 Hours* – Full Engine Overhaul

If the PV and battery backup system is financed by a 3rd party, the financier typically requires an Operations and Maintenance (O&M) agreement to protect the asset over the life of the loan. Each of the components of the system has a warranty that will need to match that term. If the system is purchased, such an agreement is an option for the property owner and an extended warranty can also be an option. The system can be monitored remotely, measuring such things as operating temperatures, frequency of battery discharge, depth of discharge, etc., to make sure the equipment was operated according to the performance limits specified on the warranty. Delta Corp will help to identify a suitable O&M party for the VOM system.

All facility microgrids and their resources will synchronize to the grid frequency when it is available. Most likely all DER in each facility will be DC coupled to the power control system (PCS), and when islanded, the facility PCS can form its own reference frequency. If the facility microgrids' join the community microgrid, one of the community resources will have to provide the grid master frequency for the others to follow. The generators will follow electric load while grid tied, and will maintain proper voltage and frequency regulation in compliance with ANSI C-84.

1.1.4 **Communication and Controls**

Delta will provide network capability from the meters and power control system to the Data Center. The Wide Area Network (WAN) will use Global system for mobile communications (GSM), 3G, 4G, or Long-term evolution communication (LTE) and the Field Area Network (FAN) will use G3-PLC (IEEE 1901.2). A need for fiber is not anticipated. Figure 3 provides a demonstration of how each component of the grid system will communicate.

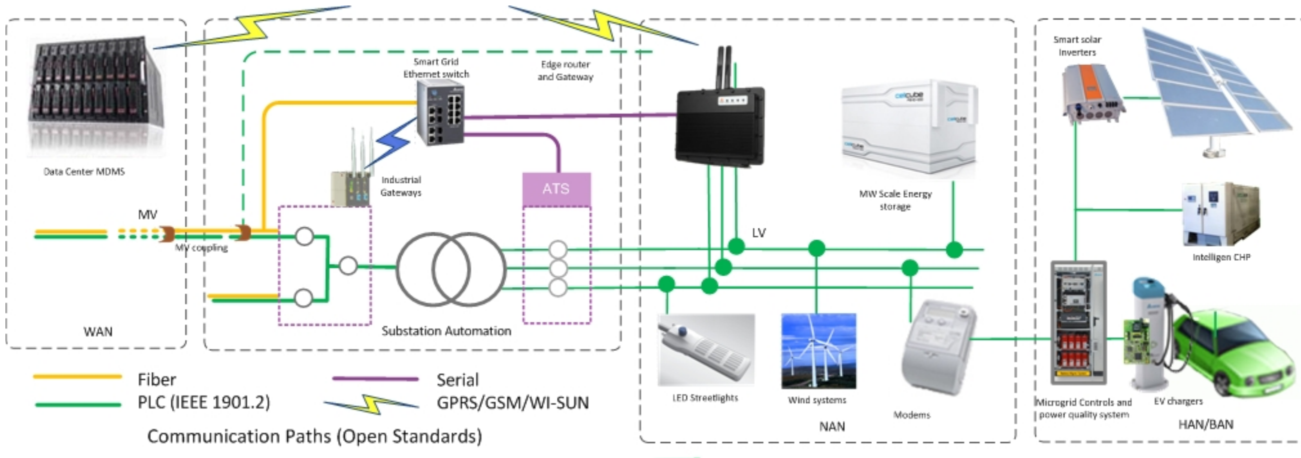

Figure 3. Two-way Communication and Control Diagram

The diagram separates communication divisions in four main groupings: 1) Home Area Network/Business Area Network (HAN/BAN), 2) Neighborhood Area Network (NAN), 3) substation automation block, and 4) Wide Area Network (WAN). The team envisions utilizing power line communications (PLC) to control various generation sources and loads. A wireless gateway can be used if PLC technology is not feasible for a particular building. Each facility microgrid may utilize a dedicated control and smart meter technology to optimize generation/consumption. When the team met with Con Edison engineers, the location and availability the automatic transfer switch (ATS) was discussed. The communications network will be designed to accommodate existing Con Edison system infrastructure.

Spirae's Wave Enterprise Gateway provides interoperability at the Enterprise level via Java Message Service (JMS), Exact Transform Load (ETL) and Web services service oriented architecture(SOA), based on Common Information Model (CIM) IEC 61968-100 and MultiSpeak for application-to-application messaging such as between Wave and third party community microgrid owner/operator systems and utility systems such as geographical information systems (GIS), outage management system (OMS), distribution management system (DMS), and demand response management system (DRMS). During the Touchpoint 2 meeting with Con Edison (Preliminary Micro grid Configuration Coordination), the technical design team worked with Con Ed engineers to determine their communication requirements.(design details are provide in Task II report section). The VOM design was developed to accommodate existing Con Edison communication infrastructure.

1.1.5 **Resiliency**

The proposed site is in a location that is in close proximity to a diverse potential customer base that includes several municipal, residential, industrial, and commercial buildings within a 0.5 mile radius. The initial selection of critical facilities was prioritized based on those that are most important to keep running during an emergency period. The proposed critical facilities list encompasses a diverse overall demand and load profile type. For instance, the VOM Fire Dept. and Police Dept. are open 24/7 and are expected to draw a continuous load with relatively low peak draws. The VOM hall is typically only operating during business hours, and is expected to draw a continuous, relatively low, non-peaking load. The Artic Glacier Ice facility's load profile will be highly dependent on weather conditions and the demand for ice production. It is expected that the ice making compressors will be responsible for large peak power draws. The gas station electricity demand will likely be concentrated between 7-9 AM and 5-8 PM. High peak power draws from gas pumps are expected during this period. A key feature of the proposed design is that it is scalable. If the demand for microgrid electricity grows, the Mamaroneck Self Storage facility has space to add additional power generation equipment. By designing the microgrid to serve a diverse set of customers, its value to the VOM will be strengthened. Load information was analyzed in detail during Task 2.

Each facility microgrid is capable of sustaining itself if the facility plans the proper mix of DER to match their critical needs. But the purpose of this project is to share power within the community, possibly to a critical load that has no DER on-site. This routing will be managed with reclosers and switches in the distribution lines below the point of common coupling. That routing will isolate and direct the power according to the community plan. The site can be set up to run on compressed natural gas (CNG) and holding containers can be sized to supplement battery resources.

The microgrid is intended to provide emergency power to critical facilities in the Village to enable them to provide essential services during times of natural disasters. The microgrid generation equipment will be housed on the roof level of the 4-story Mamaroneck self-storage facility. This will place equipment well above flood lines, ensuring reliable operation during emergency events. Battery backup CNG storage may be used to provide power if solar or the village natural gas supply are interrupted. The team worked with Con Edison to determine estimates of maximum outage periods for both electric and natural gas. Additionally, the design will employ (n+1) methodology to DER system so that microgrid remains operational if one or more generation sources fail.

Each demand energy response and power control system is black-start capable, as is the communications network. The generators will also come with black start capability. The system may use a battery backup component to help enable other black start capabilities.

1.2 Preferable Microgrid Capabilities

The sections which follow indicate the degree that the proposed design will meet the defined preferable capabilities:

1.2.1 Innovative Design Features

Each generation facility will utilize a microgrid controls and power quality system to regulate operation of DERs. Controls will be configured to automatically operate DERs when triggered by manual or pre-programmed grid and community microgrid signals. For instance, the grid control center may trigger the microgrid to utilize power form the battery storage during peak load periods. Large loads, such as the compressor loads from the Artic Glacier ice factory, can be strategically scheduled to run at a time that optimizes grid performance. Each facility can be fit with a smart meter that sends and receives information to the data centers through the gateway or power line communications network. During a power outage event, non-essential meters within the microgrid can be shut off so that critical facilities are prioritized for limited energy generation capacity.

Spirae's Wave™ platform can communicate with and control multiple types of advanced grid resources including smart inverters, controllable loads (demand response), various types of energy storage (batteries, flywheels), advanced meters, and distribution infrastructure such as modern protection relays. The Wave microgrid controller may make use of all of these resource types.

Spirae has performed detailed design for on- and off-grid microgrids, including analysis for reliability, economics, and asset lifecycle. The controls will read demand and dispatch the correct amount of power generation based on a pre-determined minimum import power level from the grid. The preliminary communications network plan for this system is outlined in question 8 of this report. The team plans to employ power line communications that allow for utility control at the automatic transfer switch. The proposed DERs can be used for peak shaving efforts. Some building level controls can be utilized to shift demand to optimal generation periods.

1.2.2 **Energy Efficiency**

Spirae views energy efficiency and demand response the same as other distributed resources. Monitoring and control are achieved through interface with Wave's virtual model of the resource. Intelligent use of the resources to satisfy the user's objective function are achieved using Wave's Peak Management Application, which relies on load and renewables forecasting to optimize the schedule and dispatch of resources to meet the system demand. The team considered demand response options including standby generators as peak reduction units in addition to utilizing waste heat that can provide absorption chillers to run off of hot water from CHP units. This measure can help to maximize the CHP system efficiency year round. Ultimately, this design path was not chosen as replacement of all chiller equipment was not a feasible option.

When Steven Winter Associates visited each of the facilities during the load characterization process, the team identified building energy efficiency measures that can reduce the load (discussed in Task II). The team identified building load reduction opportunities including: insulation upgrades, HVAC improvements, control strategy optimization adjustments, lighting and appliance retrofits, etc. This provided an additional opportunity to strengthen the grid by reducing the load on the system.

1.2.3 **Interconnection**

Spirae's Wave control platform relies on distributed hardware and internet connectivity. The hardware (hardened CPUs near the resources and server class CPUs in the control room) and internet connections are specified by Spirae and installed by others. Spirae validates the communications and deploys and commissions the Wave software. Operation is a matter of user interaction with the Wave-connected system through the Wave user interface, running on the Wave Client. Maintenance consists of installing software updates as they become available. IntelliGen's CHP (or NG generator) units can interconnect to the grid regardless of the type of grid distribution.

Details of grid interconnection were determined when the team met with Con Edison for the "Touchpoint 2: Preliminary Microgrid Configuration Coordination" meeting. A list of technical discussion points for this meeting, include: feeder layouts, switch locations, existing communications capabilities, interconnection costs, substation locations, Pad mounted equipment availability/locations, total feeder line loading, grid weaknesses, etc.

1.2.4 **REV coordination**

The proposed design supports the goals of the REV initiative and is continuously evolving to support these goals. The team is considering use of roof top PV, battery storage, cogeneration, and other technologies. One potential innovation is to utilize absorption chiller technology in combination with the cogeneration system to use cogeneration heat for cooling. This application is particularly relevant for the Glacier Ice Company as the cooling load is present year round. The team also considered use of an advanced monitoring and data display hardware/software package that will help to optimize performance and provide effective communication with customers. Another potential feature of the system involves a utility communication platform that will allow the microgrid to provide energy to the grid during peak/high demand hours. With these and other potential considerations in mind, the team is dedicated to supporting the mission of the REV initiative.

1.2.5 **Cost-Benefit Analysis and Financing**

Murphy Brother's Contracting, Inc. will be the developer and owner of the microgrid system and will work with their financial group to determine the cost/benefit of proposed system from the developer's prospective. This will include cost benefits achieved by generating power for their own buildings and the rate that they can earn by selling energy to others within the microgrid. The team plans to work with representatives from Con Edison to design the system to optimize the benefit to the utility – designing the system to provide power to the grid during peak consumption periods. A primary design factor of the system is to provide backup power to a community that is prone to flooding and frequent power outages. The team worked with local government officials to identify the most critical buildings in the surrounding area and will work with the community to quantify the value of this emergency power, possibly providing estimates of costs incurred by closing business and government services during power loss events. VOM management staff indicated that Hurricane Sandy cost the village approximately $1.2 million in capital damages repairs with additional financial losses to area business during power outages. VOM management's staff offered input throughout the design stage to optimize the cost benefit to the community.

In addition to funding from NYSERDA, the team plans to leverage private capital from several sources. The proposed building site, the Mamaroneck Self Storage facility is currently under construction and has already been financed through private investors. The phase II building is being constructed with provisions that will allow for a microgrid generation and control center (open PV space, enhanced rooftop structural requirements, adequate electrical requirements, etc.). Murphy Brothers plans to secure additional funding from key stakeholders, potentially including the Village of Mamaroneck, customers in the surrounding area, additional grants, etc. Additionally, the team may be able to offer financing for installation of the cogeneration system through a power purchase agreement. During Task 3 analysis, SWA investigated the incentives/tax credits available for the technology being considered. The financial feasibility of this option depends on the expected annual load and utility rate of the Village of Mamaroneck area. The team may choose to pursue funds available from federal organizations, such as FEMA, to help fund installation and maintenance costs.

1.2.6 Clean Power Integration

The team anticipates that a significant portion of the power generation will come from PV with battery backup. The goal of the design will be to produce the most financially feasible system while maximizing use of clean power supplies. To determine the total percentage of community load that can be covered by carbon-free generation, load profiling of the candidate critical facilities was performed. Based on the available loads, the team determined how much and what type of clean power supply is economically feasible and reasonable. At the critical facility meeting, some attendees were optimistic about potential for wind power based on systems they have observed in nearby areas. Wind may be another clean energy source that the team can incorporate. The team has also spoken with a utility-scale fuel cell manufacturer (1.3 MW+ units) and is continuing to investigate other renewable generation options.

1.2.7 Community Benefits

The Task 1 design offered reliable electricity to eight critical facilities however since the design is scalable, it is possible that more facilities can be added. In addition to the critical facilities being considered, the VOM area contains hundreds of additional commercial, industrial, and residential customers that would benefit from the microgrid. Construction of the facility would provide numerous construction and long term jobs for the community, in addition to keeping existing business powered and open during outages. When grid equipment/sizing is finalized, the team plans to quantify job creation potential for the construction/operation of the system. Most importantly, the microgrid would provide power to an area that is prone to flooding and has experienced the detrimental effects of long term power outages.

1.2.8 Strengthening the Surrounding Grid

During Task 1 planning, the team is considered several approaches to both strengthen the surrounding grid and increase information available to customers. Some measures investigated include the use of peak shaving, demand energy response, and strategic equipment scheduling to reduce load on the grid during grid overload periods. For instance, Arctic Glacier Ice may be able shift a portion of the compressor loads to nighttime periods, when outdoor air temperature is lower and grid loads are less. Additionally, the microgrid will be equipped with Volt/VAR control devices to regulate voltage and reduce reactive power, effectively increasing grid reliability and efficiency.

Since the microgrid will be powered by a set of redundant and diverse generations sources (PV arrays, battery banks, natural gas fired cogeneration systems), it will be resilient to destructive forces. The microgrid can have the ability to supply power to surrounding power grid when needed. There may also be an opportunity for generation stations within the micro grid to utilize renewable energy production for energy sales on the relevant energy market.

Task 1 Conclusion

The team examined all of NYSERDA's requirements and preferred capabilities as outlined in the feasibility assessment statement of work. The proposed Village of Mamaroneck microgrid was planned to be designed to exceed each minimum requirements defined under Task 1.1. The preliminary design plan was to address each of the preferred capabilities defined under Task 1.2 and continued to be improved in order to meet them to the highest degree possible. At this point, requirements had been established and reviewed, the team moved forward with Task 2 to develop the preliminary technical design costs and configuration. Ultimately, the goal of Task 2 was to assess whether it is technically and financially feasible to design a microgrid system to serve the VOM area under both normal operation and power outage periods. Throughout this task, the VOM microgrid team was determined to develop innovative solutions that strengthen the surrounding utility grid while benefiting the community.

2 Task 2: Preliminary Technical Design Costs and Configuration

The Village of Mamaroneck microgrid design team initially proposed to investigate the feasibility of building a single microgrid including several critical facilities within a half mile radius (Figure 4). After meeting with engineers from Con Edison to examine the area feeder layout, it became apparent that joining all critical facilities in the same microgrid would be cost prohibitive and that three separate microgrid systems should be evaluated to include all of the desired buildings. The three separate microgrid areas investigated are indicated with dashed black circles on the following map. One line diagrams of Con Edison's recommendations pertaining to each of these areas is displayed in Figure 50 - Figure 52 in the Appendix.

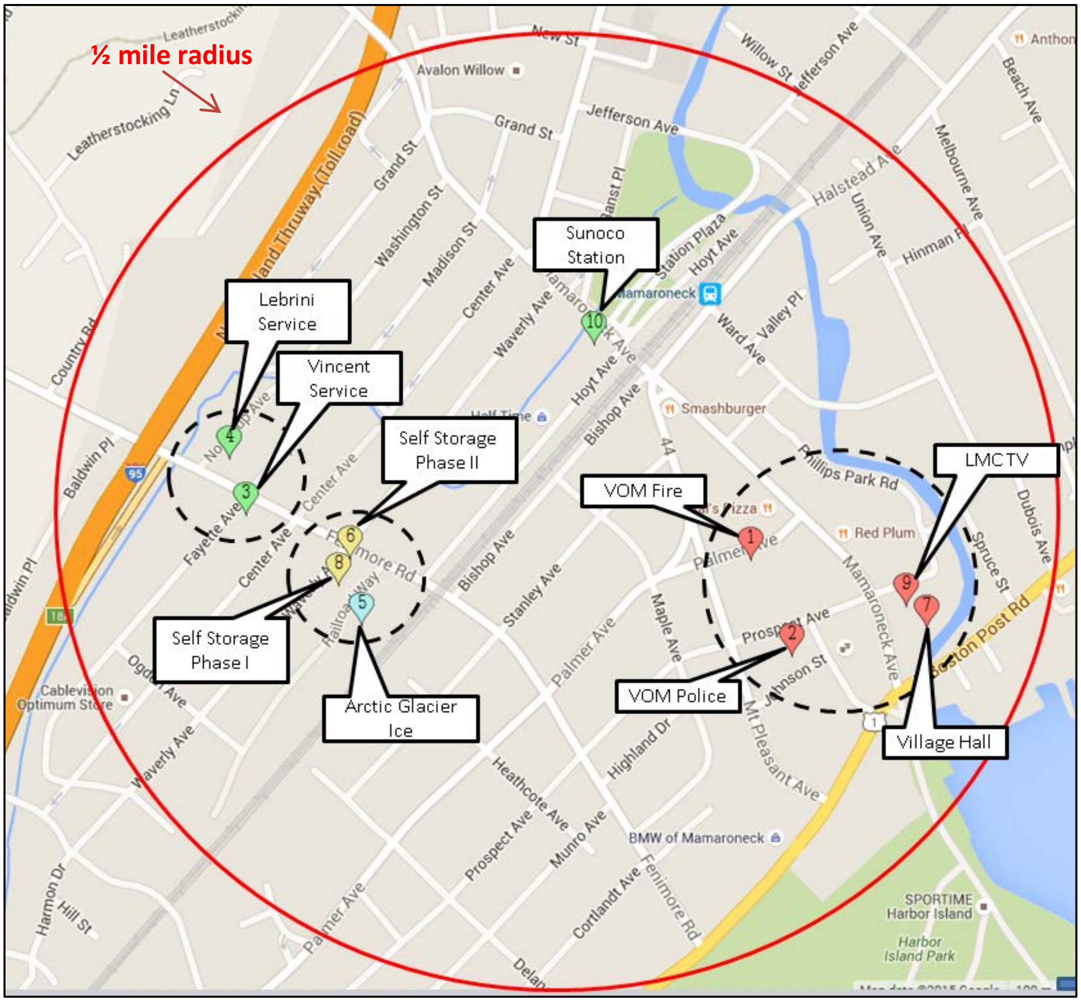

Figure 4. Proposed Facilities within 1/2 mile radius

The initial design of Mamaroneck Village Micro-Grid was to provide emergency power to the essential services of the Village of Mamaroneck as well as keeping three neighboring gas stations and the area's largest ice provider functioning when the main grid is out of service. The team now believes that because of the existing Con Ed grid structure, the design/build costs will be prohibitive. Grouping all three microgrid areas together would have required construction of approximately 0.5 miles of private cable (estimated at $500,000 - $2,000,000 per mile based on mix of overhead and underground cable). The alternative would have been to include all customers on the feeder sections between target sites, requiring complex switching and addition of 100+ separate buildings.

The proposed microgrid direction has been re-directed to align with the plans of the Village of Mamaroneck Industrial Redevelopment Steering Committee. The team has decided to design the microgrid around the Waverly-Fenimore area that is under extensive redevelopment. In December 2013, the Village applied for and received a Hudson Valley River Greenway grant. The grant enabled the Village to hire an urban planning design team, replace Urban Studio, with the goal to "to conceptualize small-scale cost effective urban interventions that build early momentum ranging up to large sustainable visions for the future." Results and continuous updates of the study are presented on a customized online dashboard[1]. The dashboard provides documentation of existing conditions and potential improvement opportunities. Key redevelopment goals include redeveloping abandoned industrial buildings to mixed use commercial buildings that can take advantage of close proximity to the train station.

Boxed in by Interstate 95 to the west, the Metro North Railroad to the east, Rockland Avenue to the south, and the Sheldrake River and Hoyt Avenue to the North, the Village of Mamaroneck industrial district (where our Mamaroneck Self Storage and Murphy Brothers Contracting offices are located) is physically separated from the rest of the village. But its proximity to major travel infrastructure allows it to be a regional location and makes it a prime spot to redevelop. It has what community developers call "walkability", 5 minutes from a Metro-North train station, 10 minutes to the vibrant village main street or Harbor Island Park, as well as easy access to I-95 or the Hutchison River Parkway. It's also served by a strong school system and a caring involved community. Whereas other microgrid projects may be addressing existing infrastructure, the Village of Mamaroneck Community Micro-grid will address an exciting change that will positively affect our entire Larchmont-Mamaroneck community. A microgrid will add immeasurable value to the future development of this area, known to the old-timers as "The Strawberry Patch".

The team maintains the vision that the Village of Mamaroneck Village Micro-Grid will be part of Phase II of Mamaroneck Self Storage & the newly constructed Murphy Brothers offices and can serve as a reserve "command center" for local, county and state government, if necessary, providing a place that essential services along with governing bodies have the ability to maintain order and direct assistance to those in need as quickly as possible, generating a continuous supply of power until the main grid is again functioning. The village mayor, Norman Rosenblum, has stated interest for this reserve command center and has confirmed that it can help maintain order during natural disasters. The original intent to promote the construction and benefits of micro-grid systems by way of media coverage and educational presentations for professionals and citizens is maintained. Mamaroneck and New York State will benefit from the construction of the Village of Mamaroneck Micro-Grid and the project will serve as an example to assist other disaster-prone communities while acting as a cornerstone of new development across the state.

This Task II report details findings from all buildings analyzed in the study and explains the process followed to arrive at the current design. However, design details are only provided for the Waverly-Fenimore microgrid.

2.1: Proposed Microgrid Infrastructure and Operations

A simplified equipment layout of the proposed microgrid located in the Fenimore-Waverly area is shown in Figure 5. Each building will be equipped with a smart meter that allows the facility to island from the microgrid feeder line. The existing utility feeder line (dashed blue line) runs from Waverly Ave and follows Fenimore Rd, terminating at the utility pole located outside of building # 11. A new cable will be

[1] http://www.replacevomstudy.com/

installed to extend the existing secondary run to the pad mount equipment box serving Arctic Glacier Ice (#1). A new Supervisory Control and Data Acquisition (SCADA) switch will be installed on the line along Waverly Ave to isolate the microgrid feeder section from the remainder of the utility grid and at each transformer linking the primary and secondary. This configuration is ideal as it does not interrupt feeder lines serving other parts of the grid.

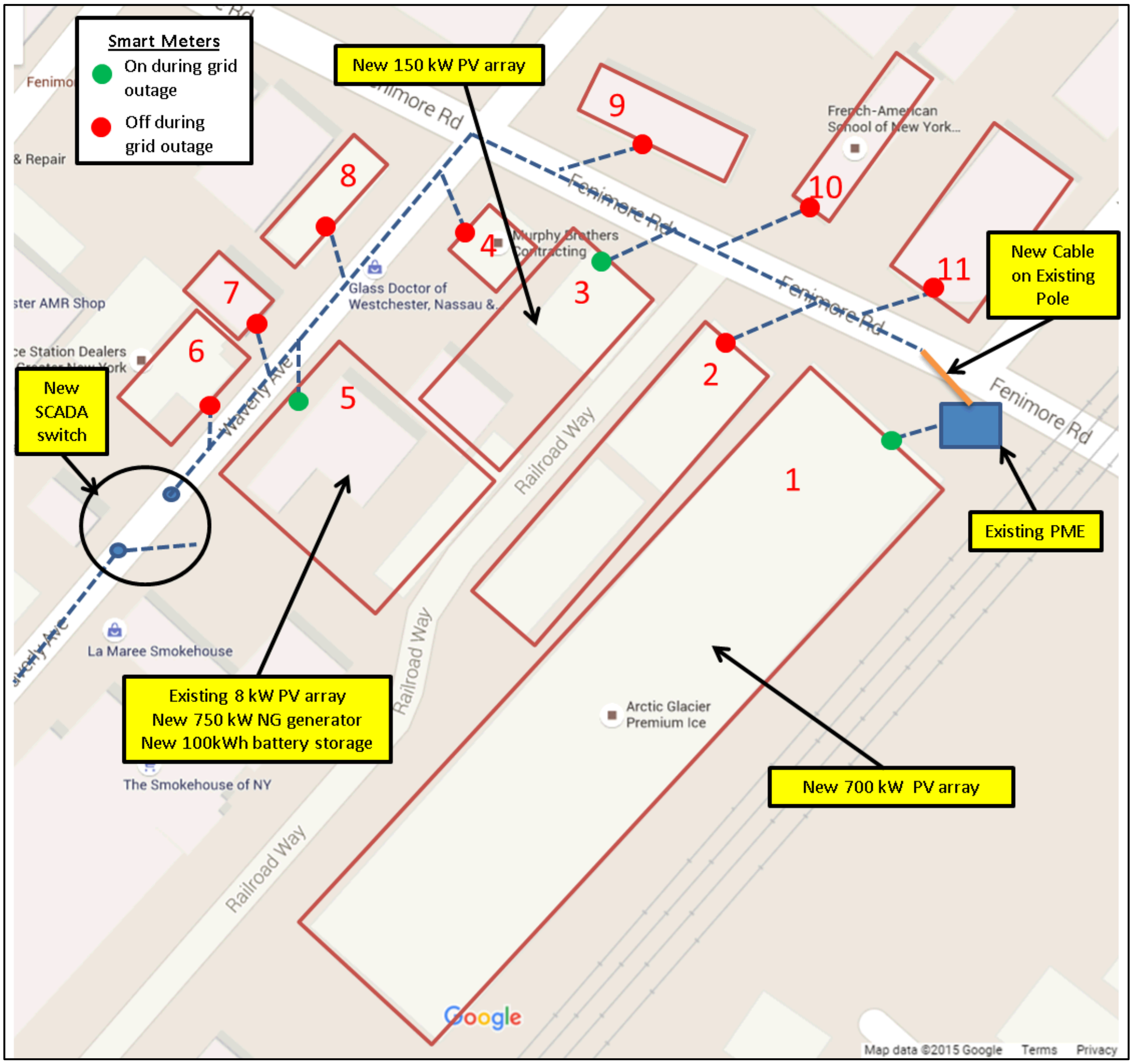

Figure 5. Simplified Equipment Layout: Waverly-Fenimore

A table displaying the address and building type that corresponds to numbering format in Figure 5 is shown in Table 4. The facilities with planned and existing generation capabilities, Artic Glacier Ice and Mamaroneck Self Storage Phase I and Phase II, are highlighted in yellow. During grid outage emergency periods, Artic Glacier Ice provides ice to the surrounding area keeping food and medications from spoiling. Mamaroneck Self Storage buildings will house several generation resources and will serve as a potential command center for Village of Mamaroneck government officials to utilize during emergency periods. This area of the Village is currently under a major redevelopment; new buildings will be designed to support the proposed microgrid.

Table 4. Waverly Fenimore Buildings

Number	Address	Building
1	500 Fenimore Rd	Artic Glacier Ice
2	520 Fenimore Rd	Non-Critical Commercial/Industrial
3	426 Waverly Avenue	Mamaroneck Self Storage Phase 2
4	560 Fenimore Rd	Mamaroneck Self Storage Phase 3
5	416 Waverly Avenue	Mamaroneck Self Storage Phase 1
6	421 Fenimore Rd	Non Critical Commercial
7	413 Fenimore Rd	Non Critical Residential
8	389 Fenimore	Non Critical Commercial
9	545 Fenimore Rd	Non Critical Commercial
10	525 Fenimore Rd	Non Critical Commercial
11	307 Hoyt Ave	Non Critical Industrial

Distributed energy resources will include PV arrays, natural gas generators, and battery storage. The operating strategy is designed to use PV generated energy when solar conditions allow, supplementing production with a natural gas generator when needed. During normal operation the grid connection SCADA switch will remain closed and all building's smart meters will allow current through. Small amounts of excess produced energy may be back fed to the utility grid if needed, potentially to support the utility grid during peak load periods. If the utility grid is interrupted, the SCADA switches will open, isolating the microgrid feeder section from the rest of the utility feeder. Based on the energy generation capacity of the PV and generators at the time, the smart meters and/or critical load sub-panels can prioritize energy use by limiting current to only the critical facilities and critical loads.

2.2 Load Characterization

To evaluate the feasibility of including various sites in the proposed microgrid, Steven Winter Associates, Inc. completed a load analysis of several facilities (including facilities that were not selected in the end). The load analysis consisted of analyzing utility data supplied by Con Edison and visiting key sites to document building features and operating trends. Results from the load characterization process are grouped by Microgrid (Fenimore-Waverly, Mamaroneck Ave, and Fayette-Northrup) and are presented in the sections that follow.

2.1.1 Fenimore-Waverly Microgrid

The critical facilities associated with the proposed microgrid located at Fenimore Rd and Waverly Ave are the Murphy Brothers Contracting storage facilities and the Arctic Glacier Ice manufacturing facility. There are an additional eight small commercial/residential buildings located on the section of feeder line that will encompass this microgrid. The area is currently in a major redevelopment stage and is being rezoned. The sections that follow provide details of the load characterization analysis for the facilities in this proposed microgrid area.

Arctic Glacier Ice

Arctic Glacier Ice, a tenant of building owner Andrew Spatz, is currently leasing space at 500 Fenimore Road in Mamaroneck and is responsible for manufacturing ice in the New York, Connecticut, and New Jersey regions. This manufacturing facility is responsible for the vast majority of the electrical load in this microgrid section due to the high electrical demand of process equipment associated with ice manufacturing. This facility is a single story building sized at approximately 60,000 ft^2. Arctic Glacier Ice is currently involved with Con Edison's demand reduction (DR) program through Enernoc, a cloud based energy monitoring software. Enernoc informs them when there is a DR call and the facility implements their DR plan by manually shutting off equipment. The facility has monitoring software that both Enernoc and Arctic Glacier have access to in order to gauge DR performance. There is no BMS that controls equipment; it has local controls only.

Arctic Glacier Ice operates all year-round, with varying daily hours of operation dependent on the consumer demands of ice, which is higher during the summer months. During the peak summer months, up to two full manufacturing shifts are required daily and during the off peak winter months, only a single partial manufacturing shift is required daily. The use of process equipment is directly associated with the demand of ice in each season.

The duration of each freezing cycle varies based on outdoor air temperature and water temperature, but is typically between 17 and 23 minutes. The number of freezing cycles required varies based on the seasonal demand. On a peak production day, the factory can produce 250 tons of ice. From May through September, all process equipment operates 24/7. During the winter, half of the ice making machines typically operate at once and will operate for 12 hours per day, 5 days per week.

The process equipment at Arctic Glacier Ice is comprised of the following components:

- Eight (8) ice makers
- Four (4) screw compressors
- Two (2) units used to recirculate the ammonia refrigerant to all process equipment and evaporator space cooling units
- A rooftop condenser used to reject heat.
- Additional smaller process equipment for:
    - Chopping the ice
    - Packaging the ice
    - Transporting the ice
    - Cooling the walk-in-freezers
    - Electric resistance heaters to melt rejected ice during winter season

An image of the process equipment and ice making equipment is shown in Figure 6.

Figure 6. Process Equipment: (left) 'Ice Makers' (right) Screw compressor

The building has a brick façade with punch-out windows. Due to the cold interior environment, space heating is only provided in the office areas of the building via rooftop units, and supplemental heating in process rooms and distribution center during the peak heating season. All cooling delivered to the facility is provided by the ammonia refrigeration system, and is connected to evaporator units in the walk-in-freezers which maintain a space temperature set point of 10°F. Lighting varies throughout the building, but is primarily LEDs in the process areas where cold space temperatures are required year-round. Lighting in the machine room is controlled by occupancy sensors. Lighting in the freezers is on 24/7. This facility has 45,000 ft^2 of flat, exposed rooftop area that can accommodate photovoltaic panels.

Based on the existing equipment at the facility and electricity interval data, it is estimated that over 90% of the electrical consumption at Arctic Glacier Ice is associated with manufacturing ice. The remaining electrical consumption is associated with space cooling and heating, lighting, and additional miscellaneous loads. Of all of the buildings investigated Arctic Ice is the only building where interval data was available (Con Edison only installs interval meters if peak load is greater than 500 kW). A plot displaying 15-min peak kW for the facility is shown in Figure 7. As seen from the data, power consumption peaks at approximately 1MW during summer periods, but drops to 500kW during winter periods. There is a constant 200kW baseline electric load during summer periods and a 100 kW electric baseline load during winter periods.

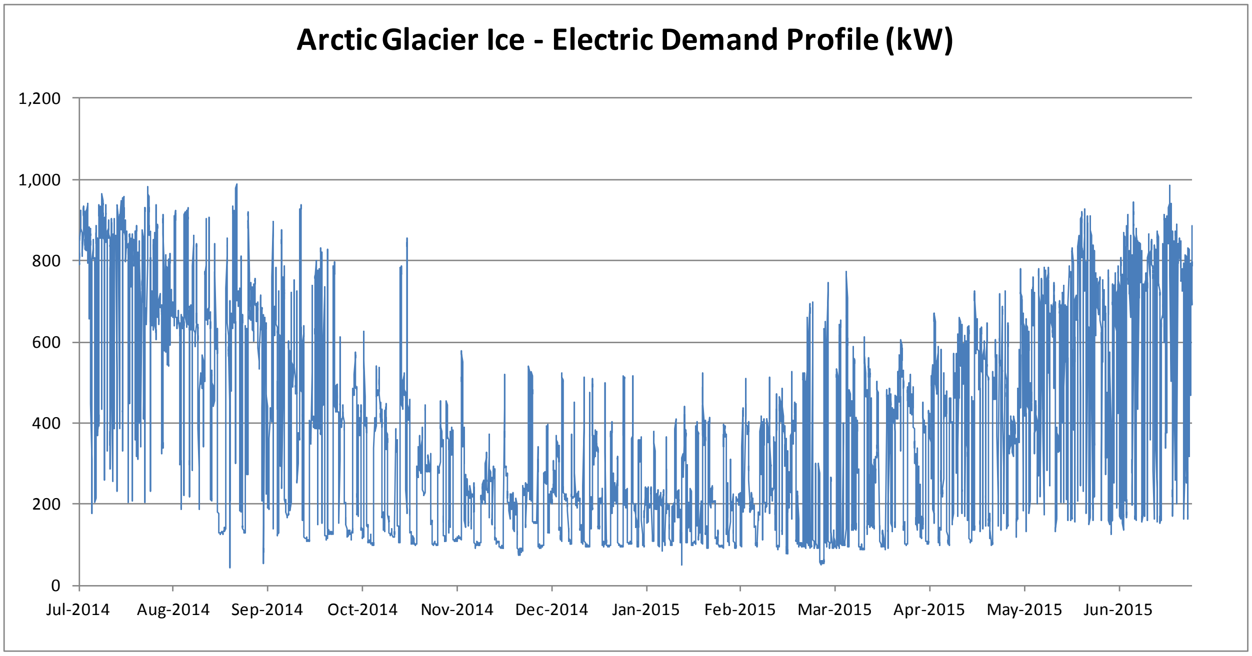

Figure 7. Arctic Glacier Ice Electric Demand Profile: 15-min data

It is also useful to examine peak consumption on a seasonal basis for a weekly time period. Figure 8 shows summer and winter consumption over a 7-day period for each season. For both seasons, an oscillating type demand profile is apparent. Demand peaks during mid-day when shifts are in full ice productions and is reduced during nighttime periods when production stops/slows. For the summer period shown, the 15-min peak ranges from approximately 400-800kW. For the winter period, peak ranges between 100kW and 300 kW. A significant seasonal difference can be observed between the two cases.

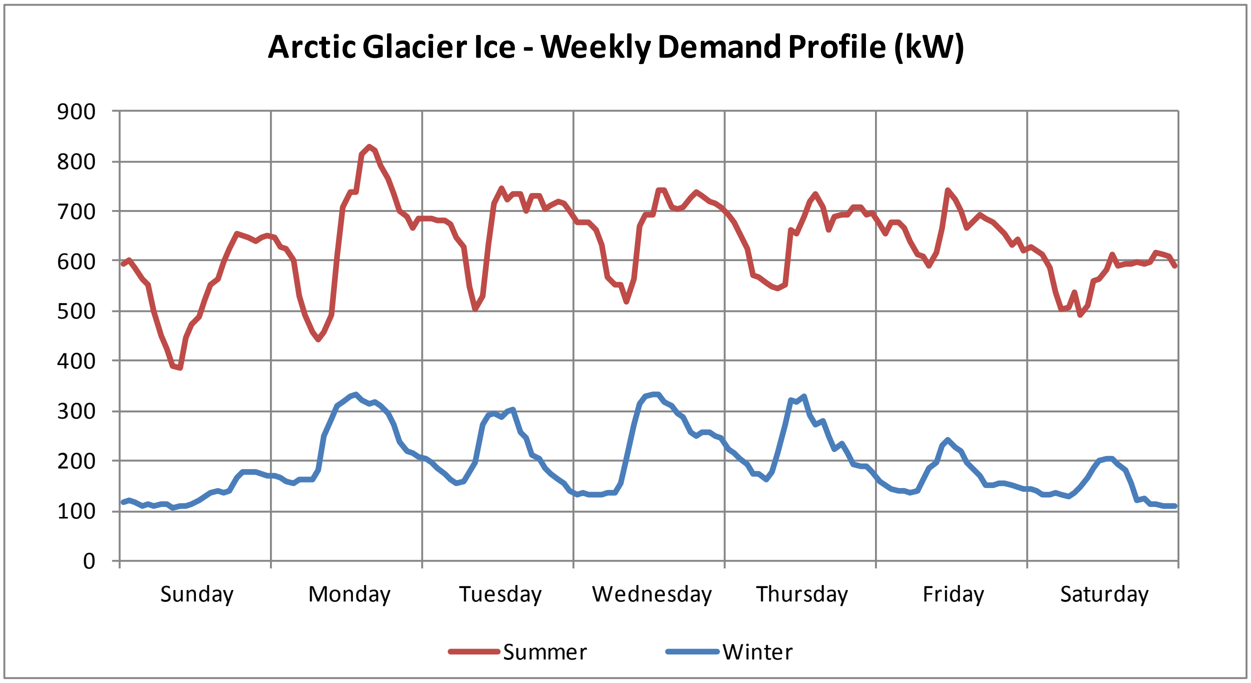

Figure 8. Typical Weekly Profile during the Summer and Winter Seasons

The facility's monthly electrical consumption profile is shown in Figure 9 which shows uses up to 600,000 kWh per month during summer periods and as low as 175,000 kwh/month during winter periods. On an annual basis, total electrical consumption is 3800 MWh/year.

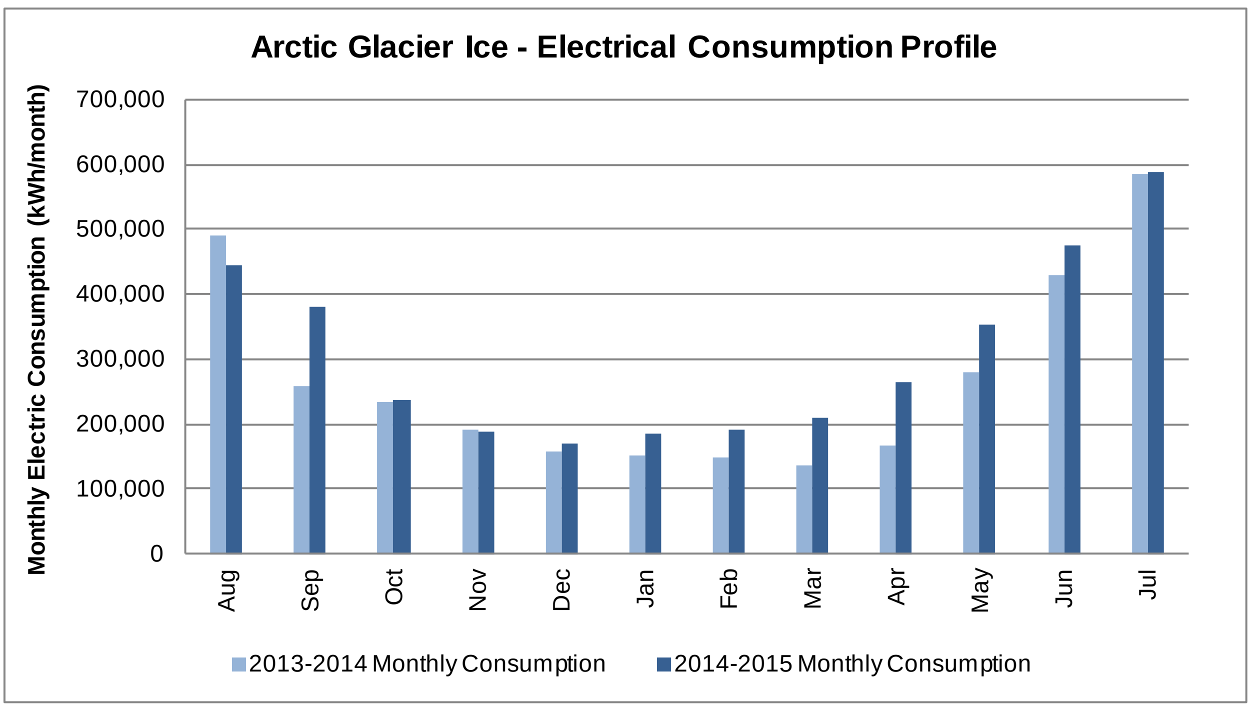

Figure 9. Electric Consumption Profile: Arctic Glacier Ice

The monthly electrical demand profile is shown in Figure 10. The figure demonstrates the differentiation of peak demand between winter and summer months with approximately 1 MW during summer months and 600 kW during winter months.

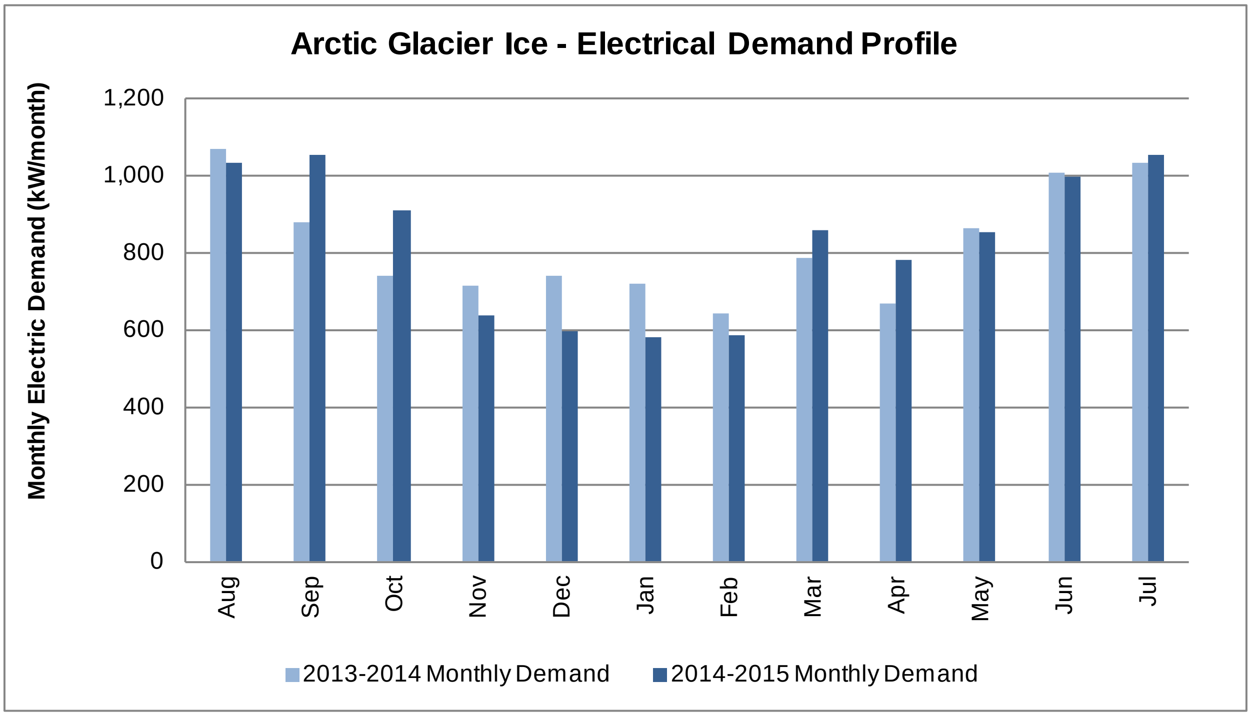

Figure 10. Electrical Demand Profile: Artic Glacier Ice

The facilities natural gas consumption profile is shown in Figure 11. Natural gas is mainly used for space heating in offices. The monthly winter peak is approximately 6000 therms/month with little-to-no gas use outside of the heating season. With the lack of continuous baseline gas load, the team determined that the site was unlikely to be a good fit for cogeneration resources.

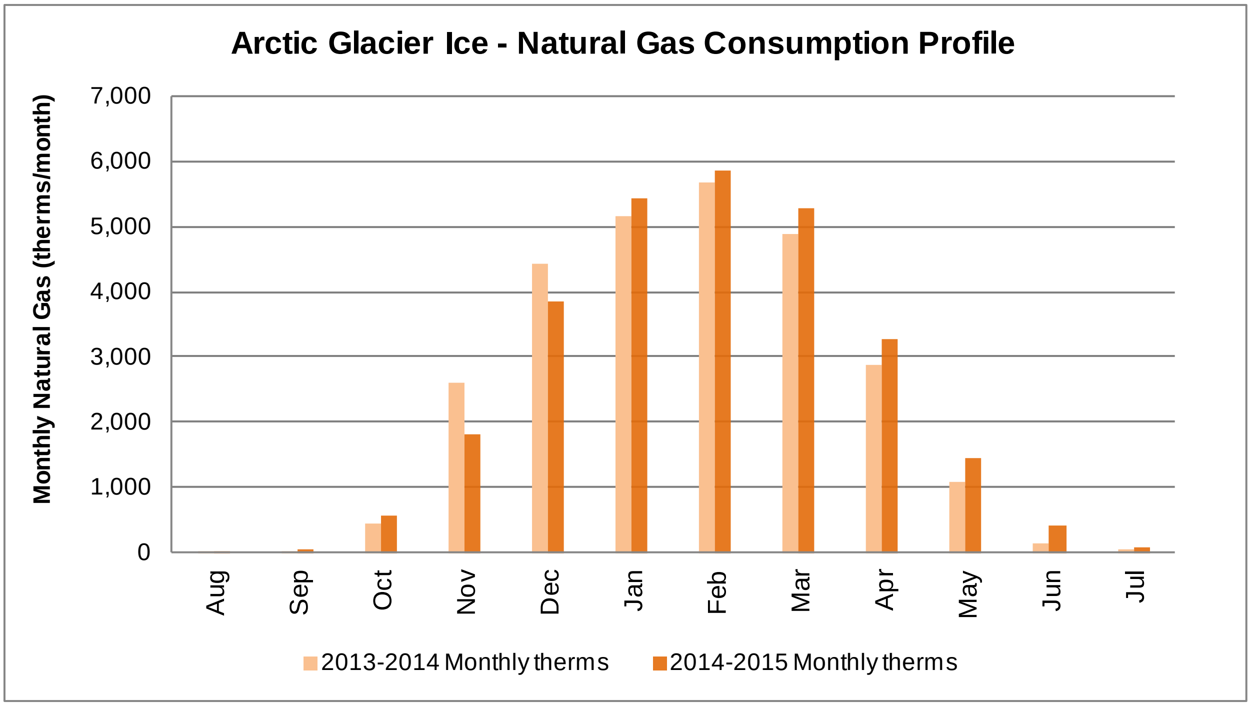

Figure 11. Natural Gas Consumption Profile: Arctic Glacier Ice

Murphy Brothers' Buildings and Mamaroneck Self Storage

Current development within the Waverly-Fenimore microgrid location consists of Murphy Brothers' Contracting constructing new buildings in a series of three phases. The location of each building for each phase is shown on the lot block survey map in Figure 12. The other existing building on the lot (aside from the new Phase I building) will be demolished.

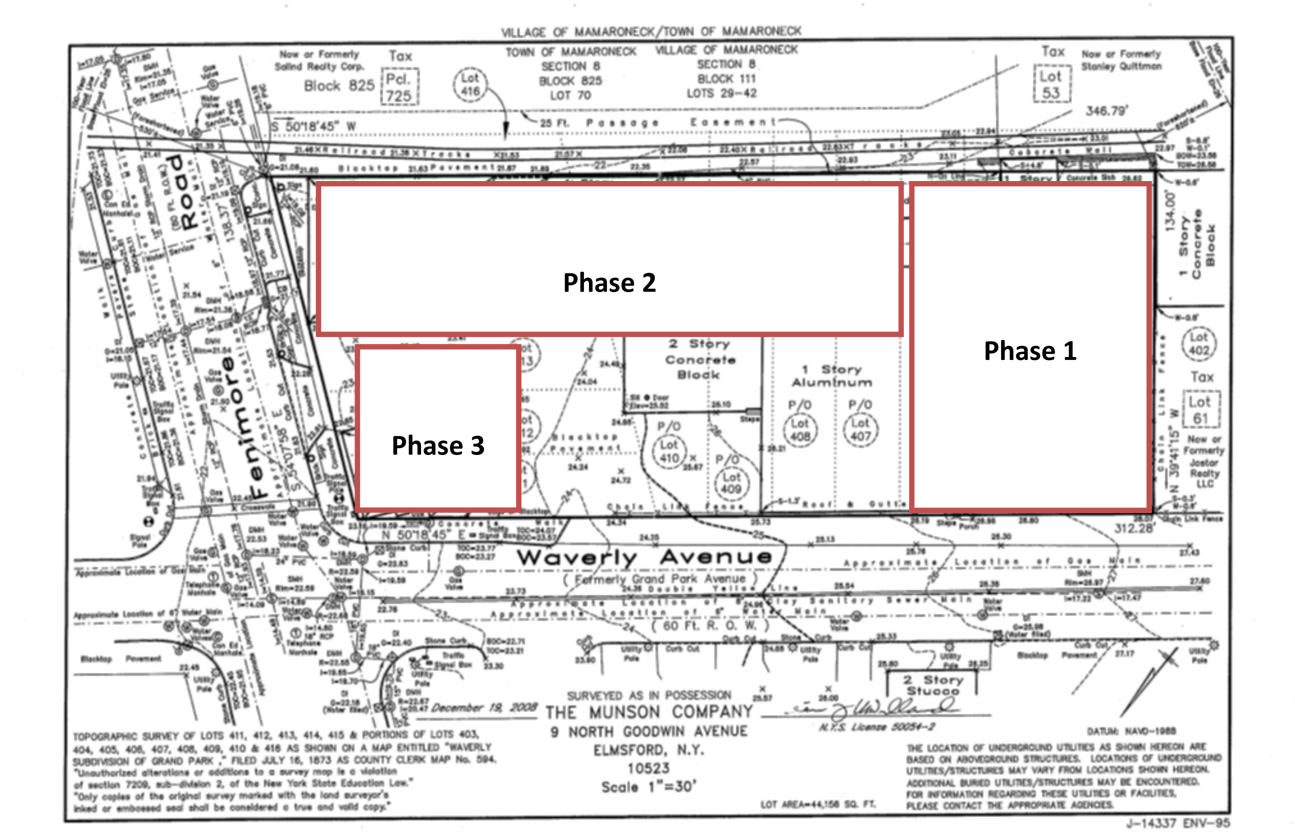

Figure 12. Three phase development plans on lot and block map

Phase 1 of development is the addition of a four-story self-storage facility at 426 Waverly Avenue (Figure 13). This building was opened to the public in November 2015. It is sized at approximately 60,000 ft^2 and houses 250 self-storage units. This facility is conditioned by an air-source heat pump system consisting of four (4) exterior Daikin VRV IV Inverters, providing energy to 32 interior fan coil units in the building. This system will heat the interior to 55°F - 60°F during the winter and cool the interior to 75°F - 80°F during the summer. This facility is equipped with LED lighting controlled via ceiling-mounted occupancy sensors, and two elevators. It also has 8 kW of photovoltaic shingles on the southwest and southeast rooftop exposures.

Figure 13. (left) General exterior (right) Solar shingles

Due to utility data being unavailable for phase 1 of the development, the electricity consumption and demand for the four-story self-storage facility at 426 Waverly Avenue has been modeled in eQuest, with the results shown below. Monthly modeling estimates of electrical consumption are displayed in a bar chart in Figure 14. The building is highly insulated and energy efficient. Only about 14% of energy use is attributed to space conditioning, so the building has little consumption variation between seasons. The largest load comes from indoor and outdoor lighting for the facility—approximately 10,000 kwh/month. The modeled total annual electrical energy consumption is 222,000 kWh.

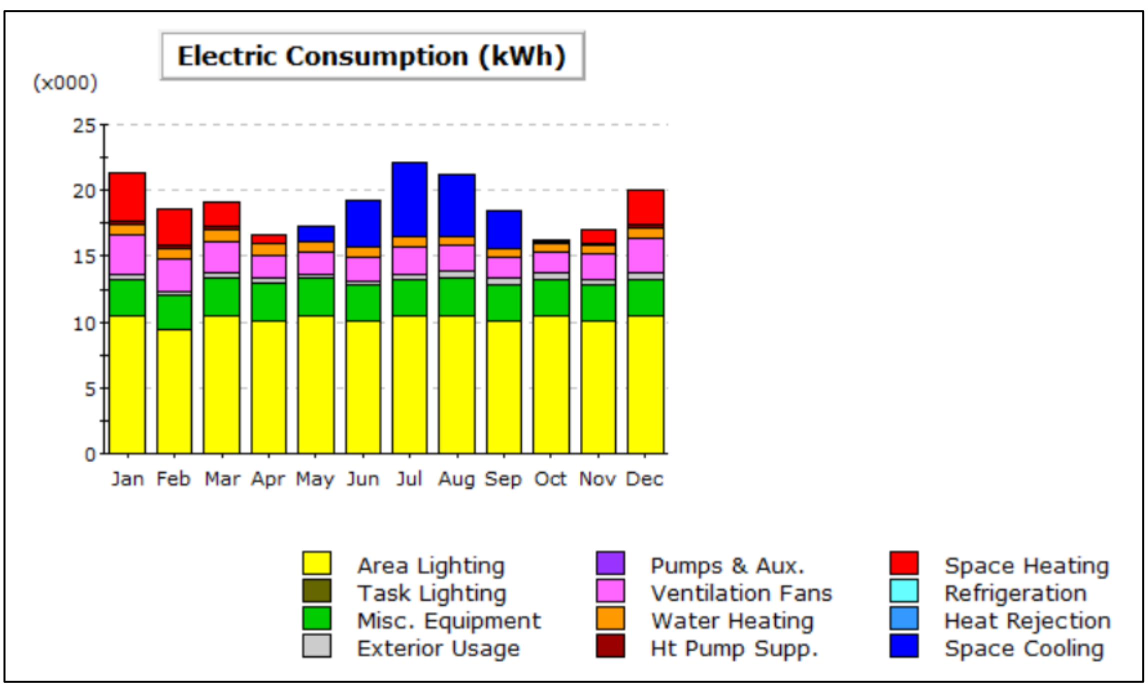

Figure 14. Monthly Electric Consumption: Phase I Self Storage

The monthly electrical demand profile for the building was also modeled in eQuest. A bar chart showing electrical demand is displayed in Figure 14. The facility draws a maximum peak of 60 kW during summer periods when cooling loads are highest and approximately 45 kW during swing seasons. As with energy consumption, lighting is the primary peak demand load.

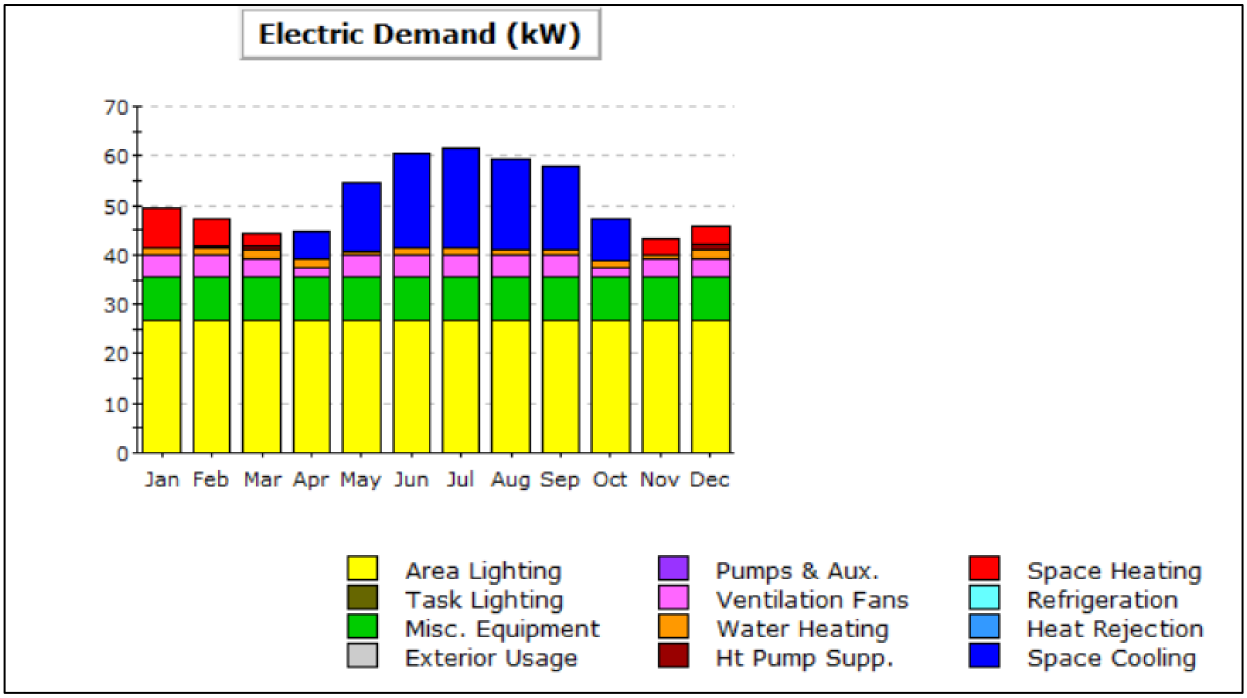

Figure 15. Monthly Demand Profile: Phase I Self Storage

Phase 2 of development consists of removing the existing woodshop and storage buildings at 522 Fenimore Road and 416 Waverly Avenue and constructing a new building with an anticipated size of approximately 100,000 ft2. This building will be a mixed-use office and self-storage building and is anticipated to be completed by 2018. This new building is anticipated to be similar to the phase 1 self-storage facility by design and utility impact based on the similarities between the building use types, but will be approximately 70% larger. The phase II building has approximately 12,500 ft^2 of roof space available for PV and is being designed with structural and electrical provisions in place to install a 150 kW system.

Phase 3 of development consists of replacing the only remaining original building in the Murphy Brother Contracting complex, located at 560 Fenimore Road with a new building or parking lot. This is anticipated to be completed by 2020. The energy consumption associated with phase 3 of this expansion has not been included because of the uncertainty of its scope.

Additional Non-critical buildings on Waverly-Fenimore Microgrid

Of the buildings that are not vacant and/or being re-developed, the team was only able to inspect Arctic Ice (#1) and Mamaroneck Self Storage Phase I (#5). However, working with Con Edison, the team was able to estimate total peak load on the feeder section for the Fenimore-Waverly microgrid. Con Edison provided a peak load profile for Arctic Ice and commented that there is an additional 50kVa from the proposed transformer (at Arctic Ice) to Waverly Ave. Accounting for the additional load from the two small commercial and one residential building on Waverly, it is estimated that he additional non critical buildings use approximately 100 kW. This brings the total annual peak of the microgrid to 1300 kW. An estimated peak demand profile for all buildings is shown in Figure 16.

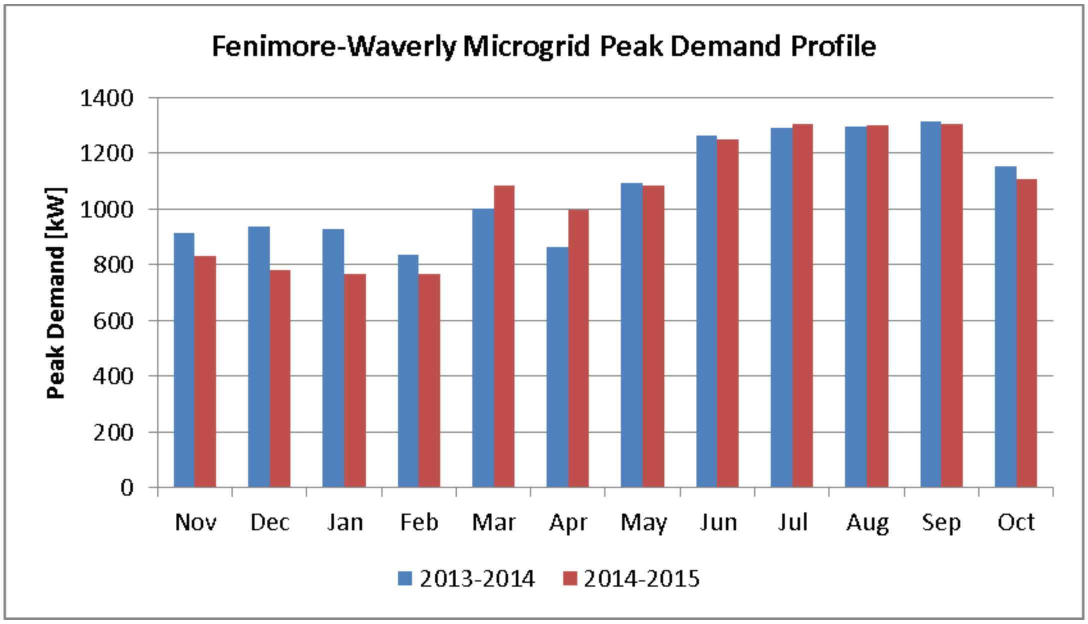

Figure 16. Electric Demand Profile: Fenimore-Waverly Microgrid

2.1.2 Mamaroneck Avenue Microgrid

The second of the three smaller microgrids analyzed includes many of the key critical facilities in the Village. A map that labels several buildings in the area is shown in Figure 17. The buildings associated with the proposed microgrid location at and around Mamaroneck Avenue are the Regatta at 123 Mamaroneck Avenue (#2), the new location of the local TV station (LMCTV) at 145/147 Mamaroneck Avenue (#5), and the Police Station at 169 Mount Pleasant Avenue (#23), and the Fire Station at 146 Palmer Ave (#24). Based on discussions with ConEdison and the results of the site visits, the team chose not to pursue this microgrid because the area feeder layout did not allow for a feasible network of the buildings (without breaking it up into several microgrids or installing underground cables to merge two feeders). The costs would be prohibitive and the model not easily replicable. Additionally, even though this area contains a larger number of critical facilities than the Waverly-Fenimore location, it was not chosen as the focus of this feasibility study because the opportunity to create a cost-effective, replicable microgrid in an area undergoing extensive redevelopment appeared to the team to be a more beneficial exercise for the area and NY State. The results of this analysis can be found in the appendix.

Figure 17. Buildings in Mamaroneck Ave Microgrid Area

2.1.3 Fayette-Northrup Microgrid and Sunoco Station

The Fayette-Northrup microgrid is a design that consists of two gas/service stations: Vincent Service and Lebrini's Service. Utility bill data was collected and analyzed for the buildings, but the team ultimately chose not to move forward with the technical design. As a result, site visit investigations were not completed. The original intent is that this section would be able to connect with the Fenimore-Waverly grid, but existing feeder layouts did not make this possible. Con Edison's recommendation for a microgrid containing these two buildings is shown in the appendix.

2.3 Distributed Energy Resource Characterization

The Fenimore-Waverly microgrid will utilize a variety of generation resources to produce the target power levels. Two solar arrays, an existing 8kW system located on Mamaroneck self-storage rooftop and a proposed new 700kW system located on Arctic Ice rooftop will generate when solar energy is available. PV energy will be the priority generation source; natural gas generation will only be used to supplement PV or serve as primary generation when solar conditions do not allow for adequate generation. A 250 kWh battery bank will support the PV systems along with a 750 kW natural gas generator. During periods when PV energy is not available and battery resources have been exhausted, the natural gas generators will act as the primary source.

Aside from scheduled maintenance, the generator can operate continuously, as long as natural gas supply isn't interrupted. The team considered on site compressed natural gas storage but chose not to include it in the final design because of infrequency of gas supply outages and added safety concerns. Absorption chilling and cogeneration was considered for Arctic Ice, however near term replacement of chiller equipment was not a financial feasible option for the facility. The team also evaluated cogeneration for use in space heating. Mamaroneck Self Storage buildings utilize air source heat pumps and Arctic Glacier Ice uses gas fired rooftop units (to heat only office space during winter). Unfortunately, these existing configurations do not lend easily to integration with CHP heat. An alternative to use the heat would be to build a separate central boiler plant, however the heat would still go unused for nearly half of year when space heating is not required.

Characteristics of the distributed energy resources of each microgrid area are shown in Table 5. During, emergency grid outages, the critical facilities may need to operate at reduced capacity if optimal solar conditions are not present.

Table 5. Distributed Energy and Thermal Generation Resources

Microgrid Area	Status	Location	Type	Rating	Fuel
Fenimore-Waverly	Existing	Mamaroneck Self storage P1	PV array	8 kW	Solar
Fenimore-Waverly	New	Arctic Glacier	PV array	700 kW	Solar
Fenimore-Waverly	New	Mamaroneck Self Storage P2	PV array	150 kW	Solar
Fenimore-Waverly	New	Arctic Glacier	Battery	100 kWh	Storage
Fenimore-Waverly	New	Mamaroneck Self storage P1	Generator	750 kW	Natural Gas

The Mamaroneck self-storage facility has an existing 8 kW PV array on the constructed with DOW Powerhouse Solar shingles. It estimated that the array produces approximately 8500 kWh per year.

Figure 18. 8kW PV array at Mamaroneck Self Storage

The proposed design includes a 700 kW PV array to be constructed on the roof of Arctic Glacier Ice. The gross building rooftop area is 65,000 ft^2, however a portion of the roof area contains ductwork and HVAC equipment. The remaining usable area is estimated at approximately 45,000 ft^2. At a conservative estimate of 16 W/ ft^2, this leaves capacity for an approximately 700 kW array. The Mamaroneck Self Storage Phase II building, with an available rooftop area of 12,500 ft^2, is currently being constructed with provisions for a 150 kW PV array. The system will be supplemented by a 100 kWh battery storage system that will be used for peak shaving and energy smoothing during passing cloud coverage. The battery bank will be located on the rooftop of the Mamaroneck Self Storage facility.

A 750 kW natural gas generator will be installed on the roof of the Mamaroneck self-storage building. Natural gas will be supplied from the 8” medium pressure Polyethylene gas line running under Waverly Ave.

2.4 Electrical and Thermal Infrastructure Characterization

The existing electrical configuration in the Fenimore-Waverly area is a single secondary feeder line that supplies all buildings except Arctic Glacier Ice (#1). A simplified electric layout diagram is shown in Figure 19. The Artic Glacier Ice building is supplied by the primary high voltage line and is stepped down at the transformer located in a pad mounted equipment (PME) box outside of the building.

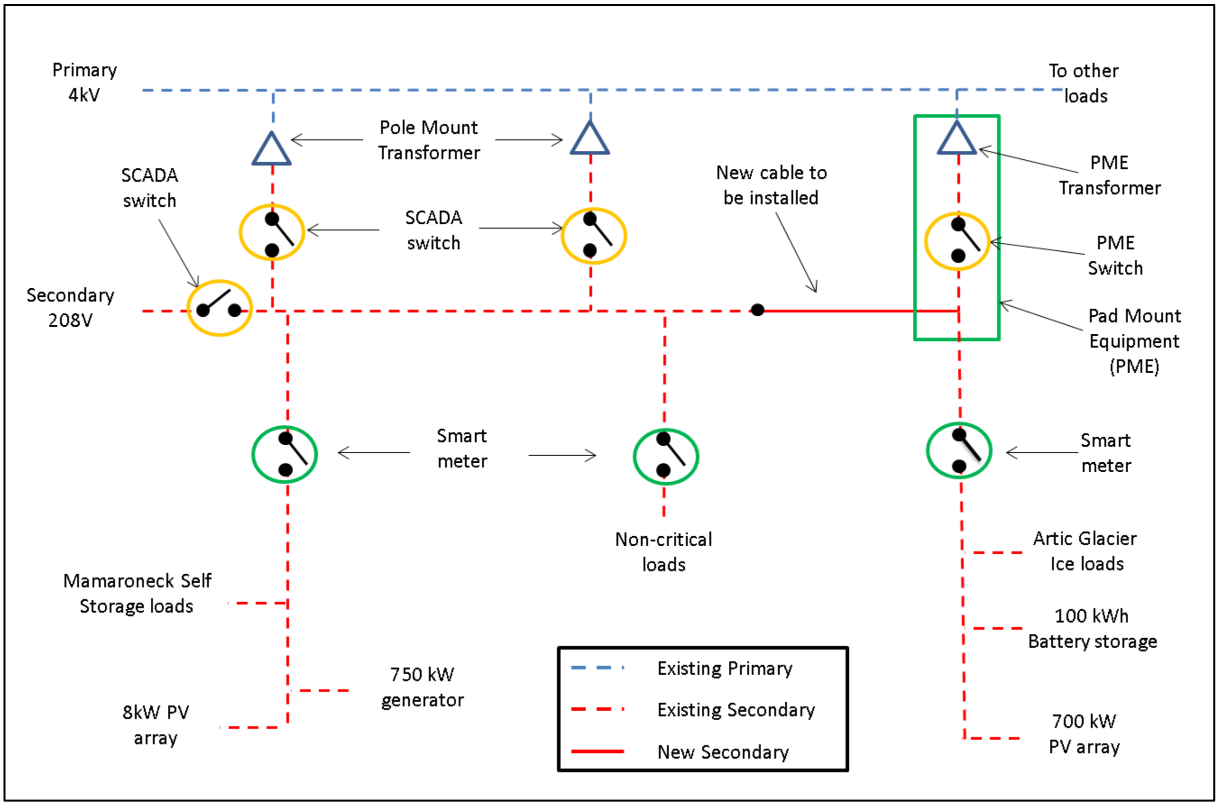

Figure 19. Simplified Electrical Layout: Fenimore-Waverly Microgrid

To join all facilities on one feeder, the existing secondary will need to be directly connected to Arctic at the PME. To isolate the target buildings from the rest of the grid, a SCADA switch will be installed on the feeder located on the Waverly Ave pole that supplies the Mamaroneck Self Storage facility. Additional SCADA switches will need to be installed at the pole mounted transformers that feed the 208 V secondary from the 4kV primary lines. If the SCADA switches are opened, the feeder section serving the target buildings will be disconnected from the grid. This will prevent the possibility of back feeding through the transformer during an islanded scenario. Current and voltage sensors will be placed before and after each SCADA switch for measurements. This information will be sent to the power conditioning system to indicate the open/close status of the switch as well as the voltage at and current through the branch. Since the system is utilizing only the 208V secondary lines, the team does not anticipate the need for additional transformers to be installed.

The proposed electrical infrastructure is designed to be resilient to the destructive natural forces in the area, primarily flooding. The generation equipment will be located on building rooftops and current carrying conductors will be pole mounted—well above flood lines. The secondary lines are not in vegetation dense area, so storm damage from falling limbs/trees is not a major concern here. For the Waverly-Fenimore feeder line, Con Edison indicated that the 3-year system average interruption frequency index (SAIFI) is 0.8685. This specifies the ratio of the total number of customer interruptions to the total number of customers served. It reveals that almost every customer in the area experienced an outage in the last three years and further supports the need for a strengthened distribution grid system in the area. The primary outage event in this index is from Hurricane Sandy, which caused power interruption to Fenimore-Waverly area for 5 days.

2.5 Microgrid and Building Controls Characterization

The microgrid controls will be handled by Spirae Wave [2] platform utilizing Delta Power Conversion System (PCS) hardware[3]. The Wave platform is a scalable program architecture for integrating and managing high levels of renewable and distributed energy resources. Controls wiring is shown on a one line diagram in Figure 20.

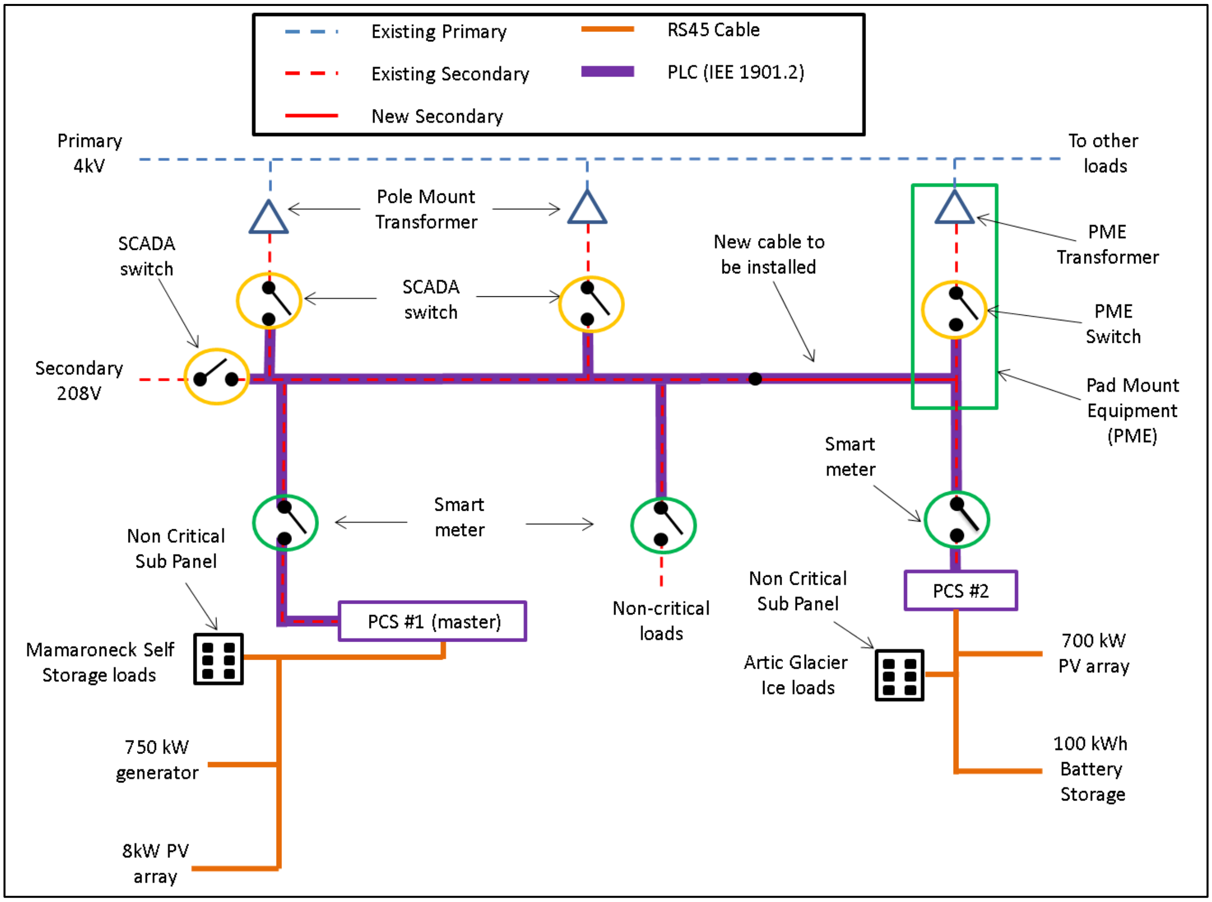

Figure 20. Simplified Controls Layout: Fenimore-Waverly Microgrid

Controls on the utility side of the meter will be power line communications (IEE 1901.2). Controls on the customer side of the meter will be RS 45 communications cables after the power control system (PCS). The PCS will regulate generation and consumption of the microgrid. One will be located at both Mamaroneck Self Storage (PCS #1) and Arctic Glacier Ice (PCS #2). PCS #1 will serve as the master

[2] http://www.spirae.com/microgrid/about-microgrid
[3] http://www.deltaww.com/fileCenter/Solutions/Download/01/0106/Delta_Microgrid%20v1.0.pdf

system and will dictate commands to PCS #2 when the grid becomes islanded. The PCS will have the ability to switch off loads on the non-critical subpanel for each facility and open/close the smart meter switches. SCADA switches will be controlled by the PCS # 1 master unit or by utility telecommunications command through the telecommunications network.

The team is planning to integrate numerous smart control technologies to optimize performance of the microgrid. Power Output and characteristics of the distributed energy resources (solar arrays, battery storage bank, and natural gas generator) will be continuously monitored and control signals will be fed back to the main microgrid controller/power quality analyzer located at Mamaroneck Self Storage. The general operation strategy will be to maximize PV generation consumption by shifting loads to periods where sunlight is available. The main opportunity to shift loads is in Arctic Ice's production schedule. Weather data can be input into the software to forecast PV production for a given day and Arctic Ice could shift their production schedule based on available resources. The controller will also be configured to receive input from Con Edison on natural gas peak and Electric Peak consumption periods. An additional goal will be to shift loads and generation to support the main grid through peak management. The team plans to work with Artic Ice's existing Eneroc software to output demand signals to the Wave platform in the PCS.

In order for the generators, PV arrays, and battery storage devices to send current back to the grid, frequency must be regulated. The generator contains internal frequency regulation typically set at 60 Hz and the PV systems inverter maintains its frequency. To send battery storage energy back to the grid, the power quality analyzer and controller will match the grid frequency.

Since a large portion of generation will be from PV, the system will employ a solar smoothing strategy that manages the smart inverters and battery storage bank. The goal of solar smoothing is to mitigate variable spikes in generation by managing the ramp rate of PV production to improve voltage stability. This process requires monitoring the state of charge of the batteries and monitoring the finite interval generation of each array. To optimize economics of the system, the battery bank will be charged at non-peak hours and will be discharged during peak hours. Load forecasts from input weather data will be used to further optimize the charge/discharge process over a 2-3 day forecast period. The program will utilize real-time wholesale energy market price data to determine whether to buy or sell energy to/from the grid.

An important feature of the control system is to be able to operate from a blackstart. Blackstart becomes initiated during a main grid outage and uses available resources to rebuild the electrical network while maintaining voltage and frequency. When grid power is available, the microgrid switches will remain closed; blackstart (isolated mode) is only initiated when the main grid become de-energized. The battery and natural gas generator will work in unison to employ power during "blackstart" mode. At the point the microgrid has been restored, the operator will switch from 'blackstart" mode to "maintain island" mode. At this time, the control system signals smart meters to shut off any current to any non-critical loads on the line. The switching of smart meters will be configured to modulate based on the available resources at that time.

2.6 Information Technology (IT)/Telecommunications Infrastructure Characterization

A simplified diagram indicating the IT/telecommunications infrastructure of the microgrid is shown in Figure 21. Communication within the telecommunication network is between three locations: 1) utility line SCADA switches, 2) the master PCS (#1), and 3) the utility data center. These locations are identified with the dashed black outline on the following diagram. The master PCS controller at Mamaroneck Self Storage will be networked with a gateway that provides two way communications between the Con Edison Utility data control centers. Communication may be general packet radio service (GPRS), Global System for mobile Communications (GSM), or WI-SUN based on the protocol that Con Edison selects during the Touchpoint 3 meeting.

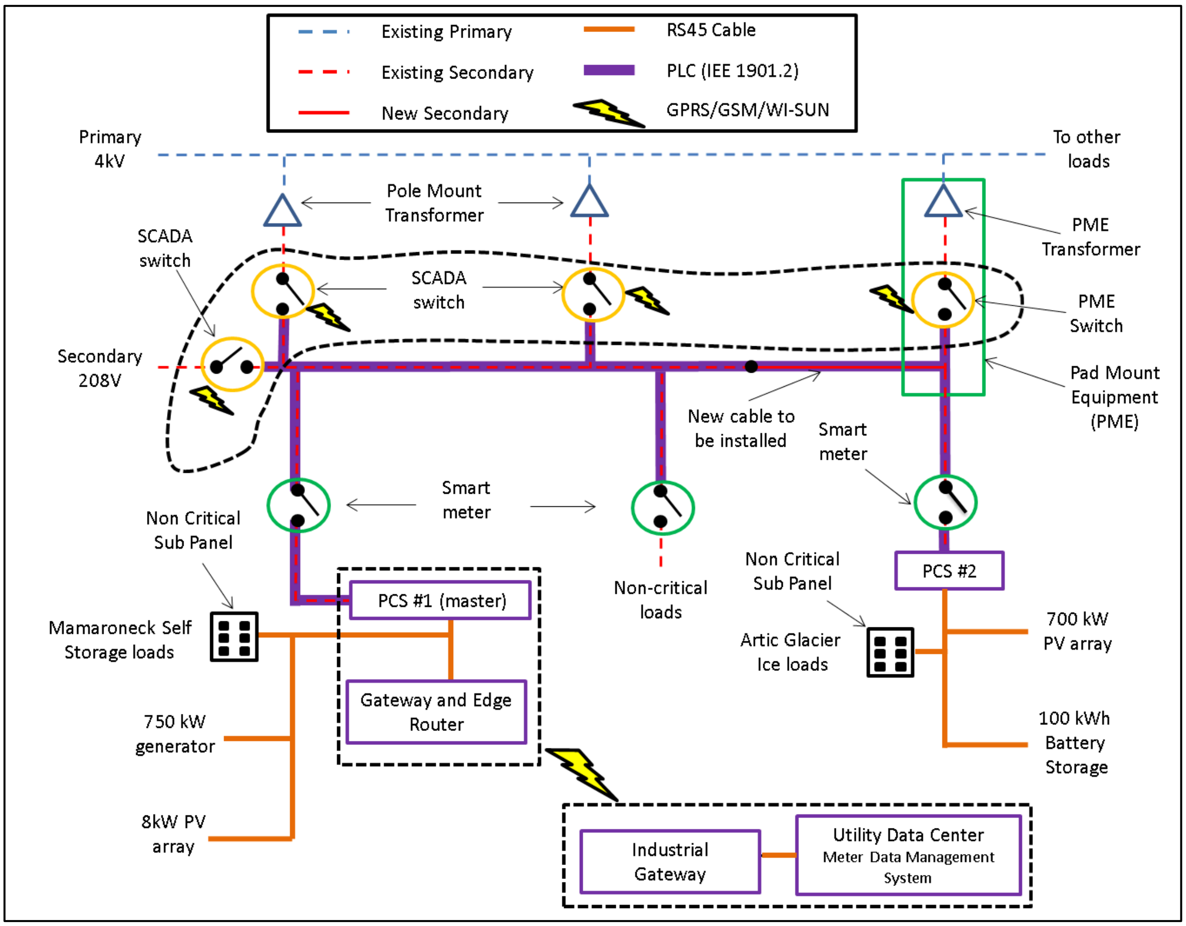

Figure 21. Simplified IT/ Telecommunications Infrastructure Layout: Fenimore-Waverly Microgrid

If communications is lost from the utility data center, the microgrid will continue to operate at the last command for a predetermined amount of time (determined in conjunction with Con Edison). If communication is lost past the time limit, the PCS will instruct SCADA switches to open and the microgrid will island. The primary goal will be to leave customer's power in operation without gaps caused by communications loss.

Task 2 Conclusion

Now that the initial technical design is complete, the team is working to collect detailed costs and finalize business structure of the microgrid. With the design concentrating on redeveloping an area around a microgrid, there is a unique opportunity to build a more efficient and cost-effective system. Based on pricing from past projects and cost resources published on existing microgrids, a cost estimate for the Fenimore-Waverly microgrid has been developed to an approximate accuracy of +/-30%. A line item list of cost estimates is displayed in Table 6. It is expected that the total system cost (materials and install) will be within the range of $3,681,000 +/- 30%. It is important to note that incentive figures have not yet been applied to these preliminary cost estimates.

Table 6. Fenimore-Waverly Microgrid Cost Estimates

Item	Cost
700 kW PV array	$ 2,030,000
150 kW PV array	$ 435,000
750 kW generator	$ 500,000
4 SCADA switches	$ 100,000
New Secondary Cable	$ 25,000
PCS, sensing, communications	$ 375,000
Spirae Wave Controls Software, O&M package	$ 125,000
11 Smart Meters	$ 6,000
250 kWh battery	$ 35,000
subpanels, misc. hardware	$ 50,000
Total	**$ 3,681,000**

Cost for PV arrays were provided through conversations with Kingspan Solar. Kingspan solar estimate install cost at this scale to be approximately $2.90/W. Generator costs were developed based on conversations with PPI power systems and cost study performed by NREL[4]. Cost of SCADA switch gear was estimated based on conversations with S&C Electric Company. PCS, sensing, and communications are based on Delta past project experience of approximately $0.25/kW per peak system capacity require for PCS control components. Spire Wave controls estimates are based off estimated implementation cost of $100,000 and standard software license fee of $25,000.Smart meters are estimated at $100/meter and remaining cost is service/installation at 6 hours per meter. Battery storage is estimated at approximately $140/kwh based on SWA's past DR projects in NY.

The proposed microgrid design will be reviewed with Con Edison engineers during the utility touch point 3 meeting to determine technical design adjustments that may need to be made to integrate the microgrid

4 www.nrel.gov/docs/.../60732.pdf

with the existing utility infrastructure. At this time, the team will seek more detailed costs associated with utility interconnection. The next step in process will be to complete the commercial and financial feasibility in Task 3. The team realizes that the project must be both technically and financially feasible in order for stakeholders to move forward with construction.

3 Task 3: Assessment of Microgrid's Commercial and Financial Feasibility

The Village of Mamaroneck is a flood prone area located in Westchester County, NY. The area, currently under major redevelopment, provides an ideal location for a microgrid. Local government officials have teamed up with several national microgrid experts to develop a microgrid system design. The team investigated several distributed energy resource options and ultimately has selected a combination of PV and natural gas generation to support the area. Critical buildings in the area include Arctic Glacier Ice and Mamaroneck Self Storage, which will be used as reserve command center for government as well as a place of refuge for Village residents. The following report describes the commercial and financial feasibility of the proposed project.

3.1: Commercial Viability – Customers

The following section describes the commercial terms/relationship between participants in the microgrid project, products expected to be produced by the microgrid and arrangements for sharing of benefits.

3.1.1 Critical Load Support

The feeder section that encompasses the Fenimore-Waverly microgrid includes 11 buildings. Three of these buildings have been classified as critical loads during a power outage: Arctic Glacier Ice and Mamaroneck Self Storage Phase I and II. In the event of grid outage, distributed energy generation will be prioritized to critical facilities by limiting current to other buildings by switching open smart meters. Arctic Glacier Ice is the area's largest ice manufacturing facility. They currently distribute ice in NY, CT, and NJ. During a power outage, ice availability becomes a necessity. Customers that rely on grid tied cooling systems to preserve food, medication, and other critical cooling processes will need ice when the grid goes down for longer than 24-48 hours. The FDA has developed a consumer power outage resource that recommends utilizing 18" blocks during outages to extend lifetime of spoilable foods[5]. As the only large scale supplier within 20 miles of Mamaroneck, Arctic Ice also supports neighboring cities with ice supply. While the current population of Mamaroneck is 19,500, surrounding counties of Westchester, NY and Fairfield County, CT provide a pool of 1.9 million customers; many of those that would require ice during an extended outage. On face value, ice preserves food that customers have already purchased, but it also provides the added benefit of providing relief to supermarkets that will be operating on limited

[5] http://www.fda.gov/Food/ResourcesForYou/Consumers/ucm076881.htm

power backup generation. This reduces the likelihood of a food crisis that can develop if a population's food supply must all be replenished at once.

An additional crucial variable in restoring and maintain order during a natural disaster/grid outage is a functioning capable government. The Mamaroneck Self Storage facility will have the ability to act as a reserve command center during emergency situations. This provides a communication hub for town officials to convene and restore order to the community. As a result, by keeping the village government in operation, all of the 19,500 residents would directly benefit.

As the area redevelopment progresses, it is anticipated that rezoning will lead to growth of mixed use commercial buildings in the area. The plan is that the new buildings would be developed to be optimally integrated into the microgrid design. As the microgrid development progresses, other critical facilities will be drawn to the area seeking uninterruptable power supplies to support their services. While this value cannot be easily quantified, it is important to consider when assessing the value of a microgrid in a developing area.

3.1.2 **Microgrid Services**

The primary source of income for the VOM microgrid will come through the sale of energy to surrounding customers through power purchase agreements. The primary consumer of DER generated energy will be Arctic Glacier Ice (total annual consumption of 3.7 million kWh). The microgrid can offer arctic ice an energy supply rate that is competitive with alternative Con Edison suppliers while offering critical load energy during main grid outages. Excess available capacity will be sold through the Independent System Operator (ISO) market during times when generation is cash flow positive for the asset owners. The DERs will also register with NYISO to become potential peak plants that can offer generation during peak demand. Additional revenue will be generated through enrollment in the Demand Response program. Arctic Ice will continue to offer 375 kW of DR capacity.

3.1.3 **Microgrid Customers**

There are currently 11 buildings in the feeder section that forms the Fenimore-Waverly Microgrid. The addresses and building types are listed in Table 7. During normal operating conditions, when solar conditions are optimal (850kW+), total solar and natural gas power generation could approach 1.6 MW. This level of power generation would satisfy the requirements of all eleven buildings on the feeder line. For reference, the total peak feeder section load is currently 1.3 MW, during normal operation, when solar conditions are not optimal, the power from the natural gas generator (750 kW) will be limited to Arctic Glacier Ice and a portion of the Mamaroneck Self Storage loads. While the initial design is to provide uninterrupted power to the three highlighted buildings, additional DER could be added in the future to provide uninterrupted power to the other buildings on the feeder loop during periods of outages and reduced solar output.

Table 7. Waverly Fenimore Buildings

Number	Address	Building
1	500 Fenimore Rd	Artic Glacier Ice
2	520 Fenimore Rd	Non-Critical Commercial/Industrial
3	426 Waverly Avenue	Mamaroneck Self Storage Phase 2
4	560 Fenimore Rd	Mamaroneck Self Storage Phase 3
5	416 Waverly Avenue	Mamaroneck Self Storage Phase 1
6	421 Fenimore Rd	Non Critical Commercial
7	413 Fenimore Rd	Non Critical Residential
8	389 Fenimore	Non Critical Commercial
9	545 Fenimore Rd	Non Critical Commercial
10	525 Fenimore Rd	Non Critical Commercial
11	307 Hoyt Ave	Non Critical Industrial

Arctic Ice and Mamaroneck Self Storage loads will be first priority to receive available power, but when their load is less than available generation, excess capacity will be offered to the other eight facilities on the feeder. There may be additional time periods where Con Edison requests that the generator is run above the microgrids required capacity to support main grid peak operations. During this case, Con Edison would offer their grid energy market as a "customer".

3.1.4 Stakeholders

A list of the stakeholders in the Fenimore-Waverly microgrid project as well as the associated impact it will have on them is summarized in Table 8

Table 8. Stakeholders and Associated Impact

Stakeholder	Impact
Customers in Microgrid	access to cost effective energy
Green energy financers	low-risk investment for loan income growth
Utility customers	support to combat power quality issues
Con Edison	
Microgrid equipment vendors	profit from microgrid equipment sales
Con Edison,	Potential loss of distribution/transmission revenue
VOM & surrounding population	critical services during main grid outages
Community at large	low carbon emission generation
Building owners in microgrid area	increase property values
ISO New England	addition of diversified energy source offering in energy market
Con Edison, Natural gas suppliers	increased profit form natural gas consumption from NG generator
Electric suppliers	reduced supply profits from energy market
Local workforce	addition of technical jobs to oversee operation
NY State/NYSERDA	support to increase grid reliability in unison with REV initiative

3.1.5 **Ownership Structure**

The microgrid ownership structure will be shared ownership between Murphy Brothers Contracting and a newly created legal entity, Fenimore Waverly Microgrid LLC. Murphy Brothers will purchase power from the microgrid for the Mamaroneck Self Storage buildings. Arctic Glacier Ice, the feeder's largest consumer will purchase a majority of the system's power. Arctic Ice will also be offered an investment stake in the LLC as chance to become part owner. Every purchaser of power will enter a contract with the microgrid owner agreeing to purchase power at competitive market rates. For instance, Arctic Ice may enter a contact with the ownership LLC to buy 2,000,000 kWh of energy from the DERs at a supply rate of $0.07/kwh with the advantage of having priority access to available capacity during main grid outages. Non critical facilities could also select the microgrid as their electric utility supplier.

3.1.6 **Power Purchase Scenarios**

During normal operation, all customers within Fenimore-Waverly feeder section isolated by the SCADA switch at the pole located outside of Mamaroneck Self storage will have the option to purchase electricity. However, non-critical facilities, will not always have microgrid power available to them. For instance, if solar conditions are poor and the Arctic Ice and Mamaroneck Self Storage facilities exceed available generation, the remaining facilities will need to draw power from the main grid. If the solar array is producing power along with the natural gas generators, the DERs will have enough capacity to meet the load in all ten buildings. During islanded mode, initiated during main grid outages, smart meters will isolate non critical loads in order to prioritize power supply to critical customers (Arctic Glacier Ice and Mamaroneck Self Storage)

3.1.7 **Customer Solicitation**

Initially, generation sources are being sized to support critical loads for the 11 buildings located on the target feeder line. The team has met with several of the building owners/business already and they are on board to be purchase electricity under cost competitive financial terms relative to other area suppliers. For remaining buildings on the feeder who are not yet actively involved in the project, the team will schedule meetings to introduce the concept and offer normal/emergency generation. Per Con Edison's recommendation, the generation resources are currently sized so that electricity is not exported outside of the micro grid area.

3.1.8 **Other Energy Commodities**

The current building stock in the Fenimore-Waverly area does not have a year-round baseline heating load that supports cogeneration integration with steam/hot water/chilled water loops. Since the area is being redeveloped, the team has the opportunity to work with area developers as buildings are designed. The goal will be to create a community design where building loads can complement one another to achieve the most efficient use of energy. When Arctic Ice is at a point where they must upgrade chiller equipment, they may consider swapping to absorption chillers that can be integrated with a combined heat and power system.

3.2: Commercial Viability – Value Proposition

The following sections describe the value that the microgrid is expected to provide directly to its participants, to the community at large, the local electric distribution utility and the state of New York.

3.2.1 Community Cost and Benefits

The village of Mamaroneck is located in a flood prone area and has recently experienced several major flooding and power outage events. For instance, in October 2012 Hurricane Sandy devastated the region with flooding and left many without power for five days. In August 2011 Hurricane Irene left similar flooding damage, creating power outages for many of three days. These storms caused power reliability issues for many cities along the eastern coast. The Fenimore-Waverly microgrid is in a unique geographic location, being bound between the Sheldrake River, eastern coastline, several additional area tributaries. In this area, the presence of water can create major flooding events and power outages in even modest rainstorms. In March 2007, a seemingly average rain event caused dangerous flooding and power outages in the area for 4-5 days. A combination of frozen ground and high tide conditions during a rain event caused water to flood the area. An emergency rescue carried out with a front loader from this disaster is shown in Figure 22.

Figure 22. Emergency Flood Rescue in March 2007 Rain Storm

A microgrid in the Village would enable the opportunity to keep critical facilities up and running during these unfortunately common events. Construction and long term operation of the microgrid system would provide technical jobs to support the area workforce. These jobs would include A) mounting, wiring, and maintaining PV panels. B) structural, electrical, and plumbing installation for natural gas generator install as well as monthly maintenance to keep engines running at optimal levels C) controls wiring and software interfacing among different systems D) administrative support to solicit and bill customers as well as managing O&M contractors. Initial construction could potentially support 5+ full time technical staff and laborers over a period of 4-8 months. There are no direct costs foreseen to the community, unless the Village of Mamaroneck chooses to invest in a stake of project ownership.

The Army Corp of Engineers (USACE) recently presented results of an engineering study that analyzed the Sheldrake River Basin at the Village of Mamaroneck[6]. The report highlights the need for water management redevelopment in the area and describes a plan to control current flooding issues. The current USACE plan includes the following provisions:

- Rivers to be widened up to 45 feet for Mamaroneck and up to 33 feet for Sheldrake.
- Channels will be lined with concrete or sheet piling (between 5 and 17 feet high (average wall height 8.5 feet) where natural slope is not possible.
- Will establish permanent easements with private property owners to allow construction and operation and maintenance of the channel.
- Replacing Waverly Avenue Bridge.
- Permanent removal of the Ward Avenue Bridge and three pedestrian brides –Centre Avenue and the two footbridges in Columbus Park.
- Raising of 8 houses in Harbor Heights and 1 building on Fenimore Road.

The total project cost is expected to be about $70 million. Expense breakdown is expected to be as follows:

- Federal share is 65 percent or $45.3 million.
- Non-federal share is 35 percent or $24.4 million.
- Current Village share estimated $6 - $8 million (subject to change)

A map of the flood risk associated with the Mamaroneck and Sheldrake river basin in shown in Figure 23. The approximate area that contains Arctic Glacier Ice and Mamaroneck Self Storage are indicated with red circle containing an “M” in Figure 23.

[6] http://www.nan.usace.army.mil/Missions/CivilWorks/ProjectsinNewYork/MamaroneckandSheldrakeRivers.aspx

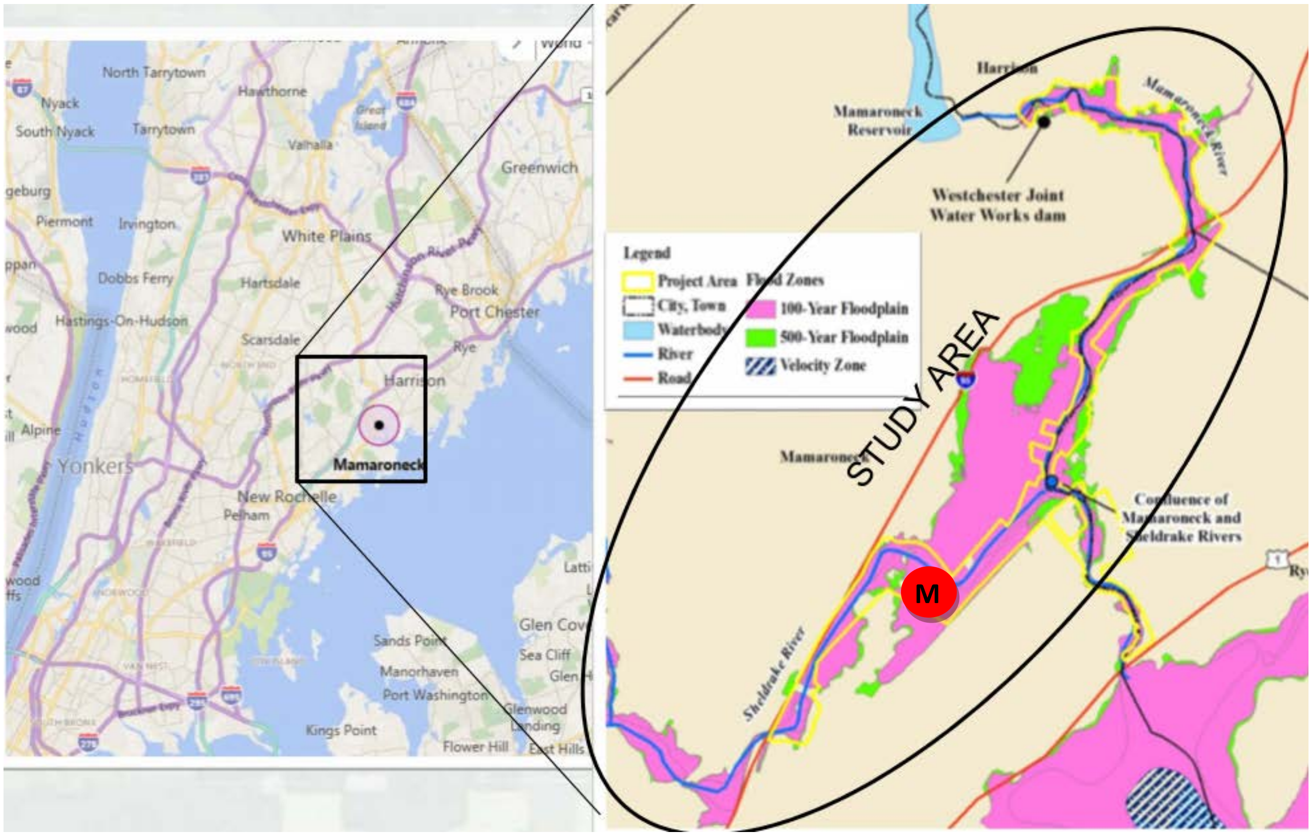

Figure 23. Flood Risk Management Study Map

The USACE's current water management redevelopment efforts aligned with the industrial advisory board's economic redevelopment actions provide an ideal environment for the Fenimore-Waverly microgrid. The federal/state interest in this area provide added support for improved grid resiliency and access to critical services in the area.

3.2.2 Utility Cost and Benefits

Any addition of localized generation reduces the energy that must pass through the utilities transmission and distribution network. The generators in this microgrid have a potential peak generation capacity of 1.6 MW. This has the potential to defer new substations, transformer upsizing schedules, and overloaded lines. Integrating the microgrid with the main utility system will involve cost for both Con Edison and the microgrid owners. Costs to the utility may involve time from an engineering team to oversee integration design and purchasing new equipment that is compatible with modern microgrid technologies. Some of this cost may be split between the utility and the customer. Over the long term, the utility may lose income from a reduction in distribution and transmission quantity, but the grid system will ultimately become more resilient.

3.2.3 Business Model

The business model is very similar to conventional suppliers in the electricity marketplace. The owner/operator entity will enter into power purchase agreements with Arctic Ice and other facilities in the area to sell a predetermined about of energy at a set rate (based on dynamic market prices). The model is very repeatable and the proposed system can be replicated throughout all of NY State. A SWOT analysis that list strengths, weaknesses, opportunities, and threats of the model is shown in Table 9.

Table 9. SWOT model

Strengths	**Weaknesses**
-experienced leadership team, initial approval from town officials, expert technical consultants	-financial success is highly leveraged on Arctic Glacier Ice's power purchase agreement
-design is easily replicable	-construction is contingent on financing rates, incentives, and securing investors
-simple design that takes advantage of Con Edison feeder layout, not capital intensive to require distribution network	-several regulatory and contractual hurdles to overcome
Opportunities	**Threats**
-expansion of microgrid customers along Waverly Rd and surrounding distribution feeders	-several energy suppliers to compete with
-area is under redevelopment thus offering flexibility in design	-customers may consider adding their own generation resources (decreasing revenue for microgrid)
-additional rooftop space available in the area to add more PV generation	-owner will be subject to legal liability of adhering to power purchase agreement

3.2.4 Unique Project Features

There are several aspects that make this project unique. Most notably, the area is under a major redevelopment, so buildings can be designed to be optimized to the microgrid – rather than the conventional approach of trying to force microgrid applications into an existing building set. The design team believes that this makes for a far more replicable model. The team has also chosen to use advanced controls technology and hardware. The system will use Delta power conditioning systems paired with Spirae Wave control software. These components will allow for an optimal generation and consumption modulation.

3.2.5 **Project Replicability and Scalability**

This project is unique in the manner that it lies in the heart of a redevelopment zone that will be evolving over the next few years. It provides a means to design a building to be optimized with an existing grid, rather than trying to design a grid around a static set of existing buildings. The model of utilizing a combination of PV and natural gas generation can be replicated in most areas. It does not require buildings to have a baseline thermal load for cogeneration, however the design can be modified if the opportunity exists. PV capacity is limited to available rooftop space (or ground mount space) but generator(s) can be sized to meet almost any microgrid

3.2.6 **Project Motivation**

The area of the village of Mamaroneck at Fenimore Rd and Waverly Ave are in a zone that easily becomes flooded due to its proximity to local rivers/tributaries. It has seen damaging floods three times over the past eight years (2007, 2011, and 2012). An image from a 2007 rain event is shown in Figure 24.

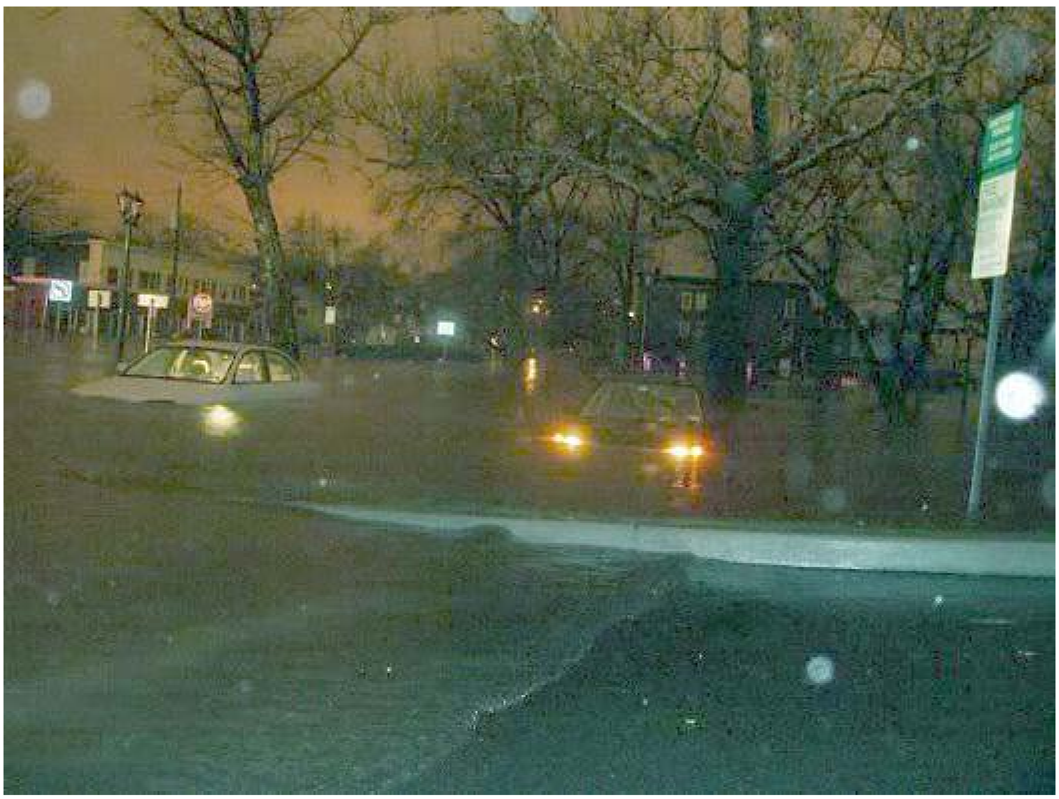

Figure 24. 2007 flood in VOM

The microgrid is being designed to sustain these weather events. The primary precaution to resist natural forces is locating all generation equipment above floods lines. Generators and PV will be mounted on rooftops, thus removing the risk of flood damage. The generators can stay functional as long as natural gas supply doesn't get interrupted. Additional images taken during the aftermath of the 2011 Hurricane Irene flood are shown in Figure 53 of the appendix.

3.2.7 **Value Proposition**

Murphy Brothers Contracting **–** MBC will increase the reliability and value of the buildings that they own in the surrounding area and may earn investment profit by funding initial capital.

Investors – This group will obtain investment profit by funding initial capital costs.

Village of Mamaroneck – The Village government will be able to use Mamaroneck Self Storage Phase II offices as central command centers during grid outages. This will allow the government to maintain order during emergency periods.

Mamaroneck Self Storage Phase II **–** This facility will retain power during grid outages and will be able to purchase power at a less cost than utility supplier options during normal operation. The value of the property is expected to increase as a results of the generation components and power reliability.

Non-critical facilities – These facilities will have access to energy at a rate less than what the utility suppliers currently offer. If critical facilities are not using all generation capacity during grid outages, these facilities will be next in line to receive power. The value of these properties is also expected to increase as a result of being included in the microgrid area.

Utility – The surrounding grid will be strengthened and become more resilient to outages. The utility will be able to shed load during peak periods by enabling the microgrids DERs to generate and demand response loads to throttle down.

Community – This group will primarily benefit by having access to critical services during grid outages. The community will have the option to use Mamaroneck Self Storage Phase II as a place of refuge during grid outages. Once the Army Corp's of Engineers water management upgrades are implemented, flooding risk in the area will be diminished.

NY State – The state will see value by progressing the REV initiative and strengthening the state's electric grid.

3.2.8 **Project Cost and Revenue**

The purchaser of power will have the option to purchase energy at a supply rate that is lower than Con Edison's offering. For instance, if Arctic Glacier Ice purchases 3,000,000 kWh per year from the micro grid generation sources and can purchase energy at a supply rate of $0.075/kwh rather than $0.09, they can save $45,000 per year on supply charges. Mamaroneck Self Storage facilities, with an estimated annual consumption of 500,000 kWh, could save approximately $7,500 annually.

Additional revenue streams will come from obtaining power stability during grid outages. For instance, on a peak production day Arctic will produce approximately 250 tons of ice. With an estimated revenue of $0.05/lb., keeping the ice manufacturing business open during a summer grid outage could translate to avoided loss of revenue of $25,000 per day. Through utilization of the 0.96 MW generation capacity available to demand response programs (including a 20% fraction of PV capacity) and the additional 375 kW in Arctic Glacier's load shedding ability, the purchasers can receive monetary demand response benefits. If a total combination of 500 MW can be dedicated to the demand response program, it can carry a potential value of $60,000 annually (at $120/kw/yr).

3.2.9 Alignment with State Policy Objectives

The REV initiative seeks to increase clean reliable generation sources within the NY utility grid system while increasing the reliability of energy availability to customers. A primary goal of the initiative is to cut down on greenhouse gas emissions through implementation of renewable generation and building energy reduction. In order for a microgrid to fulfill these objectives, its generation needs to be from low carbon sources. The proposed project includes a variety of solar PV and clean natural gas generation resources that support this effort. The Spirae Wave software is a control system that will optimize use of these resources.

3.2.10 Promotion of New Technology

This project promotes smart technology by utilizing the Spirae Wave software, an advanced control system that can optimize energy consumption and DER generation. The project will demonstrate another successful application of the control technology in a community microgrid setting. The team also plans to employ smart meters (advanced metering infrastructure) to differentiate between power consumed from the utility suppliers and power from the DERs. The team plans to utilize small scale battery storage (100kwh-250kwh) to supplement the PV system. An exact battery has not been finalized, but the team has been communicating with EOS energy storage and may install their new Lithium ion battery for grid storage.

3.3: Commercial Viability – Project Team

The following section describes the structure of the project team and the roles, strengths and resources of its members and other necessary partners.

3.3.1 Community Support Approach

The Village of Mamaroneck microgrid design team has been working with local Village of Mamaroneck leaders including the mayor and Village manager since the project's start. The local government is optimistic about the benefits that the microgrid will bring to the community and has been very instrumental in helping the project progress. A key part of the team's success has been the constant communication with the community. Shortly after the project began, the team held a meeting at the village hall to explain the projects goals to several local leaders: fire chief, police chief, business owners, village staff, etc. During this meeting, community members provided input and voiced opinions on the project path, including the desire for clean energy generation and more reliable power for the flood vulnerable areas. Additionally, the design team gave an educational seminar to community members at the Mamaroneck library to explain why the concept was being considered for Mamaroneck and what technologies/facilities were being evaluated. Local residents were engaged in the presentation and very excited to hear of the potential energy/resiliency upgrades in their hometown.

3.3.2 Project Roles

Murphy Brothers Contracting will be a partial owner of the microgrid among several investors structured under a newly formed limited liability corporation— Fenimore-Waverly Microgrid, LLC. Murphy Brother Contracting will be the applicant and developer of this system, managing a set of technical contractors during construction and design. Additionally MBC will be the operational lead of the microgrid, managing power purchase agreements and maintenance schedules. Delta Group is the global leader in power and thermal management solutions and will be the supplier and consultant handling the grid's power conditioning systems. Spirae LLC has extensive experience with the development of distributed energy resource management systems and micro-grid control systems both in Europe and in the US and will provide and maintain the control software that manage microgrid operations. Steven Winter Associates, Inc. will provide be an energy efficiency and construction consultancy that will assist with the detailed design and project management.

3.3.3 Public-Private Partnerships

There may be a public/private partnership if the Village of Mamaroneck chooses to invest in the system and become a part owner. Since the Village government will benefit during a grid outage by having the option to utilize Mamaroneck Self Storage as a central command center, there is added incentive for the Village to invest in the system. The contract has not been developed yet but it is likely that the Village of Mamaroneck may become part owner of the microgrid.

3.3.4 Financial Strength of Applicant

The applicant for the phase II award is Murphy Brothers Contracting, however the eventual project owner will be split among several entities: MBC, Mamaroneck Self Storage LLC (actual facility owned by Sean & Chris Murphy), East Coast North Realty (actual land owned by Sean & Chris Murphy) as well as a limited liability corporation of investors specific to the microgrid operation.

3.3.5 Project Team Qualifications

The applicant and partial microgrid owner for the Phase II proposal will be Murphy Brothers Contracting. The company was started in 1979 by brothers, Sean and Chris Murphy. Since then, they have developed an award-winning company known throughout the greater Westchester Hudson Valley region and southern Fairfield County (CT) for building custom homes, renovating existing homes and distinctive light commercial projects. Directly employing (45) area people, Murphy Brothers manages about 20+ projects at any given time, engaging with hundreds of individuals from subcontractors, suppliers, owners' representatives, building code officials and utilities on a daily basis. The company is located in Mamaroneck, NY on the site of the proposed Mamaroneck Micro-Grid construction project.

Delta Group, will be the supplier and consultant handling the grid's power conditioning systems. Delta Group, founded in 1971, is the global leader in power and thermal management solutions, and recently ranked 1st by Commonwealth Magazine's "Most Admired Company Survey" for the 13th consecutive year, achieving the 5th place among 2,000 large enterprises in the 2014 edition. The company has worldwide R&D facilities in Taiwan, China, Thailand, Japan, the U.S., and Europe and has been awarded international honors for innovation. Delta has developed into a leading international photovoltaic solution provider since 2008. Delta Group brings expertise in on-grid/ off-grid PV system solutions for customers worldwide in the field of residential, commercial, and utility industries as well as substantial experience with micro-grid systems having installed over 3,000 such systems across the world.

Spirae LLC will provide and maintain the control software that manage microgrid operations. Spirae, LLC, based in Fort Collins Colorado, has been in business since 2002. The company has extensive experience with the development of distributed energy resource management systems and micro-grid control systems both in Europe and in the US. The firm has approximately 55 full time employees and possesses the resources necessary to support the teams work under the NY Prize Community Grid Competition. Spirae is an innovative technology company that delivers scalable smart grid solutions to global partners and customers and specializes in the integration of large-scale renewable and distributed energy resources, the development of local and wide area controls, energy service platforms and power system simulations.

Steven Winter Associates, Inc. will provide be energy efficiency and construction consultancy that will assist with the detailed design and project management. Since it was founded in 1972, the firm has worked to improve the planet's buildings and communities by optimizing their construction and operation, by improving the systems and products they are made of, and by enhancing the services they house. The company has a long history of managing research contracts with local, state and federal agencies. Their unique grasp of building performance and energy engineering considerations has been recognized by many, including the NYC Mayor's Office of Sustainability and Long Term Planning which selected SWA as the only multifamily energy firm to assist in the analysis of city-wide benchmarking data from Local Law 84.

The VOM Mayor, Norm Rosenblum, has pledged his support of this project and stated the following in his letter to NY Prize:

> The Village of Mamaroneck has long been pursuing efforts to harden our community and make our businesses and residents more resilient to the impacts of hurricanes, Nor'easters and other major storms, particularly as it relates to power outages and damages. Since large portions of the Village are within FEMA mapped flood plains, with impacts from both tidal and riverine flooding, it is important to maintain power for these areas in order for them to operate sump pumps and other emergency equipment to protect structures. With Hurricane Sandy, one of the most destructive storms in our recorded history, two thirds of the Village was without electricity.

LMCTV, the local television station, has been a crucial partner in getting the word to the community about the proposed microgrid and NY Prize's efforts. They have filmed several segments and presentations and aired them on television. They continue to aid the team in promoting the microgrid project and informing the community about its benefits.

3.3.6 Selected Contractors and Suppliers

The team has not yet developed contracts with vendors however there are preferred vendors that will likely be selected. For the solar PV array, the team has been working with Kingspan Solar to determine reasonable system capacity and pricing of arrays. For the microgrid controls hardware including power conditioning units and inverters, Delta Electronics, Inc. For microgrid controls software, Spirae, Inc. For SCADA switch hardware the team has been communicating with S&C Electric Company. These vendors will provide initial detailed design quotes, however the team will search for the best price to build a reliable system. The applicant, Murphy Brothers Contracting, will act as the general contractor/developer of the project and will manage construction/subcontractors.

3.3.7 Identification of Project Investors

Specific investors have not been identified outside of Murphy Brothers Contracting. The amount of outside investment needed will be based on the NY Prize award and the annual rate of return on the system. Besides Mamaroneck Self Storage LLC and East Coast North Realty, MBC will seek investments from the Village of Mamaroneck, local building owners, residents (crowd funding), and investors/developers who see the VOM Community-shared Microgrid as a benefit to the future of Industrial Area Development plan, in attracting businesses as well as multifamily projects.

3.3.8 Legal and Regulatory Advisors

The team has been consulting with Jerome L. Garciano of Robinson & Cole, LLP to design the microgrid's business structure and forecast potential legal hurdles. Mr. Garciano is an associate in the firm's real estate and development group whose practice focuses on state and federal tax financing incentives affecting the built environment. Mr. Garciano provides tax support for developers, syndicators, investors, nonprofit sponsors, and government agencies in renewable energy and real estate developments using the Historic, New Markets, Renewable Energy, and Low-Income Housing Tax Credits. He has recently been involved in several microgrid development projects nationally and has developed a specialty in formulating their business and financial structures. The team plans to continue to consult with Mr. Garciano during the next phase of NY Prize's program. Jerome Garciano is an associate in the firm's Real Estate + Development Group whose practice focuses on state and federal tax financing incentives affecting the built environment. Mr. Garciano provides tax support for developers, syndicators, investors, nonprofit sponsors, and government agencies in renewable energy and real estate developments using the Historic, New Markets, Renewable Energy, and Low-Income Housing Tax Credits.

3.4: Commercial Viability – Creating and Delivering Value

The following section describes the mechanics of ensuring that expected value is delivered to project participants.

3.4.1 Selection of Microgrid Technologies

The specific microgrid technologies chosen include natural gas generation and PV arrays. These two generation sources complement one another and have the ability to operate in both normal operation and grid outages when combined into an integrated system. PV is an ideal carbon neutral generation resource however, its variability requires that it has backup generation. If sized correctly, natural gas generators can modulate supply to supplement PV and cover a full load of a system. The challenge of employing PV in large quantities (MW scale) is that it is space intensive, however, there is a large supply of available roof area in the surrounding buildings making PV a feasible option. Natural gas fired generation is a relatively simple, cost effective technology that has been widely employed for continuous and peaker plants. One downside is that its operation is dependent on the utilities natural gas supply. While an interruption is rare, the team would need to keep onsite compressed natural gas to operate the islanded grid if natural gas becomes available. With the low probability of this occurrence, the team has not included CNG storage in the design.

3.4.2 Assets to Leverage towards Project

Murphy Brothers Contracting, Inc. is construction management/development firm that has been operating since 1979 specializing in high-end residential and light commercial projects in the greater Westchester, Hudson Valley, and southern Fairfield region. The business has (45) full-time employees and a revenue stream of 20+ projects typically occurring simultaneously. The eventual owner of the microgrid will be split between Murphy Brothers Contracting and an investor-owned LLC entity. A majority of the capital costs is likely to be sought from investors/developers who see the VOM Community-shared Microgrid as a benefit to the future of Industrial Area Development plan, in attracting businesses as well as multifamily projects. MBC may seek to leverage current real estate properties, including the Mamaroneck Self Storage buildings to secure investment capital.

3.4.3 Generation and Load Balancing

The system capacity is designed to support the critical loads of the microgrid ~750 kW. During normal operation, PV will be able to power a majority of the load. A natural gas generator will modulate based on PV output and facility demand. For instance, if 500 kW of solar capacity is available and the load is 750 kW, the generator will provide the remaining 250 kW. For periods where solar PV generation exceeds local facility demand, a small battery storage bank is installed to store energy for later consumption. Although not in the current design, the team may choose to install bi-directional transformers that will give the DERs the option to send excess capacity to the main grid if the demand scenario occurs.

3.4.4 Special Permissions and Permitting

The microgrid's generation components are PV and natural gas generation. These two DERs are very commonly paired in microgrid systems; the team does not expect any unique permits that would not be required in other microgrids. The only unique permits anticipated are local zoning and building code ordinances. The team is restricted on building height (PV and generator cannot exceed max limited height), but has planned the design with this restriction accounted for.

3.4.5 **Development, Construction, and Operation Approach**

Murphy Brothers Contracting, Inc. will be the developer MBC will manage a set of specialized contractors that will be tasked to construct the system components. The system construction may go out to bid so that the team can ensure that the best talent is brought in. The following vendors/contractors (in addition to others) will be approached to submit quotes: generator – TTI Power, controls software – Spirae, SCADA switch gear – S&C Electric, Power conditioning systems – Delta Electronics. Once the system is built, MBC will manage its operation.

3.4.6 **Community Benefits and Costs**

The community will realize several direct and indirect benefits from the microgrids construction. They may incur costs to gain these benefits under two scenarios: A) an individual directly invests in the microgrid B) the Village of Mamaroneck use public funds (tax payer money) to invest in the system. A primary benefit will be access to clean reliable energy year round. By keeping Arctic Ice open and manufacturing during grid outages, the local residents will reap the benefit of access to ice to keep food, medications, etc. from spoiling. Mamaroneck Self Storage Phase II is being built with space that can be used as a government command center during emergencies. This benefits the community by maintaining government order during emergencies. Additionally, for an area that is a redevelopment process, the microgrid will likely increase property values and attract businesses/residents to the area.

3.4.7 **Utility Requirements**

In order for the microgrid to be cost effective and technically feasible, it will require the utility to comply with several requests. It is important that the utility makes the distribution lines available to the microgrid so that energy can be distributed among facilities. This will require adding several SCADA switch along utility-owned poles and wires. The rate that the utility charges to use these lines will have a substantial impact on the micro grid’s cost effectiveness.

Additionally, in order for the “community microgrid” concept to realize full potential, the utility needs to occasionally allow the microgrid to export energy to the main grid. If microgrids are limited to only net import of energy, the system will be much less cost effective and the grid as a whole will be less reliable.

3.4.8 **Past Demonstration of Selected Technologies**

The chosen microgrid generation source, roof-mount PV and natural gas generators have been frequently used in microgrid systems. The two DERs are complementary to each other as they allow for both clean generation and reliability. One example of a similar system in operation is the Fairfield, CT microgrid. The system, constructed in a similar coastal area, uses 47 kW of PV and 300kW of natural gas and has been in operation since October 2015. Delta currently has project involvement in over 3000 global generation projects. As a result, the company has experience in almost every facet of microgrid generation and controls. Spirae Wave software has also proven to be a preferred control option for microgrids system. In a recent installation at Fort Devins, CO the Spirae Wave system has helped to achieve the first steps of a net-zero district of buildings and is targeting an area peak load reduction of

15%. The team believes that the combined experience in a diverse set of past projects will drive the success of the Village of Mamaroneck microgrid.

3.4.9 Operational Scheme

The project development and operation will be overseen by Murphy Brothers Contracting as part of Phase Two of the overall Mamaroneck Self Storage project. (An additional 60-80,000sf) Along with project architect Kim Martelli, MBC plans to employ technical consultants including Steven Winter Associates, Spirae LLC, and Delta Group. The technical consultants will make all detailed design and equipment decisions and MBC will oversee construction. Investments funds to cover capital costs will be held in a trust fund controlled by Jerome Garciano of Robinson and Cole LLP. Funds for construction will be release by Robinson and Cole LLP at required stages of construction. Once the microgrid is operation, Murphy Brothers Contracting, under either will manage all operation, maintenance, and billing to customers under an LLC separate from Mamaroneck Self Storage LLC, East Coast North Realty and MBC.

3.4.10 Customer Billing and Metering

The project owner will enter into power purchase agreements with large facilities in the microgrid (Arctic Ice, Mamaroneck Self Storage buildings). Energy consumers will agree to purchase a set amount of energy from the microgrid at an agreed upon rate. Smart meters will be installed at each facility to monitor their usage and the microgrid operator will have access to this real-time data to determine monthly bills.

3.4.11 Existing Business and Commercialization Resources

There are several similar microgrid designs that have been built in recent years. The VOM design team has modeled the proposed microgrid based on existing designs that have proven technical and financial feasibility. For instance, in October 2015, Fairfield, CT completed a microgrid that was a result of CT DEEP's microgrid program. The Fairfield system includes 47 kW of PV and 300kW of natural gas generation. The VOM proposed design replicates several of these successful features. Additionally, there are several technical white papers and business plans that the team has evaluated. In addition to lesson's learned from past experience, a few publications reviewed in developing the proposed business plan included:

Massachusetts Clean Energy Center, Microgrids – Benefits, Models, Barriers and Suggested Policy Initiatives for the Commonwealth of Massachusetts:http://nyssmartgrid.com/wp-content/uploads/Microgrids-Benefits-Models-Barriers-and-Suggested-Policy-Initiatives-for-the-Commonwealth-of-Massachusetts.pdf.

Siemens, The business case for microgrids:
http://w3.usa.siemens.com/smartgrid/us/en/microgrid/Documents/The%20business%20case%20for%20microgrids_Siemens%20white%20paper.pdf

Microgrid Institute, Why there is No One Microgrid Business Model:

http://microgridknowledge.com/microgrid-business-model/

Microgrid Knowledge, Regulatory and Business Models for Community Microgrids:

http://www.microgridinstitute.org/uploads/1/8/9/9/18995065/microgrid_institute_-_ieee_pes_presentation_v2.1.pdf.

Zaragoza University, Microgrids, a new business model for the energy market:
http://www.icrepq.com/icrepq'14/515.14-Sanz.pdf.

3.4.12 Market Barriers

The microgrid market presents significant financial entry barriers. This is partially a result of the intensive engineering study that must be completed in order to design a feasible system. Once microgrids become more common and the design process becomes streamlined, this financial barrier will certainly be reduced. Additionally, some of the critical components such as power conditioning systems, control software, and large scale generators have relatively high retail costs. This is partially because microgrid components are in a niche market with a low demand; as a result vendors can charge high prices. As with any technology, as it becomes more widespread and more manufacturers enter the market, costs will come down.

The proposer has assembled a team of technical and legal experts to act as consultants to the developer through the process. The team's experience with past projects will help guide the design to an optimized cost and functionality. It is anticipated that the team's past experience coupled with the drive of the REV imitative and NY Prize awards will propel the project forward. The detailed report resulting from this study will be significant evidence that can be used to attract investors that can make the project possible.

3.5: Financial Viability

The following section describes the case for financial viability for development and operation of the microgrid by addressing no less than the following items below:

3.5.1 Revenue Streams to Owner

The revenue streams available to the microgrid owner are summarized in the simplified analysis in Table 10. The analysis assumes 2,500,000 kWh of sales to customers for the year, with 1,000,000 kWh coming from PV generation and the remainder from the natural gas generators. Using an annual rate of $120/kW and an estimated DR capacity of 375kW, DR revenues have also been estimated. The streams are expected to be fixed unless DERs or customers are added/removed.

Table 10. Simplified Annual Revenue Streams

Revenue Streams	Value
Sale of $2,500,000 kwh ($0.15/kwh)	$ 375,000
NYISO Demand Response Revenue for 375 kW ($120/kW)	$ 45,000

3.5.2 **Additional Incentives**

Initial estimates indicate that the total cost to build the system will be approximately $3.6M with a majority of the capital cost attributed to the large PV arrays. The financial viability of the system is limited by the revenue it can produce and the amount that must be borrowed in interest bearing money. In order to make the system attractive to outside investors, substantial incentives will be required. Some of the funding that the team plans to pursue includes Demand Response incentives, NY Prize implementation award incentives, and renewable energy incentives and tax credits (federal and state) for PV.

The project is unique in the way that one of its primary facilities, Mamaroneck Self Storage Phase II, has not been constructed yet and still in design stage, construction projected to be completed in 2-3 years. MBC sees Mamaroneck Self Storage (phases 1 &2) as the anchor in the VOM Industrial Area Development plan. It is the first new building in the Industrial Area constructed in the last 20 years. The area's walkability feature, in a strong community with good schools, will be a major draw to investor/developers for multi-family and mixed use construction. The design of Mamaroneck Self Storage Phase 2 will be altered based on the level of funding that can be achieved for microgrid system components, thus creating a unique timing dilemma. The team seeks to understand the exact incentives that the project will be eligible for before modifying the Mamaroneck self-storage building to suite the microgrid's needs.

3.5.3 **Capital and Operating Costs**

A simplified summary of expense streams is shown in Table 11. The interest to borrow money to buy capital equipment will be a major expense. In this analysis, it is assumed that $1.5M is borrowed. As the loan is paid off, interest payment will successively decrease. There is also an operating cost to produce the energy and maintain the equipment. For this analysis, it has been estimate at a rate of $0.05/kwh. This includes the price of natural gas to the generators, replacement of PV inverters, etc. The table also includes several additional categories for legal and management expenses.

Table 11. Simplified Annual Expense Streams

Expense Streams	Value
Interest on Capital Equipment Loan of $1.5M (4%)	$ (60,000)
Mixed Rate Generation of 3,000,000 kwh Cost ($0.05/kwh)	$ (125,000)
Insurance	$ (15,000)
Legal and Accounting	$ (10,000)
MBC Management	$ (10,000)

3.5.4 **Ensuring Profitability**

The sustained profitability of the microgrid is rooted in revenues exceeding expenses. To keep revenues coming in, the microgrid must be able to provide reliable power so that customers are willing to enter power purchase agreements. Additionally, to secure demand response revenue, loads must be managed to ensure that DR capacity is available. The team will concentrate on keeping expenses low by performing routine maintenance on the systems – therefore avoiding long term downtime.

3.5.5 **Financing Structure**

The team aims to secure funding from the NY Prize competition to support development and construction stages. If the NY Prize award does not cover the full cost of the design/build then the team will secure funding from private lenders. The private lenders will be represented by an entity in the form of a limited liability company – Fenimore-Waverly Microgrid LLC. Based on the ownership fractions, the team will share in profits produced by system. It is anticipated that the microgrid will be able to financially support its own operation costs with revenues. Murphy Brother's Contracting will be responsible for efficiently operating the microgrid so that revenues exceed expenses.

3.6: Legal Viability

The following section describes the legal terms and conditions and other requirements necessary to develop and operate the microgrid.

3.6.1 **Ownership Structure and Team Members**

A diagram displaying the simplified ownership structure is shown in Figure 25. The ownership will consist of two main entities, Murphy Brothers Contracting and Fenimore-Waverly Microgrid LLC. Murphy Brothers will serve as the minority investor and majority managing member. Fenimore-Waverly LLC will represent the outside investor stakeholders. At the time of this report, the membership of the Fenimore-Waverly LLC has not been finalized, however it is believed that the entity will include some of the following investor-members: Village of Mamaroneck, Arctic Glacier Ice, property owners on Fenimore Rd and Waverly Ave, community members of VOM, local business and real estate owners, private equity investors seeking profit. These potential investors are represented as Investors 01-50 in the diagram below and will receive benefit from tax credits and microgrid generation profits.

The applicant for Phase II of the NY Prize feasibility study will be Murphy Brothers Contracting. MBC will be responsible for assembling the financing investor-members and leading the next investigation and design phase. The existing technical team core, Steven Winter Associates, Delta, and Spirae, will continue to support Murphy Brothers Contracting in development of the design during next phase.

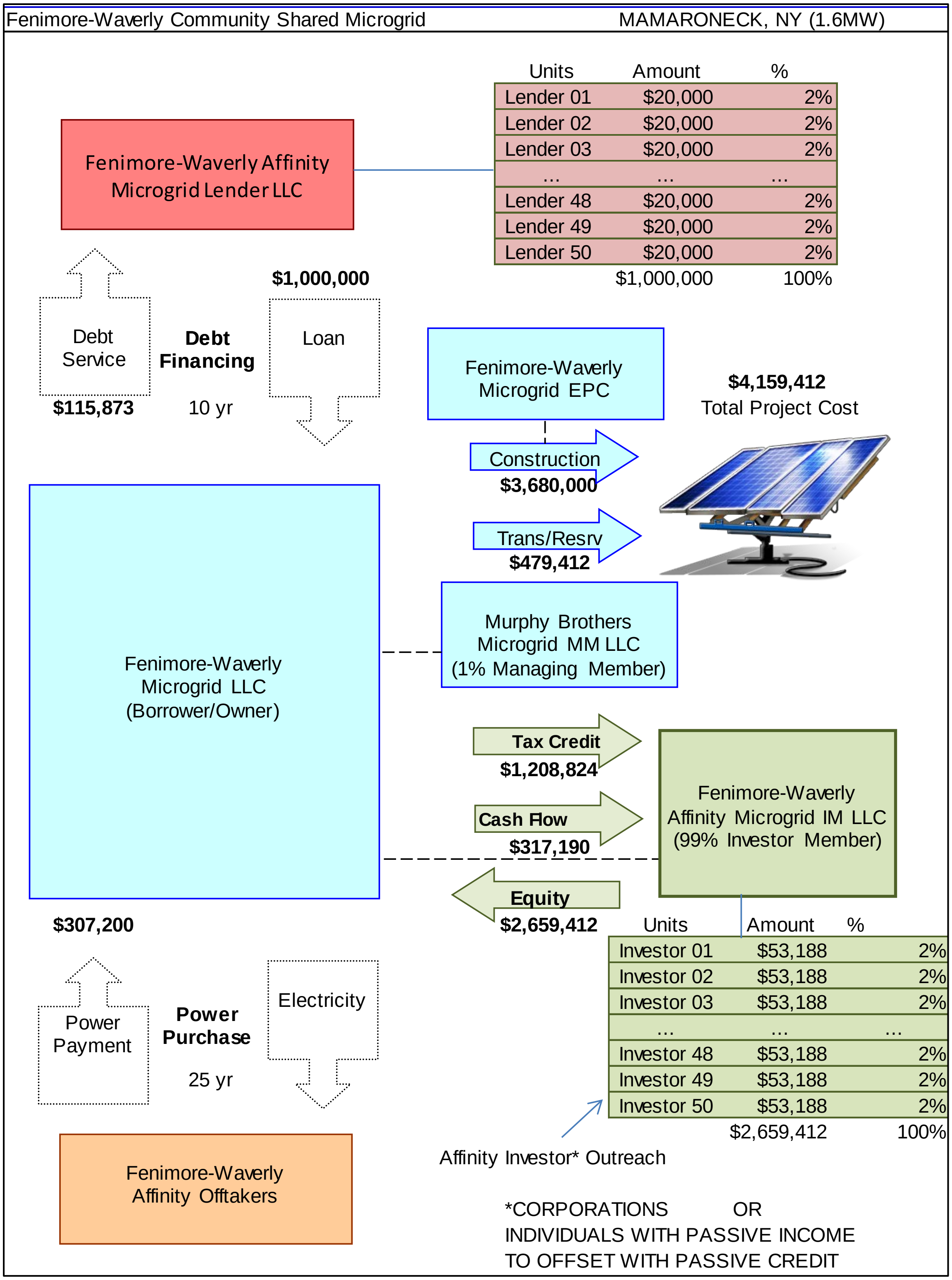

Figure 25. Simplified Ownership Diagram

3.6.2 Microgrid Site Ownership

Microgrid equipment will be located on properties of three separate entities. A summary of equipment, location, and the property owner is shown in Table 12. The VOM microgrid design team has been communicating with all property owners through the initial design stage and currently has verbal approval to utilize the facilities to house DER and associated equipment. The roof space of Arctic Glacier Ice being utilized for PV production will be leased to Fenimore-Waverly LLC for the duration of microgrid operation. It is anticipated that Con Edison may charge the microgrid ownership a utility pole rental fee for additional switchgear required at transformers–similar that electric companies rent utility pole space to cable providers. This arrangement has not been finalized with con Edison.

Table 12. Equipment Location and Property Owner

DER Equipment	Location	Property Owner
150 kW PV array, Power Control System #1, 750 kW generator	Mamaroneck Self Storage Phase II	Murphy Brothers Contracting
700 kW PV array, Power Control System #2	Artic Glacier Ice	Andrew Spatz
SCADA switchgear	Distribution lines/poles	Con Edison

3.6.3 Protecting Customer Privacy Rights

Privacy rights of the customers will be handled in similar fashion to the way the Con Edison (and other utilities) currently handle their sensitive data. Energy consumption and peak usage will not available to outside companies/individuals unless the customer signs a data release form. All control and data acquisition systems will be installed with firewall security systems and data encryption to prevent theft of potentially sensitive data. Spirae and Delta will coordinate efforts to develop customer security protocols for the proposed system.

3.6.4 Potential Regulatory Hurdles

There are several anticipated hurdles that the project will need to overcome in order to be implemented. One of these potential hurdles is approval by the Village's planning and zoning commission. The team has been developing the design with the intent that it must be approved by the board and has been in communication with Village of Mamaroneck mayor and other key officials to ensure that the proposed design does not get held up at this stage. The team also envisions that there may be some regulatory hurdles between Con Edison and the NY Public Service Commission to determine rights of the micro grid use of Con Edison's distribution network. As NY REV Initiative continues to evolve over the next few months, these hurdles will become more apparent and appropriately handled.

Task 3 Conclusion

The Fenimore-Waverly microgrid provides an opportunity to create reliable power generation in a natural disaster prone area. Its clean generation sources of PV and natural gas fired generators provide a low carbon footprint that achieves REV initiative goals. The design team believes that the design is technically feasible and makes a strong business case through a proposed shared ownership structure. As the area redevelops over the next few years, this microgrid will provide a strong foundation for a resilient community. It demonstrates a model that can be replicated across NY State and its implementation will help revolutionize the NY grid system. Several images and video media links documenting key events and community involvement are included in the appendix of this report.

4 Task 4: Benefit Cost Analysis Summary Report

The Village of Mamaroneck design team worked with analysts from Industrial Economics Corporation to gather information needed to develop a cost-benefit analysis of the Fenimore Waverly Microgrid. The information supplied to Industrial Economics Corporation is organized in Sub Task 4.1-4.6 and the benefit cost analysis report produced by IEC is reported in Sub Task 4.7

4.1: Facility and Customer Description

In order to fully analyze the economics of the proposed system, it is important that the design team understands the facilities and customers that will be served. A summary of facility/customer characteristics including name, rate class, type, economic sector, annual electric consumption, peak electric demand, and support available/needed during grid outage is provided in Table 12. Since site visits and metered data were not available for non-critical facilities, they were grouped into general categories of large commercial/industrial, small commercial/industrial, and residential. Annual consumption estimates were made based on building type, square footage, and typical kbtu/sq ft data available through Energy Information Administration statistics

Table 13. Facility and Customer Description Summary

Facility Name	Rate Class	Facility / Customer Description (Specify Number of Customers if More Than One)	Economic Sector Code	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Supply Required Per Day During Major Power Outage
Arctic Glacier Ice Factory	*Large Commercial/Industrial (>50 annual MWh)*	*Ice-manufacturing plant*	*Manufacturing*	*3,637*	*1.035*	*75%*	*24*
Mamaroneck Self Storage Phase I	*Large Commercial/Industrial (>50 annual MWh)*	*Self Storage Facility*	*All other industries*	*227*	*.062*	*0%*	*0*
Mamaroneck Self Storage Phase II	Large Commercial/Industrial (>50 annual MWh)	Self Storage Facility and mixed use office/ industrial	*All other industries*	238	.065	50%	24
Large C&I	Large Commercial/Industrial (>50 annual MWh)	Large C&I (3 buildings)	*All other industries*	335	.110	0%	0
Small C&I	Small Commercial/Industrial (<50 annual MWh)	Small C&I (4 buildings)	*All other industries*	120	.045	0%	0
Residential	Choose an item.	Residential (1 building)	*Residential*	12	.003	0%	0

4.2: Characterization of Distributed Energy Resources

Each of the proposed distributed energy resources were characterized by resource name, facility name, energy source, nameplate capacity, average production (normal and emergency) and fuel consumption rates. A summary of DER characterization metrics supplied to IEC is displayed in Table 14.

Table 14. Distributed Energy Resource Summary

Distributed Energy Resource Name	Facility Name	Energy Source	Name plate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Average Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
						Quantity	Unit
8 kW PV array	*Mamaroneck Self Storage Phase I*	*Solar*	*0.008*	*8.8*	*0.0241*	*0*	*MMBtu/MWh*
700 kW PV array	*Arctic Glacier Ice*	*Solar*	*.700*	*835*	*2.29*	*0*	*MMBtu/MWh*
150 kW PV array	Mamaroneck Self Storage Phase II	*Solar*	.150	165	0.452	0	*MMBtu/MWh*
750 kW Generator	Mamaroneck Self Storage Phase I	*Natural Gas*	.750	3,400	9.4	10.7	MMBtu/MWh

4.3: Capacity Impacts and Ancillary Services

In addition to benefits achieved from backup power during grid outages, information was collected on capacity impacts to the grid, ancillary services provided to the customer and utility, and environmental impacts based on emissions rates. An estimate of the peak load support available from each DER is summarized in

Table 15. For PV peak load support, a peak capacity of 20% of nameplate capacity was used. The natural gas generator name plate capacity was de-rated to 93%.

Table 15. Peak Load Support

Distributed Energy Resource Name	Facility Name	Available Capacity (MW/year)	Does distributed energy resource currently provide peak load support?
750 kW natural gas generator	Mamaroneck Self Storage Phase II	0.70	☐ Yes
100kwh battery	Mamaroneck Self Storage Phase II	0.1	☐ Yes
700 kW PV array	Arctic Glacier Ice	.14	☐ Yes
150kW PV array	Mamaroneck Self Storage Phase II	.018	☐ Yes

As part of the proposed microgrid, Artic Glacier Ice would continue to be enrolled in the demand response program. Current and future demand response capacities at Arctic Glacier Ice are shown in Table 16.

Table 16. Demand Response Capacity

Facility Name	Capacity Participating in Demand Response Program (MW/year)	
	Following Development of Microgrid	Currently
Arctic Glacier Ice	.375	.375

The microgrid's impact on utilities distribution and transmission capacity were examined to gauge potential deferral of electrical upgrades through reduced capacity requirements. With a peak load support of 0.96 MW, it is assumed that that the local distribution lines (supplying to the microgrid's primary feeder) will be relieved of this capacity. Estimating a 5% electrical loss through transmission lines, a capacity of 1.01 MW would be relieved from transmission lines (under the scenario where all DERs are producing at maximum capacity). To clarify, the distribution lines within the microgrid's switchgear would not see a decrease in capacity, however the surrounding distribution lines on Waverly Ave will need to supply less current to the target buildings.

Additionally, the Delta Power conditioning system (PCS) will have the ability to provide frequency or real power support, voltage and reactive power support, and black start or system restoration support. Each of these ancillary benefits will offer value to the microgrid facilities and surrounding grid. While there are no documented power quality issues in the target buildings in recent years, the proposed microgrid system will diminish the possibility of power quality issues through monitoring and adjustment performed by the Delta PCS.

A weighted emissions rate for CO2, SO2, NOx, and PM are provided the microgrid generation sources in Table 17. The weighted rates are calculated based on 23% of energy being generated by PV and 77% being generated by the natural gas generator.

Table 17. Emissions Rates

Emissions Type	Emissions per MWh	Unit
CO_2	0.4388	Metric tons/MWh
SO_2	3.75E-06	Metric tons/MWh
NO_x	3.45E-04	Metric tons/MWh
PM	2.63E-05	Metric tons/MWh

4.4: Project Costs

Project cost data based on preliminary design specifications was compiled for capital costs, initial planning and design costs, and fixed/variable operations and maintenance costs. A list of capital components, installed costs, and equipment lifetime are provide in

Table 18. The total sum of capital costs in this list is approximately $3.7 million. This value does not include an estimate of initial design and planning costs, which are estimated at $330,000. Services included in this estimated planning value are initial design and engineering, marketing, contracting with customers, legal fees.

Table 18. Capital Costs

Capital Component	Installed Cost ($)	Component Lifespan (round to nearest year)	Description of Component
700 kW PV array	2,030,000	20	Rooftop solar at Mamaroneck Self Storage phase II
150kW PV array	435,000	20	Rooftop solar at Arctic Glacier Ice
750 kW generator	500,000	25	Natural gas generator
4 SCADA switches	100,000	25	Pole mount SCADA switches
New secondary cable	25,000	60	Pole mount cable
PCS, sensing, communications	375,000	20	Power conditioning system hardware
Wave Control Software	125,000	20	Control software with updates
11 Smart meters	6,000	25	Smart meters to replace existing meters
100 kWh battery	35,000	5	Lead acid battery
Sub panels, misc hardware	50,000	30	Misc electrical comps, switches, panels

An additional project cost includes the fixed O&M that is required to sustain operation of the systems. The estimated fixed cost for a 20 year operation period is presented in

Table 19. Annual costs included a software license from Spirae ($25k), administration salary ($35k), and routine generator fluid changes ($2k). At year 8 and 15, a moderate generator overhaul is completed to replace combustion components that may need refurbishing. At year 10, there is budget allocated for inverter replacement on the PV arrays.

Table 19. Fixed O&M costs

Year	Fixed O&M Cost ($)	What cost components are included in this figure?
1	62,000	Software licensing, minor generator service, admin salary
2	62,000	Software licensing, minor generator service, admin salary
3	62,000	Software licensing, minor generator service, admin salary
4	62,000	Software licensing, minor generator service, admin salary
5	62,000	Software licensing, minor generator service, admin salary,
6	62,000	Software licensing, minor generator service, admin salary
7	62,000	Software licensing, minor generator service, admin salary,
8	87,000	Software licensing, minor generator service, admin salary, generator overhaul
9	62,000	Software licensing, minor generator service, admin salary
10	198,000	Software licensing, minor generator service, admin salary, inverter replacement
11	62,000	Software licensing, minor generator service, admin salary
12	62,000	Software licensing, minor generator service, admin salary
13	62,000	Software licensing, minor generator service, admin salary
14	62,000	Software licensing, minor generator service, admin salary,
15	87,000	Software licensing, minor generator service, admin salary, major generator overhaul
16	62,000	Software licensing, minor generator service, admin salary
17	62,000	Software licensing, minor generator service, admin salary
18	62,000	Software licensing, minor generator service, admin salary
19	62,000	Software licensing, minor generator service, admin salary
20	62,000	Software licensing, minor generator service, admin salary

The team has not budgeted for any variable operating costs outside of natural gas supply rates. Potential sources of variable rates not accounted for include increasing roof lease costs at Arctic Ice, environmental fees for greenhouse gas emissions, unanticipated repairs, etc.

Since generation is a combination of PV and natural gas generators, operation is dependent on solar conditions and availability of natural gas. The PV system has the ability to run for an indefinite amount of time if solar energy is available and the natural gas generator/battery can be used to supplement and smooth generation load. Under maximum load conditions, the natural gas generator may need to provide approximately 12.6 MWh of energy over a 12 hour period. With a generator efficiency of 10.7MMBtu/ft^3 of gas and a gas energy content of 1025 BTU /ft^3 , this would require a 24 hour fuel supply of 131,532 ft^3 of natural gas.

4.5: Costs to Maintain Service during a Power Outage

To determine the costs associated with maintaining service during a power outage, facility specific information was gathered and shared with IEC. The process included identifying existing generation sources and the costs incurred during a grid outage. Currently there are no existing backup generation sources at the critical facilities. With the current configuration, the facilities cannot provide services to the community in the event of a grid outage. Both Arctic Glacier Ice and Mamaroneck Self Storage would need to rent generator equipment. Estimated generator hookup and rental costs are shown in Table 20.

Table 20. Cost of Maintaining Service Without Backup Power

Facility Name	Type of Measure (One-Time or Ongoing)	Description	Costs	Units	When would these measures be required?
Arctic Glacier Ice	*One-Time Measures*	*Hooking up additional portable generator*	*500*	*$*	*For outages outside of winter season*
Arctic Glacier Ice	Ongoing Measures	*Generator Rental*	*2410*	*$/day*	*For outages outside of winter season*
Mamaroneck Self Storage Phase II	One-Time Measures	Hooking up portable generator	300	$	During outages, year round
Mamaroneck Self Storage Phase II	Ongoing Measures	Generator Rental	575	$/day	During outages, year round

4.6: Services Supported by the Microgrid

An additional factor in determining the value of backup generation involves an understanding of the extent that the service is effected by a grid outage. It is estimated that both Arctic Glacier Ice and Mamaroneck Self Storage will experience a 25% loss in services due to limitation imposed by operating on backup generation. This loss in service is primarily due to a forced reduction in service capacity under the conditions where the PV array is not at its peak output. For Arctic Ice, this would require a slight decrease in ice making and refrigeration capacity. For Mamaroneck Self Storage some units would not receive conditioned air and full lighting. Available electric capacity would be reserved for critical loads including elevator and the command center.

If no electricity is available, it is assumed that arctic ice loses 100% of service ability (no ice making). It is assumed that Mamaroneck self-storage would lose 90% of service ability as a small percentage of the storage units could still be accessed without electricity.

4.7: Industrial Economics Corporation Benefit Cost Analysis

The following section, Sub Task 4.7, is the benefit cost analysis report that Industrial Economic Corporation generated with information from Subtask 4.1-4.6. It describes financial implications of two scenarios – Scenario 1: No major power outages over the assumed 20-year operating period and Scenario 2: The average annual duration of major power outages required for project benefits to equal costs.

PROJECT OVERVIEW

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

Arctic Glacier Ice, a producer and wholesaler of high quality packaged ice, which it distributes to retail, commercial, and industrial customers.[7]

Mamaroneck Self Storage Phase II, a climate-controlled self-storage, office, and mill-shop facility.[8]

In addition, the project would offer power at a reduced rate to Mamaroneck Self Storage Phase I and eight other customers: a large commercial/industrial customer that occupies three buildings; six small commercial/industrial customers located in four buildings; and a residential customer at a single building. These customers, however, are considered non-critical and would not receive power from the microgrid during an outage.

The microgrid would be powered by an existing rooftop 8 kW photovoltaic (PV) array at Mamaroneck Self Storage Phase I and three new distributed energy resources: a 750 kW natural gas unit that would also be located at Mamaroneck Self Storage Phase I; a 700 kW PV array that would be installed at

[7] http://arcticglacier.com/.
[8] http://archive.constantcontact.com/fs178/1110532512779/archive/1121601563028.html.

Mamaroneck Self Storage Phase II; and a 150 kW rooftop PV array that would be installed at Arctic Glacier Ice.[9] In addition, the microgrid would incorporate a 100 kWh lead acid battery. The project's proponents anticipate that the natural gas and PV units would produce electricity for consumption during periods of normal operation. During a major outage, the system would have sufficient generating capacity to supply 75 percent of average electricity use at Arctic Glacier Ice and 50 percent of average use at Mamaroneck Self Storage Phase II. Project consultants also indicate that the system would have the capability 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. Of note, 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.[10] It also

[9] Because the 8 kW PV rooftop array at Mamaroneck Self Storage Phase 1 is already installed and operating, the energy it generates and the capacity it provides are not treated as benefits of the microgrid.
[10] 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,

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.[11]

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

Table 21. **BCA Results (Assuming 7 Percent Discount Rate)**

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justifying use of a low discount rate specific to its long term effects." The model also uses EPA's temporal projections of social damage values for SO_2, NO_x, and $PM_{2.5}$, and therefore also applies a three percent discount rate to the calculation of damages associated with each of those pollutants. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.]

[11] 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.

ECONOMIC MEASURE	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 2.7 DAYS/YEAR
Net Benefits - Present Value	-$3,630,000	$94,300
Benefit-Cost Ratio	0.6	1.0
Internal Rate of Return	-8.1%	7.4%

Scenario 1

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

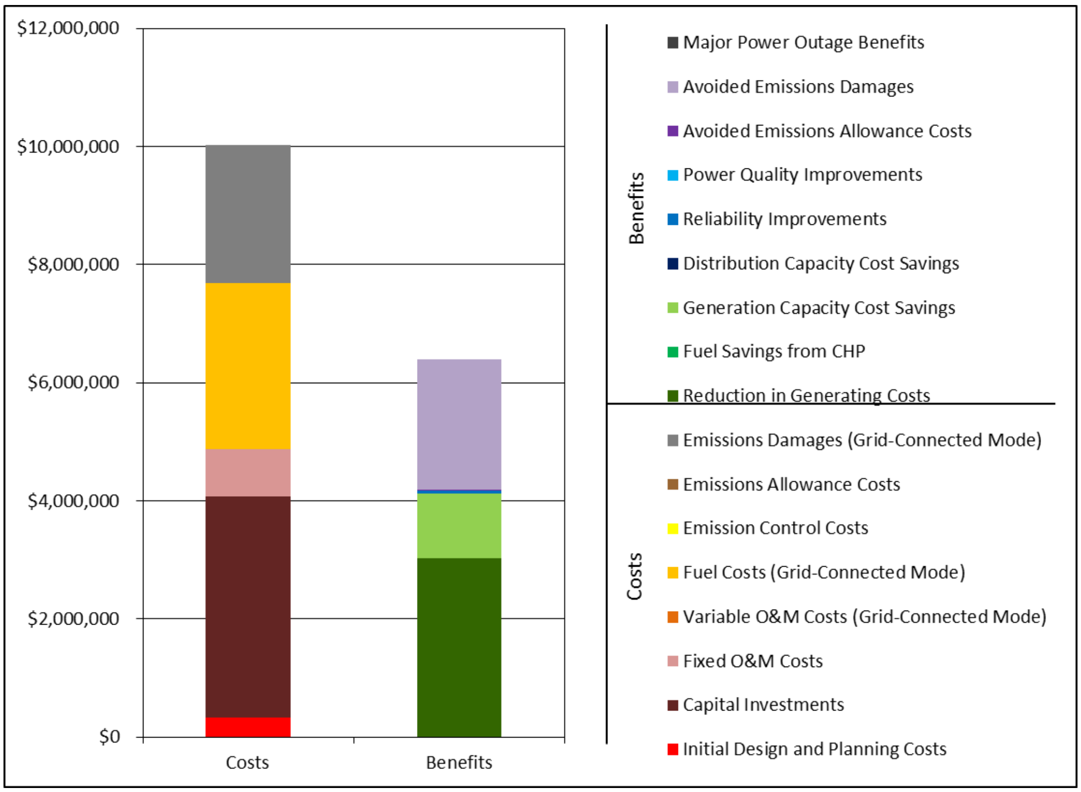

Figure 26. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

Table 22. 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	$330,000	$29,100
Capital Investments	$3,740,000	$324,000
Fixed O&M	$802,000	$70,800
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$2,820,000	$249,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$2,340,000	$153,000
Total Costs	**$10,000,000**	
Benefits		
Reduction in Generating Costs	$3,030,000	$268,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$1,090,000	$96,600
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$50,900	$4,500
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$1,490	$132
Avoided Emissions Damages	$2,220,000	$145,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$6,400,000**	
Net Benefits	**-$3,630,000**	

Benefit/Cost Ratio	**0.6**	
Internal Rate of Return	**-8.1%**	

Fixed Costs

The BCA relies on information provided by the project team to estimate the fixed costs of developing the microgrid. The project team's best estimate of initial design and planning costs is approximately $330,000. The present value of the project's capital costs is estimated at approximately $3.7 million, including costs associated with acquiring and installing the new PV arrays and natural gas generator; switches, panels, and cables; power conditioning system hardware; control software; smart meters; and the lead acid battery. The present value of fixed operation and maintenance (O&M) costs over a 20-year operating period – including periodic replacement of inverters, servicing and overhaul of the natural gas generator, software licensing and labor – is estimated to be approximately $802,000.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of fuel for the system's natural gas generator. 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 State Energy Plan (SEP), adjusted to reflect recent market prices.[12] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $2.8 million.

The analysis of variable costs also 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 the natural gas generator would not be subject to emissions allowance requirements. In this case, the damages attributable to emissions from the new natural gas generator are estimated at approximately $153,000 annually. The majority of these damages are attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $2.3 million.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. In the case of the Village of Mamaroneck's proposed microgrid, the primary source of cost savings would be a reduction in demand for electricity from bulk energy suppliers, with a resulting reduction in generating costs. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $3.0 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. The reduction in demand

[12] The model adjusts the State Energy Plan's natural gas and diesel price projections using fuel-specific multipliers that are 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.

for electricity from bulk energy suppliers would also reduce emissions of CO_2 and particulate matter from these sources, and produce a shift in demand for SO_2 and NO_x emissions allowances. The present value of these benefits is approximately $2.2 million.[13]

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.[14] Based on the project team's application of standard capacity factors for PV systems and natural gas generators, the analysis estimates the present value of the project's generating capacity benefits to be approximately $1.1 million over a 20-year operating period. The potential benefits of the project with respect to distribution capacity are unclear; the analysis does not attempt to quantify these benefits.[15]

The project team has indicated that the proposed microgrid would be capable of providing ancillary services (real power support, reactive power support, and black start support) 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 market for ancillary services is 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 such services.

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 $4,500 per year, with a present value of $50,900 over a 20-year operating period. This estimate is calculated 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:[16]

System Average Interruption Frequency Index (SAIFI) – 0.11 events per year.

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[13] 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.

[14] Impacts on 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.

[15] The electricity generated by the microgrid would be distributed over existing utility lines. Project consultants indicate that the capacity required for the feeder section within the microgrid' s switches will not diminish, but that the capacity requirement for the distribution cable that runs between the microgrid and the substation will be reduced.

[16] www.icecalculator.com.

Customer Average Interruption Duration Index (CAIDI) – 181.2 minutes.[17]

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.[18] 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.

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 (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.[19,20]

[17] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for Consolidated Edison.
[18] http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1.
[19] 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.
[20] 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.

As noted above, the Village of Mamaroneck's microgrid project would serve two facilities during an extended outage: Arctic Glacier Ice and Mamaroneck Self Storage Phase II. The project's consultants indicate that at present, neither of these facilities is equipped with a backup generator. If an extended outage occurred, Arctic Glacier Ice could meet 75 percent of its service requirements by relying on a portable generator; this would entail a one-time cost of $500 to install the generator and additional costs of $2,410 per day to operate it (a backup generator would not be required for outages during the winter). If the generator failed or if a rental unit was unavailable during a spring, summer, or fall outage, Arctic Glacier Ice would experience a complete loss in its operating capabilities. Similarly, Mamaroneck Self Storage Phase II could meet 75 percent of its service requirements by relying on a portable generator; this would entail a one-time cost of $300 for installation and operating costs of $575 per day. In this case, a backup generator would be necessary year-round. If the unit failed or a rental unit was not available, the facility would experience a 90 percent loss in operating capability.

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:

Arctic Glacier Ice would rely on a portable generator for outages that occur in the spring, summer, or fall, experiencing a 25 percent loss in operating capabilities while the generator operates. If the backup generator fails, the facility would experience a complete loss in operating capability.

Mamaroneck Self Storage Phase II would rely on a portable generator, experiencing a 25 percent loss in capability while this unit is in operation. If the portable generator fails, the facility would experience a 90 percent loss in operating capability.

In both cases, the supply of fuel necessary to operate the portable generator would be maintained indefinitely.

In both 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 employs the ICE calculator to estimate these costs, based on each facility's location, economic sector, and average electricity use. The calculator provides the following estimates:

For Arctic Glacier Ice, a value of approximately $383,000 per day.

For Mamaroneck Self Storage Phase II, a value of approximately $51,000 per day.

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the two facilities is approximately $122,000 per day.

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 2.7 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.

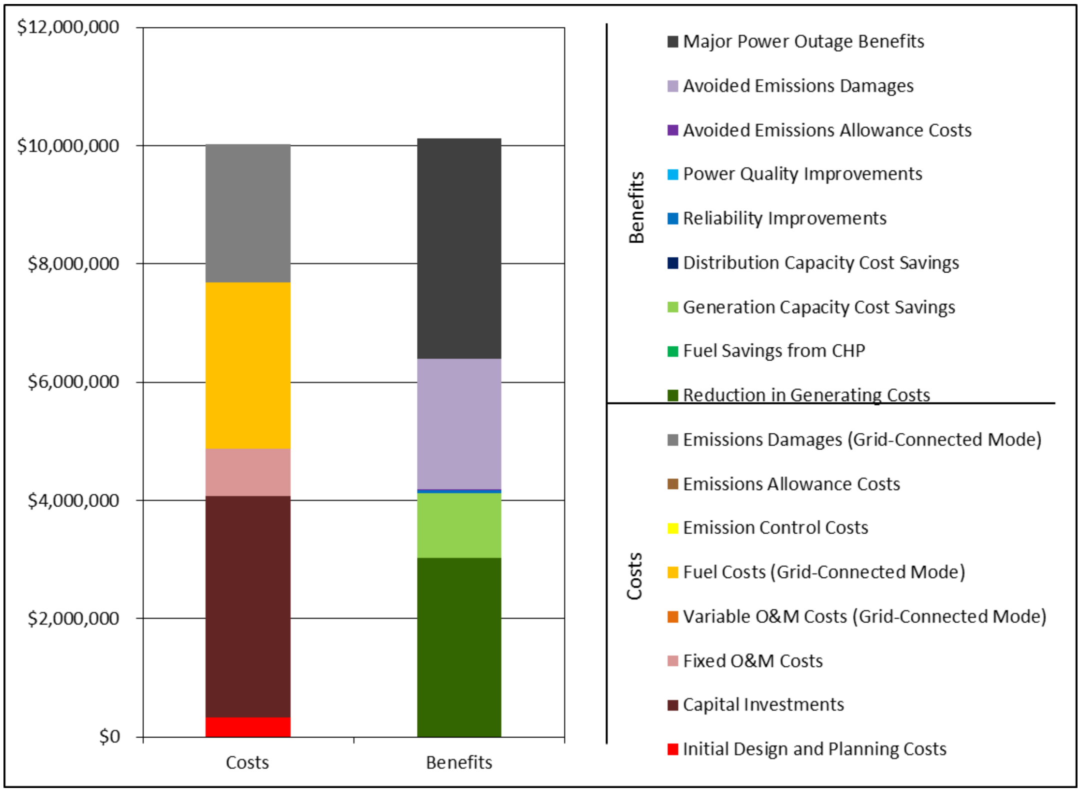

Figure 27. Present Value Results, Scenario 2 (Major Power Outages Averaging 2.7 Days/Year; 7 Percent Discount Rate)

Table 3. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 2.7 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$330,000	$29,100
Capital Investments	$3,740,000	$324,000
Fixed O&M	$802,000	$70,800
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$2,820,000	$249,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$2,340,000	$153,000
Total Costs	**$10,000,000**	
Benefits		
Reduction in Generating Costs	$3,030,000	$268,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$1,090,000	$96,600
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$50,900	$4,500
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$1,490	$132
Avoided Emissions Damages	$2,220,000	$145,000
Major Power Outage Benefits	$3,720,000	$329,000

Total Benefits	**$10,100,000**	
Net Benefits	**$94,300**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**7.4%**	

Task 4 Conclusion

Industrial Economics Corporation has analyzed the financial impact of the proposed microgrid system based on the frequency of grid interruptions. According to this analysis, the benefit-cost ratio approaches the breakeven point at 2.7 days of outage per year. In a scenario with no outages per year the system carries a benefit cost ratio of 0.6, indicating a negative net present value. It is important to consider that there are several monetary costs that were not factored into this analysis. For instance, if an outage occurs and the Mamaroneck Self Storage is used as a reserve command center, there is a value to the avoided costs by maintaining order and government operation. Additionally, by supplying local area residents with ice, there is a value to avoid spoiled food and medications. During the next stage of the NY Prize Competition, the team may revise the design to improve the cost benefit of the system under both operating scenarios.

5 Task 5 Conclusions

The VOM microgrid design team is encouraged by the results of the NY Prize Phase 1 study and is actively pursuing Phase II funding. The team plans to use this report as a resource to approach investors and is currently evaluating capital sources as well as enhancing the design team with additional subject matter experts. The unique feature of this design is that it lies in an area that is currently under redevelopment and is being supported the Army Corps of Engineer's through water risk management improvements. This allows building designers to optimize their buildings to integrate with the proposed microgrid in a scalable manner. The design model provides a framework that can be replicated to strengthen the grid around all areas of NY.

A report conclusion indicating key findings and recommendations, project results and lessons learned, and environmental and economic benefits are presented in the sections that follow.

Findings and Recommendations

Tasks 1-4 lead to a series of findings that drove the evolution of the microgrid system's design. The key findings and recommendations from each Task are summarized as follows.

Task 1

- There is an abundance of critical services located within a ½ mile radius in the village of Mamaroneck. These include Arctic Glacier Ice, police station, fire station, town hall, LMC TV, Mamaroneck Self Storage (reserve command center) and several gas stations.
- In order to comply with NY Prize requirements, the facilities must have the ability to island from the remainder of the grid. With the facilities scattered across several non-conjoined buildings on different feeders, this presents a challenge of combining all facilities onto one circuit
- The Village of Mamaroneck industrial area located at Fenimore Ave and Waverly Rd is under a major redevelopment lead by a federal grant, the Army Corp of Engineer's water mitigation efforts and the Industrial Steering committee's area redevelopment plan.

Based on Task 1 findings, the team recommended that a mix of solar PV and natural gas generation be used to meet the generation requirements. CHP and fuel cells were dismissed after review of the building loads led to the conclusion that there was not a compatible load in any of the facilities that would benefit from the heat those technologies produce. For controls, it is recommend to use the Spirae Wave control system paired with the Delta Power Conditioning system. The team continues to seek input from community members and VOM government officials on how we can adjust the design to meet their requirements in addition to NY Prize/REV requirements. It is recommended that the microgrid's design focus be aligned with the FEMA, Army Corp of Engineers, and Industrial Steering committee's goals of redeveloping the Mamaroneck-Sheldrake river basin area.

Task 2

- The critical facilities of interest are not located on the same electrical supply feeder. Grouping them onto a single circuit would require installing several hundred feet of private cable and extensive switching. It may be most practical to group facilities into three separate microgrids.
- The Fenimore-Waverly microgrid provides ideal opportunity for Con Edison grid integration as it is located on the end of a feeder run. Integrating to the grid will require joining Arctic Ice to the secondary feeder and installing switches at pole transformers. The feeder section can be islanded from the distribution line that supplies it without interrupting service to other customers.
- The Fenimore-Waverly microgrid facilities consume 4.5 GWh annually and have a peak power draw of 1.3MW. Approximately 80% of this electrical load is from Arctic Glacier Ice's manufacturing process.
- Mamaroneck Self-storage buildings do not use gas. Arctic Glacier Ice uses gas for roof top units to heat office space. Total annual gas consumption is approximately 30,000 therms. There is no substantial baseline heating load outside of winter periods
- The target buildings have energy efficiency opportunities including LED retrofits, insulation and air sealing, process equipment upgrades, future absorption chiller - CHP potential at existing chillers end of life, envelope insulation and air sealing, and ventilation and temperature setback opportunities,

- The facilities in the Fenimore-Waverly area have over 105,000 sq. ft. of roof space available for PV arrays.

Based on Task 2 findings, it is recommended that the Fenimore Waverly Microgrid is further pursued for design. This is based on the added value from simultaneous area redevelopment effort and grid interconnection complexity. Based on available roof space and load requirements, the recommended additional distributed energy resources include one 150 kw PV array, one 700kW PV array, one 250kW battery bank, and one 750kW natural gas generator.

Task 3

- The initial capital cost of the microgrid materials is approximately $3.7 M.
- The ownership and operational structure of the microgrid will be shared between Murphy Brother Contracting (minority investor, developer, and sole operator) and Fenimore-Waverly Microgrid LLC (separate investor owner group).
- There are several stakeholders involved in the development and operation of the microgrid including VOM, NYSERDA, ISO, Con Edison, community members, and project investors, legal and regulatory authorities. Each of these stakeholders must work in unison for implementation and operation to be successful.
- Selling energy to facilities within the grid will require a moderately complex power purchase agreement that is contingent on availability of solar PV generation and cost of natural gas generation compared to ISO market supplier rates.

The next step in the business/ownership development is obtaining initial commitments from interested investors and creating preliminary terms for customer power purchase agreements. The cost-benefit ratios will need to be improved before soliciting outside investors.

Task 4

- The total operating cost of the microgrid over a 20 year period is approximately $10,000,000
- The selected distributed energy resources can contribute up to 0.96 MW of demand response capacity.
- During a grid outage, the downtime cost for Arctic Glacier Ice is $383,000/day and for Mamaroneck Self Storage Phase II is $51,000/day.
- For the scenario where the area experiences no grid outages per year, the proposed design has a net present value of -$3,630,000 , a benefit cost ratio of 0.6, and an internal rate of return of -8.1%
- In order to achieve a benefit cost ratio of 1.0, a grid outage would need to occur 2.7 days/year. This scenario would yield a net present value of $94,300 and an internal rate of return of 7.4%

The task 4 analysis indicates that design may need to be adjusted to increase net present value under each operating scenario. The team recommended approach is to reevaluate the design for cost reduction and efficiency gain opportunities. A crucial added value may lie in attracting another critical services to the redevelopment area in order boost the grid-outage scenario's value. In order to reduce system operating cost during normal operating scenario, the team may have to reconsider combined heat and power. The most feasible scenario would include working with Arctic Ice to negotiate a scenario where ice making equipment is converted to absorption chillers and is fed from cogeneration heat.

Project Results and Lessons Learned

This feasibility study has resulted in a replicable microgrid design that will support critical services in a developing area of the Village of Mamaroneck. The design has been optimized for integration into the existing grid, minimizing the need for additional expensive infrastructure and switching. Along the path taken to arrive at the final design, the team recalls several lessons learned that can be of assistance to future design efforts.

Going into the project, the general strategy included identifying the key critical facilities of the Village that were within a ½ mile radius of each other. It was expected that since the facilities were in such a close proximity that they were supplied electricity by the same feeder. This turned out not be the case, which meant grouping all of the initially selected facilities into one grid would require extensive switching hardware and the addition of private cables to link feeders. Ultimately, this misunderstanding of the grid layout caused the team to spend weeks investigating facilities that were not a feasible option for a single community scale microgrid; an invaluable lesson none the less.

A key factor in boosting a generator's financial value is creating a combined heat and power scenario where electrical generation's waste heat can supplement a facility's base heating load. After narrowing down buildings that provided opportunity for practical grid integration, the remaining facilities did not offer a cost-effective opportunity for CHP. Investigating ways to capitalize on this opportunity should be investigated further. In an area under redevelopment, numerous possibilities could abound. Working with the surrounding community to add complimentary facilities that could benefit from this waste heat is definitely worth pursuing. A symbiotic relationship among businesses, building types, facilities could be a recipe for microgrid development in the future. More important than utility lines could be the mix of uses in the area that would maximize microgrid efficiency and community diversity, something that is always highly desirable.

Environmental and Economic Benefits

In addition to sustained availability of critical services during grid outage, the proposed microgrid design offers several environmental and economic benefits. The PV (23%) and natural gas (77%) generation mix produces electricity at a carbon emissions rate of 0.4388 metric tons CO_2/MWh, which is very similar to the existing Con Edison generation (which is estimate at 0.39 metric tons/MWh). This slight increase is because the current generation mix is primarily natural gas and nuclear—already a relatively low weighted CO_2 emissions rate. However, the 850 kW+ PV capacity helps supports the REV 2030 imitative of obtaining 50% of NY's generation from renewable sources. The existing facilities in the Fenimore-Waverly Microgrid provide energy efficiency opportunities, specifically insulation and temperature/ventilation setback opportunities at Arctic Glacier Ice. These energy improvements can help support REV's goal of 23% reduction in energy consumption of 2012 code buildings.

The primary economic benefits stem from avoided costs suffered during major grid outages. For Arctic Ice, the microgrid may be able to avoid losses of $383,000/day and for Mamaroneck Self Storage Phase II, 51,000/day. Industrial Economic Corporation has determined that the grid outage would need to last for 2.7 days/year for the benefit cost ratio to reach 1.0. The team is evaluating opportunities to improve the designs financial strength in order to attract investors to fund further design investigation and eventual implementation.

Appendix A Mamaroneck Avenue Microgrid Analysis

The buildings associated with the proposed microgrid location at and around Mamaroneck Avenue are the Regatta at 123 Mamaroneck Avenue (#2), the new location of the local TV station (LMCTV) at 145/147 Mamaroneck Avenue (#5), and the Police Station at 169 Mount Pleasant Avenue (#23), and the Fire Station at 146 Palmer Ave (#24). Ultimately, the team chose not to pursue this microgrid because the area feeder layout did not allow for a feasible network of the buildings (without breaking up into several microgrids or installing underground cables to merge two feeders). Before this decision was made, the team visited several of the sites and analyzed historical utility consumption data. The results of this analysis are below.

Police Station

169 Mount Pleasant Avenue houses the Village of Mamaroneck Police Department, Justice Court, Building Department, and Planning Department. The facility has three stories, plus a basement, an attic, and an annex. The police desk and detective bureau are both open 24/7, year-round. The courtroom is open up to 18 hours per day, Monday – Friday. Offices throughout the facility are open from approximately 8am – 10pm Monday – Friday. The building has a brick façade with single-pane windows (Figure 28).

Figure 28. Police Station Façade at 169 Mount Pleasant Ave

The facility has two (2) separate heating systems, each equipped with a single boiler. The primary boiler produces steam, which is delivered to radiators located along the perimeter of the facility through a two-pipe distribution system. This boiler currently operates using fuel oil but is anticipated to be switched to natural gas. The second boiler produces heating hot water (HHW), which is delivered to the building's air handling units (AHUs). This boiler operates using natural gas. The annex is heated by a rooftop unit (RTU). Several areas of the facility are provided heat by reversible heat pumps located above the ceiling.

Several areas of the facility are served by a variable refrigerant flow (VRF) system. Refrigerant R410A is delivered to reversible heat pumps located throughout the facility. These heat pumps are controlled by local thermostats. Four (4) Mitsubishi condensing units located outside the facility serve this VRF system.

Three (3) air handling units with direct expansion (DX) cooling coils provide cooling to the remainder of the facility. AH-1 and AH-2 serve the courtroom and AH-3 serves the locker room. Condenser units for this system are located outside.

AH-1, AH-2, and AH-3 provide fresh air to the courtroom and locker room, in addition to providing cooling and heating to these spaces. Major HVAC equipment is controlled remotely by the BMS contractor. A 50 gallon gas-fired domestic hot water (DHW) tank serves the facility's bathrooms. Lighting throughout the facility is provided by a variety of fluorescent fixtures. All lighting is operated by manual switches. The facility is equipped with one (1) Cummins Quiet Site generator rated at 250 kW (Figure 29). This generator is able to power the entire building in the event of a grid outage. The building has a pitched, exposed rooftop and appears to be suitable for installing solar generation capacity.

Figure 29. Existing Generation Asset at 169 Mount Pleasant Avenue

A bar chart showing monthly electric consumption at the police station is shown in Figure 30. Consumption peaks during winter months, likely due to increased heating demand on the multiple VRF systems. The annual electric consumption is approximately 330,000 kwh/year

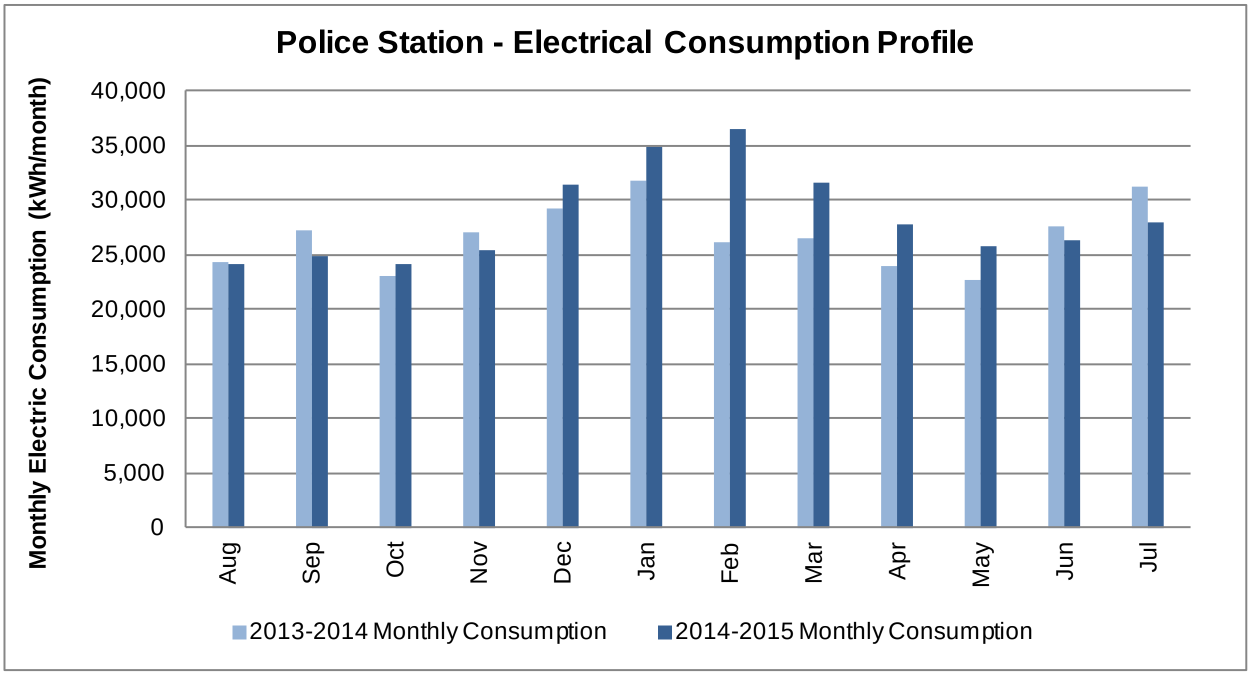

Figure 30. Electrical Consumption Profile: Police Station

A bar chart displaying electrical demand profile of the police station building is shown in Figure 31. The profile is relatively constant throughout the year showing dips in the swing season peroids. Peak demand ranges from 50-70kW.

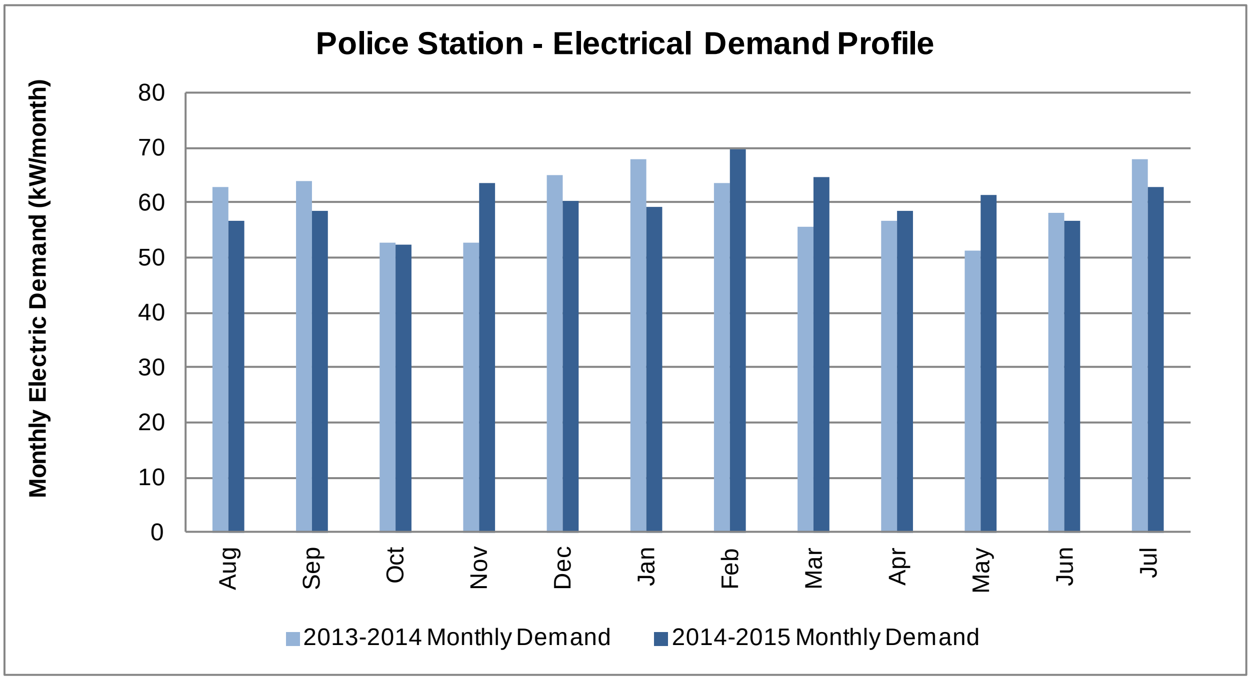

Figure 31. Electrical Consumption Profile: Police Station

The Regatta

The Regatta is a residential building located in downtown Mamaroneck at 123 Mamaroneck Avenue. An image of the front face of building is shown in Figure 32. The facility was built in 1996 and is comprised of six (6) above-ground floors and a two-story parking garage located below the ground floor level. A small portion of this building is leased by the Village of Mamaroneck and houses the Village Hall. The remainder of the building is dedicated to residential space and contains (15) 1-bedroom apartments, (75) 2-bedroom apartments, and (24) 3-bedroom apartments.

Figure 32. Front Building Façade: Regatta, 123 Mamaroneck

This facility operates 24/7. The parking garage is also accessible 24/7. 123 Mamaroneck Ave has a brick façade. Windows are operable and have double-pane glazing with aluminum frames. The facility has a flat roof with built-up insulation of an unknown thickness. Two (2) A. O. Smith natural gas fired boilers with a capacity of 2,500 MBH each provide heating to the apartments throughout the facility. These boilers operate lead/lag and produce heating hot water (HHW). HHW supply temperature varies from 160 °F – 185 °F based on an outside air reset schedule, controlled by a Honeywell aquastat. Two (2) constant volume HHW pumps rated at 5-hp deliver HHW to baseboard fin-tube radiators located along the perimeter of the building and to the two (2) packaged units in the lobby. Three (3) natural gas fired rooftop units (RTUs) provide heating and cooling to the building's hallways and stairwells (Figure 33). These units are programmed to maintain hallway space temperature at 72 °F year-round.

Figure 33. Gas Fired Boilers (left) and Gas-fired RTU (right): The Regatta

123 Mamaroneck Ave has no central cooling plant. Apartments are equipped with through-the-wall packaged terminal air conditioning units (PTACs). Each living room has one (1) 10,000 btuh unit and each bedroom has one (1) 8,000 btuh unit, for a total of (114) 10,000 btuh units and (237) 8000 btuh units. Each unit is equipped with manual controls. Hallways and stairwells are cooled with the same three (3) RTUs that provide heating to these spaces.

Figure 34. Typical living room PTAC: The Regatta

Radiators in apartment units have thermostatically controlled valves whereas PTACs have manual controls. Fifty five (55) exhaust fans located on the roof provide ventilation for kitchens and bathrooms located throughout the facility. Each exhaust fan has a 5-hp motor and operates 24/7. This facility has no BMS or central controls. Domestic hot water (DHW) at is produced by one (1) natural-gas fired boiler and is delivered at 125 °F.

Figure 35. DHW Boiler: The Regatta

Lighting throughout the corridors, apartments, and parking garage is provided by CFLs. Lighting in the stairwells is provided by fluorescent T8 fixtures. Corridor, stairwell, and garage lighting operates 24/7. Two (2) elevators serve this facility. Each elevator serves all floors and has a 19-hp motor. There is one (1) generator of an unknown capacity located in the parking garage. This generator provides backup power to fire equipment only. Each apartment includes a full-service kitchen with electric appliances. Each floor contains a laundry room with two (2) washing machines and two (2) electric dryers.

Figure 36. Backup Generator: The Regatta

A bar chart displaying the electrical consumption profile for the master meter on the Regatta is shown in Figure 37. The load ranges from 30,000 kwh/month in swing seasons to 46,000 kwh/month during the heating season. The annual energy consumption is approximately 470,000 kWh.

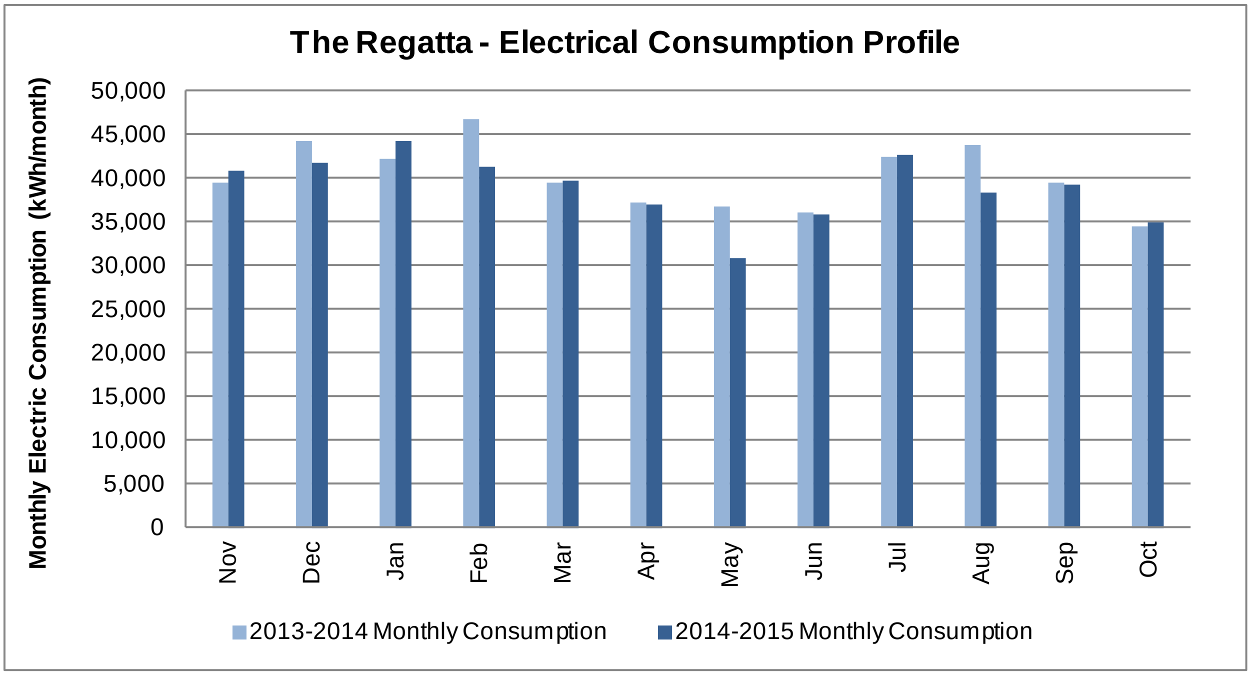

Figure 37. Electrical Consumption Profile: The Regatta

A bar chart showing the electrical demand profile at the Regatta is shown in Figure 38. Power consumption ranges from 80 kW during swing season to 110 kW during summer. This range is likely driven by the wall mount PTAC use.

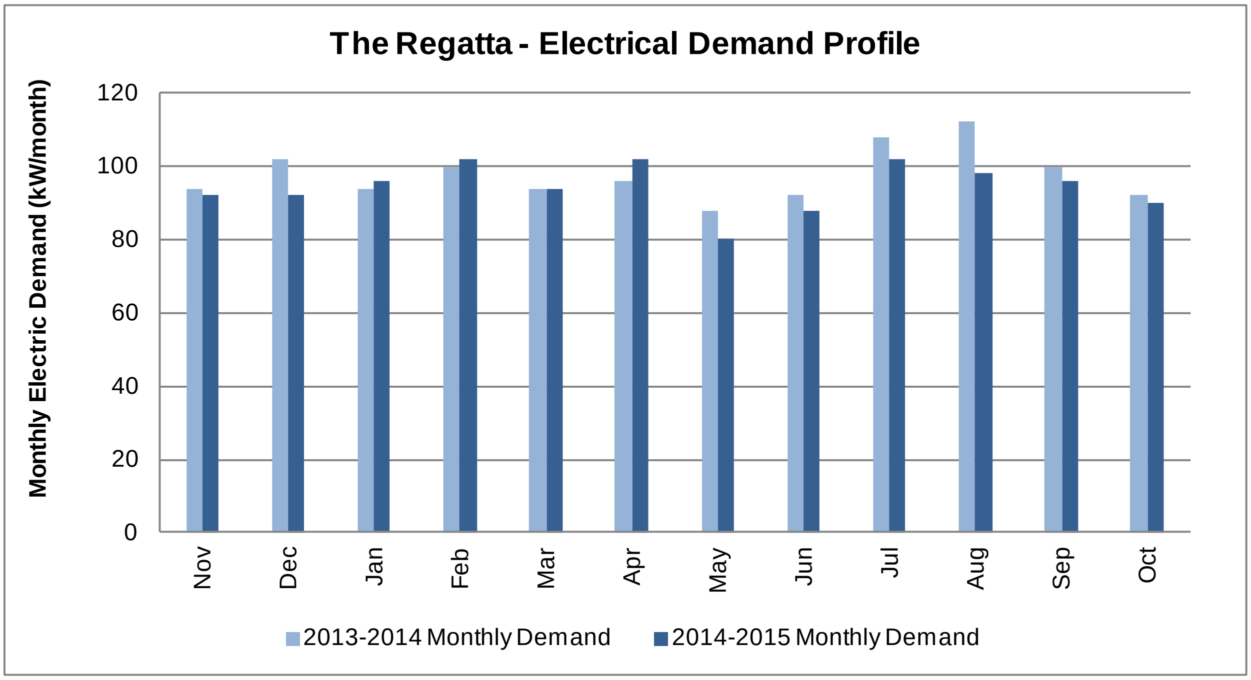

Figure 38. Electrical Demand Profile: The Regatta

The monthly natural gas consumption profile at the Regatta is shown in Figure 39. Gas consumption is driven by space conditioning; however, there is a small baseline load for central water heating year round. Peak gas consumption is 14,000 therms during heating season but baseline gas use is approximately 900 therms per month. This small baseline gas load could be an ideal application for a micro CHP system, potentially a capacity of 20-25 kW.

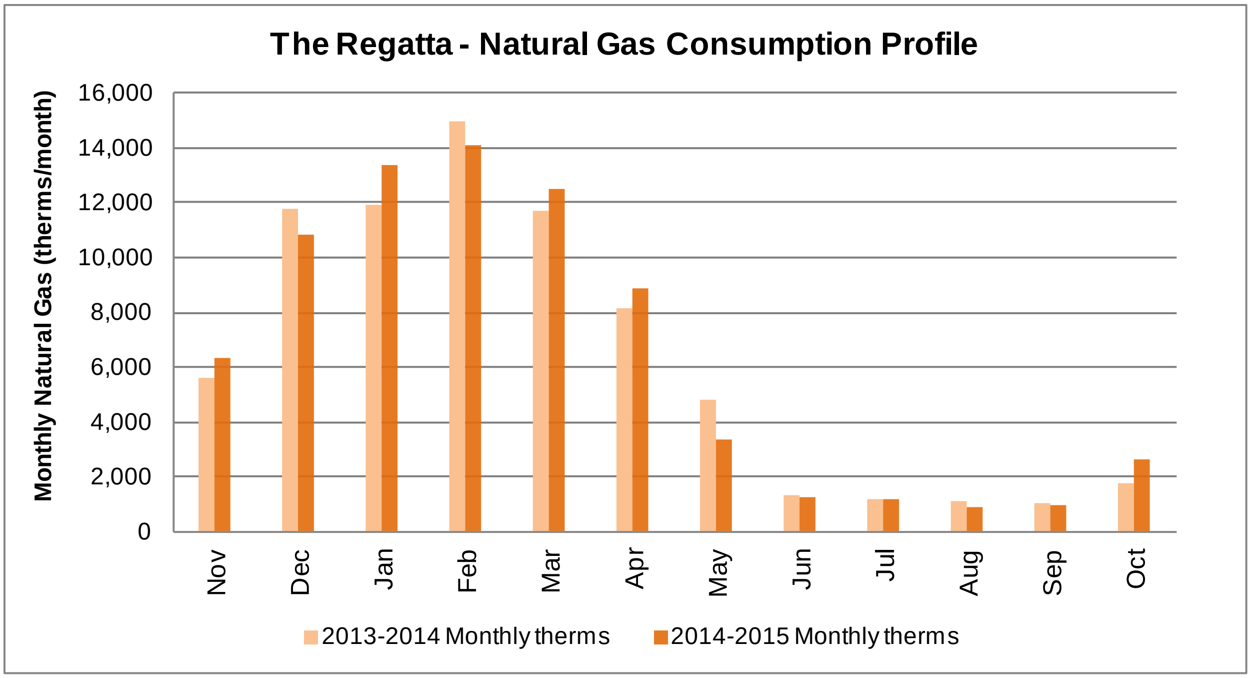

Figure 39. Natural Gas Consumption Profile: The Regatta

LMC TV

Current development within the proposed Mamaroneck Avenue microgrid location consists of LMCTV moving to a new location, 145/147 Mamaroneck Avenue.

145/147 Mamaroneck Avenue is a currently vacant four-story plus cellar building located in downtown Mamaroneck. This building is approximately 4,200 ft^2 in size, approximately 100 years old and was Mamaroneck's old fire house before the fire house was relocated. The building façade consists of brick and single-paned punch-out windows with a rollup garage door facing Mamaroneck Avenue. This building is attached to neighboring buildings on its north and south walls. This building was deemed suitable for a new location for LMCTV. This building has an exposed north/south pitched rooftop and appears to be suitable for installing solar generation capacity

Figure 40 LMC TV future location at 145/147 Mamaroneck Ave

The energy consumption associated with LMCTV's new location cannot be projected due to the unknown changes in existing equipment and operation. The utility use at their current location is not separately metered.

Fire Station

146 Palmer Avenue houses the Village of Mamaroneck Fire Department and was built in 2009. The facility is approximately 25,000 sq. ft. and has three above-ground floors and one below-grade level. The building contains a garage, event rooms, kitchens, a gym, and an attic. An image of the front face of the building is shown in Figure 41. The building is always occupied from 8AM to 12AM, and is usually occupied overnight. 146 Palmer Avenue has a brick façade with double-pane windows.

Figure 41. Fire Station Facade at 146 Palmer Avenue

Two natural gas boilers heat hot water that provides space heating for the entire building. Hot water at 180 °F is circulated with four pumps (two ½ hp. two 3hp), all controlled by one drive. Heating hot water is delivered to coils in the building's air handling units and to the radiant heating system. There are small electric heaters in the attic and stair wells that provide additional heating. One (1) 60-ton air-cooled scroll compressor chiller manufactured by Trane provides chilled water (CHW) to the facility's AHUs. The chilled water pumps were inaccessible; however, SWA estimates that two (2) 5 hp CHW pumps are sufficient to deliver CHW to the facility's AHUs. Six (6) AHUs provide conditioned air to the facility. All AHUs have both a heating hot water coil and a chilled water coil. All AHU supply fans are 3hp.

The facility also has six (6) exhaust fans, each of which is 1.5 hp. Major HVAC equipment is controlled remotely by the BMS contractor. A 50 gallon gas-fired domestic hot water (DHW) tank serves the facility's bathrooms. Lighting throughout the facility is provided by a variety of fluorescent fixtures. All lighting is operated by motion sensors. The facility is equipped with one (1) Cummins generator rated at 250 kW. This generator is able to power the entire building in the event of a power outage.

The facility has one (1) hydraulic elevator with a maximum capacity of 2,100 lbs. driven by a 25 hp motor. The facility also has air compressors used for filling oxygen tanks, two (2) washing machines, one (1) dryer, two (2) full-service kitchens, and three (3) vending machines.

A chart displaying monthly electrical energy consumption profile at the fire station is shown in Figure 42 .Monthly energy consumption ranges from 25,000 kWh during swing seasons and up to 35,000 kWh during heating season. The annual energy consumption is 350,000 kWh.

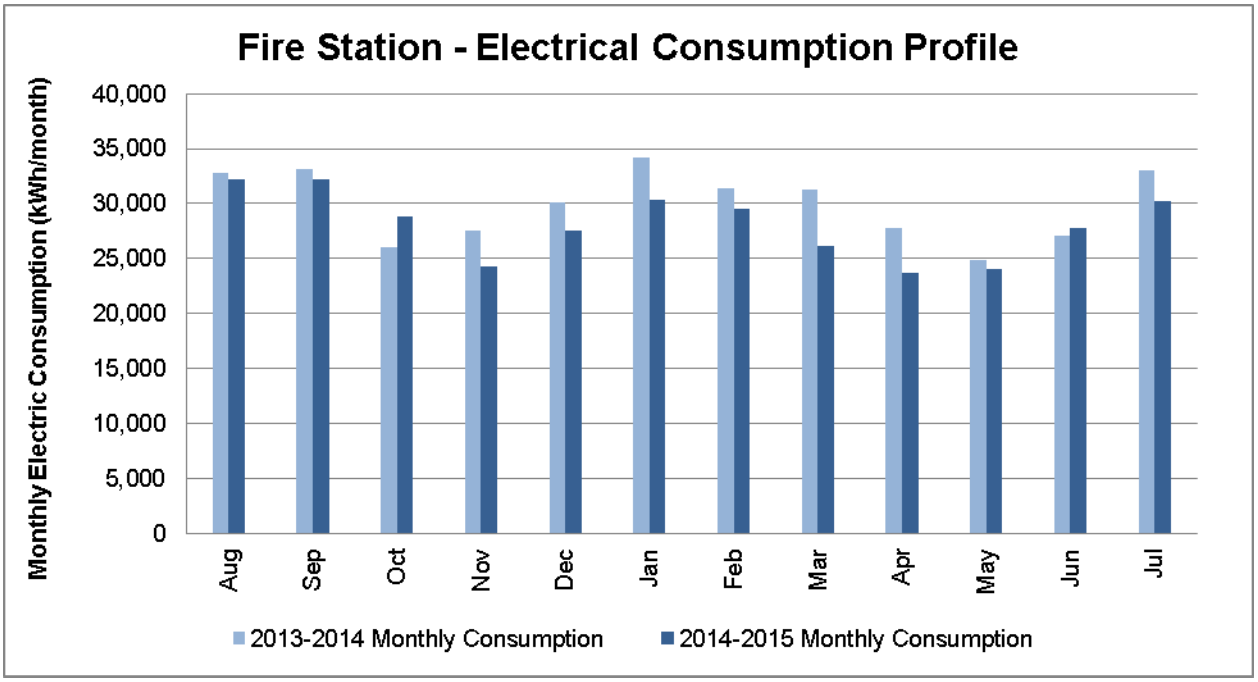

Figure 42. Electrical Consumption Profile: Fire Station

A chart displaying the electrical demand profile at the first station is shown in Figure 43. Peak demand ranges from 50kW to 70kW throughout the year. The highest peak load occurs during swing season months (September and May).

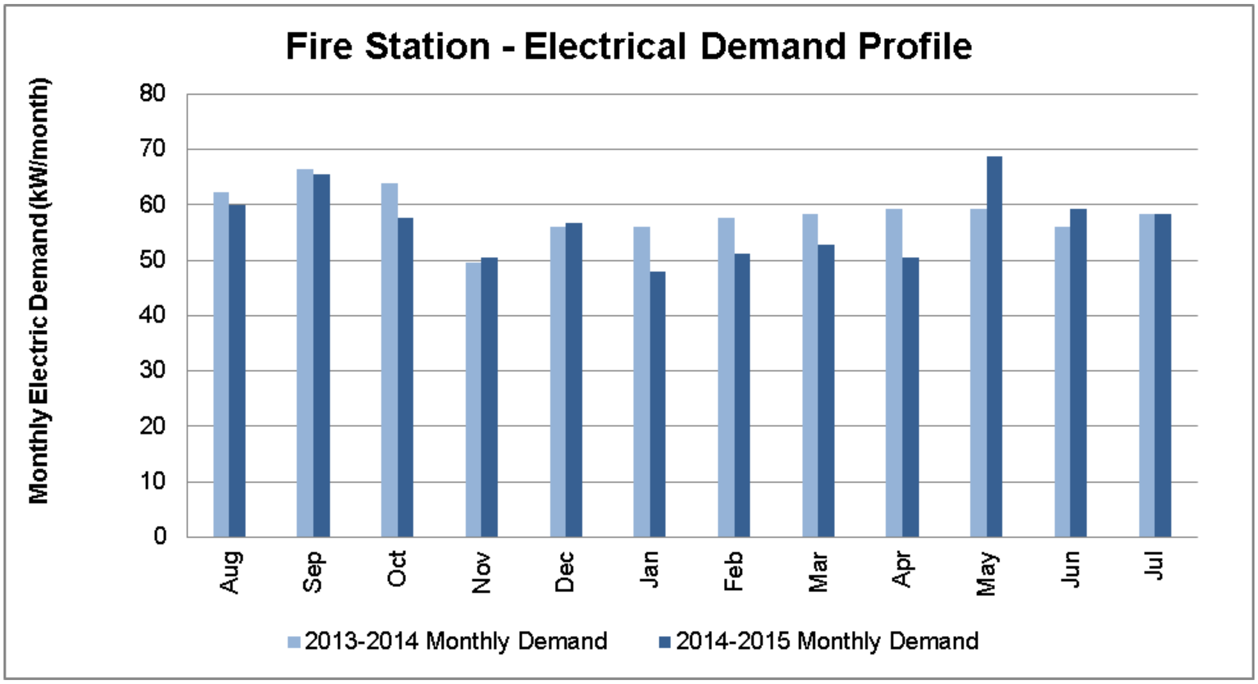

Figure 43. Electrical Demand Profile: Fire Station

Appendix B Fayette-Northrup Microgrid and Sunoco Station

The Fayette-Northrup microgrid is a design that consists of two gas/service stations: Vincent Service and Lebrini's Service. Utility bill data was collected and analyzed for the buildings, but the team ultimately chose not to move forward with the technical design. As a result, site visit investigations were not completed. The original intent is that this section would be able to connect with the Fenimore-Waverly grid, but existing feeder layouts did not make this possible. Con Edison's recommendation for a microgrid containing these two buildings is shown in below.

Lebrini's Service Station

The monthly electrical consumption profile of Lebrini's Service Station, located at 711 Fenimore Rd, is shown in Figure 44. Monthly Electric consumption ranges from 1500 kWh during summer months to 2600 kWh during winter months. The annual consumption is 24,000 kWh.

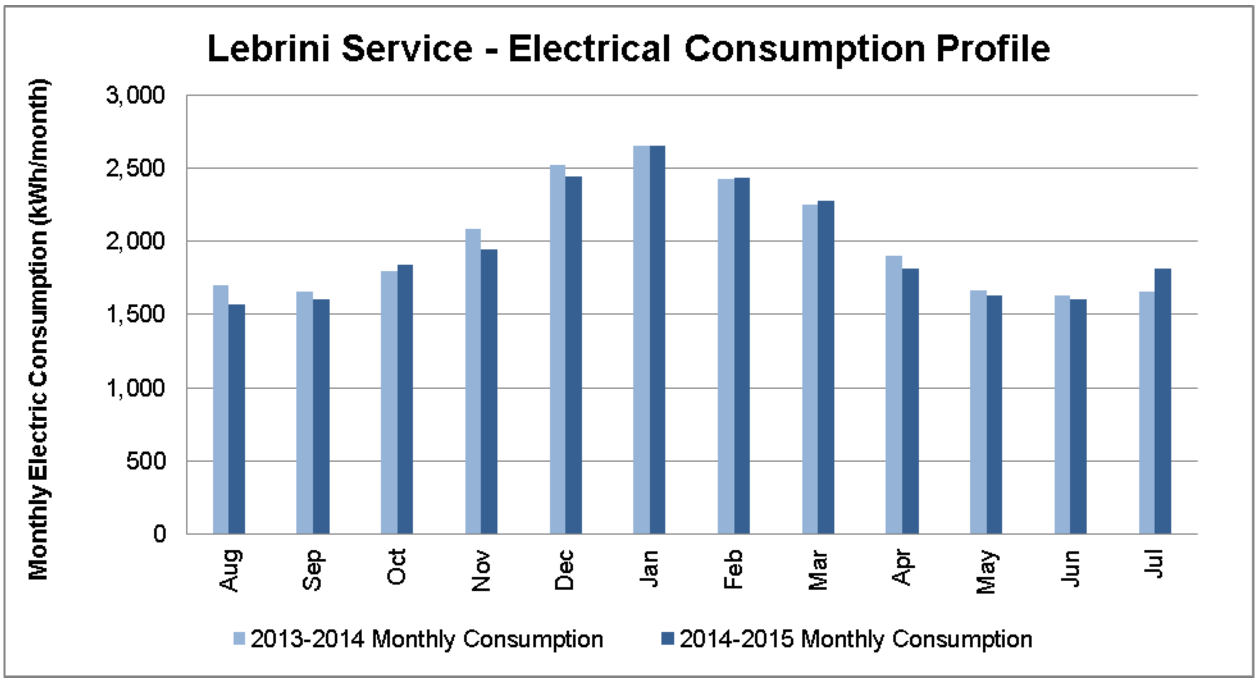

Figure 44. Electrical Consumption Profile: Lebrini Service

A partial-year electrical consumption profile for Vincent Service station, located at 636 Fenimore Rd, is shown in Figure 45. For the data available monthly electrical consumption was 4,000-5,000 kWh. If consumption is relatively constant year round, it is likely that annual consumption is around 55,000 kWh.

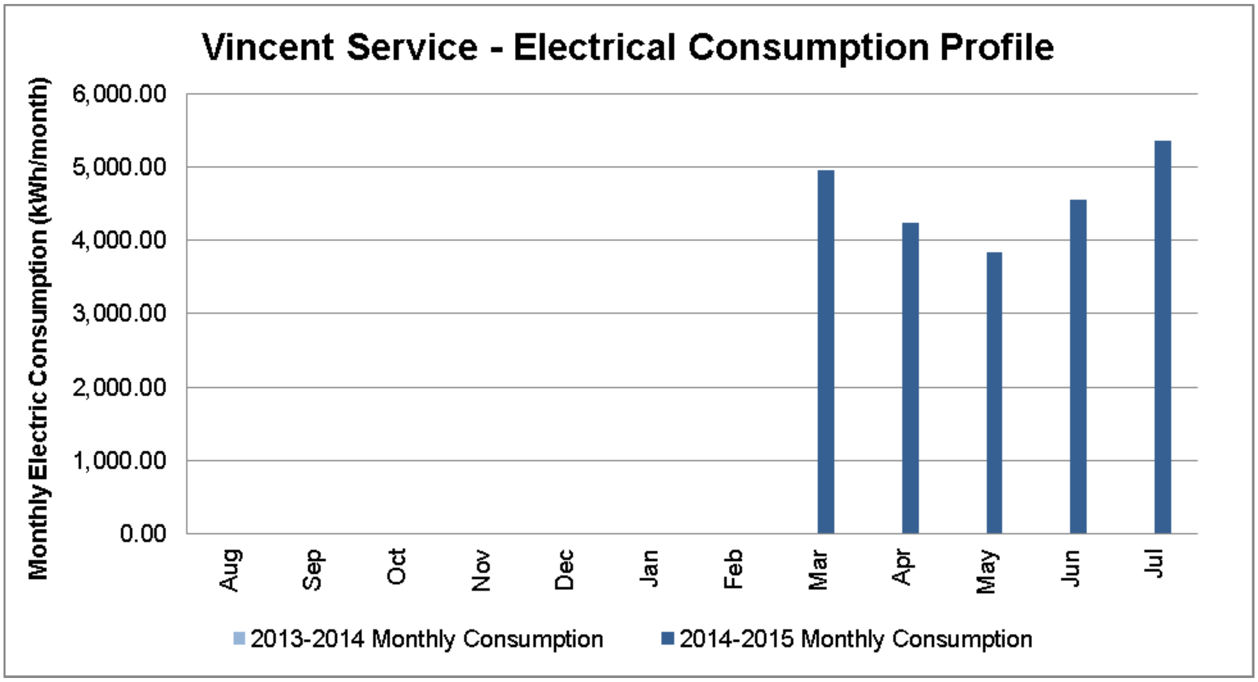

Figure 45. Electrical Consumption Profile: Vincent Service

A bar chart showing data for electrical demand profile at Vincent Service is shown in Figure 46. Data was only available for March through July months of 2015. For the data available, peak demand ranged from approximately 20-25kW.

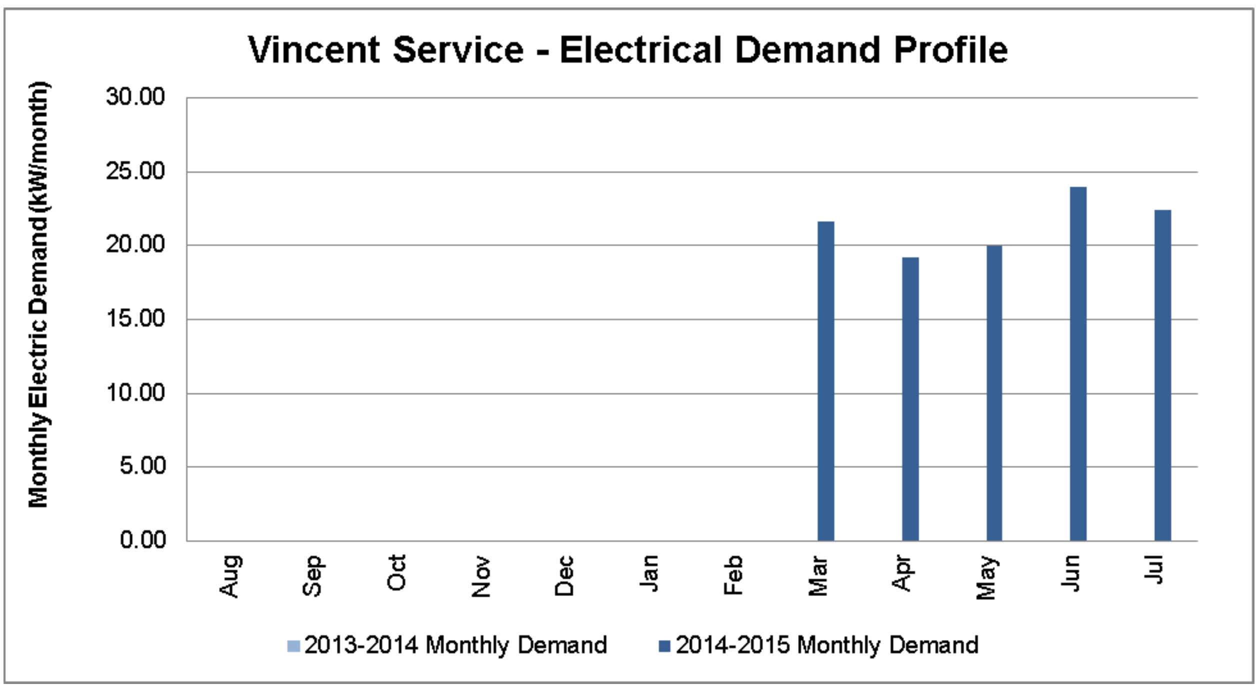

Figure 46. Electrical Demand Profile: Vincent Service

Natural gas consumption at Vincent Service is shown in Figure 47. As with electrical data, only March through July 2015 data was available. The gas use is space heating driven; using over 800 therms in March and close to zero usage during summer months.

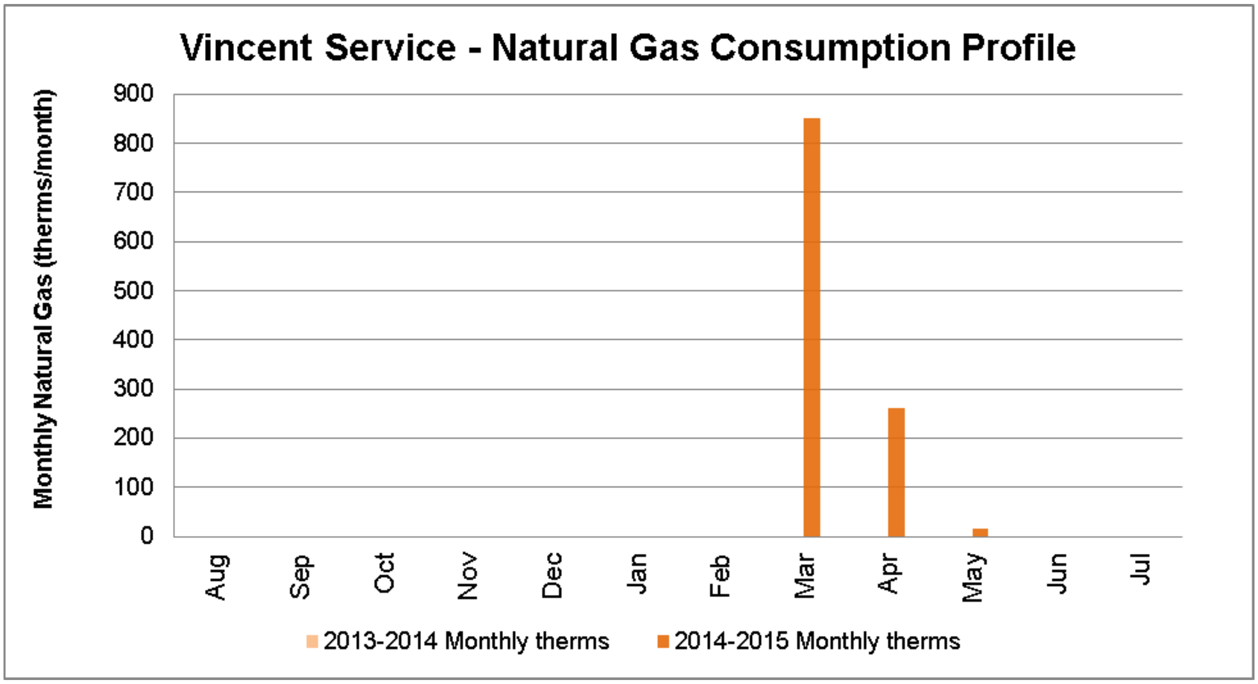

Figure 47. Natural Gas Consumption Profile: Vincent Service

Sunoco Gas Station

The VOM Sunoco station, located at 540 Mamaroneck Ave, was initially included as a potential critical facility to include in the microgrid. However, due to its far proximity from other critical facilities, it was ultimately excluded from the design. Before this decision was made, the team had collected and analyzed past utility data. A bar chart displaying electrical consumption is displayed in Figure 48. Monthly electrical consumption ranges from 10,000 kWh in summer months to 16,000 kWh in winter months. Annual consumption is approximately 140,000 kWh.

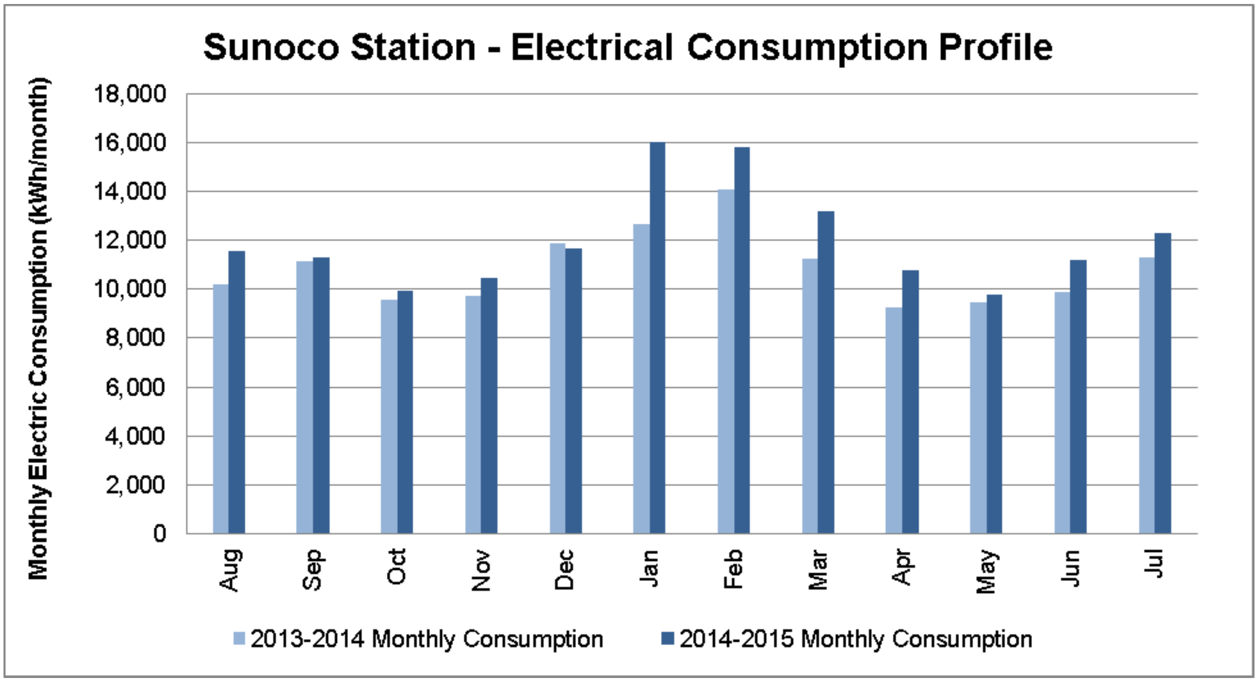

Figure 48. Electrical Consumption Profile: Sunoco Station

A bar chart showing the peak monthly demand at the Sunoco Station is shown in Figure 49. Peak demand ranges from 20 kW during summer months to approximately 33 kWh during winter months.

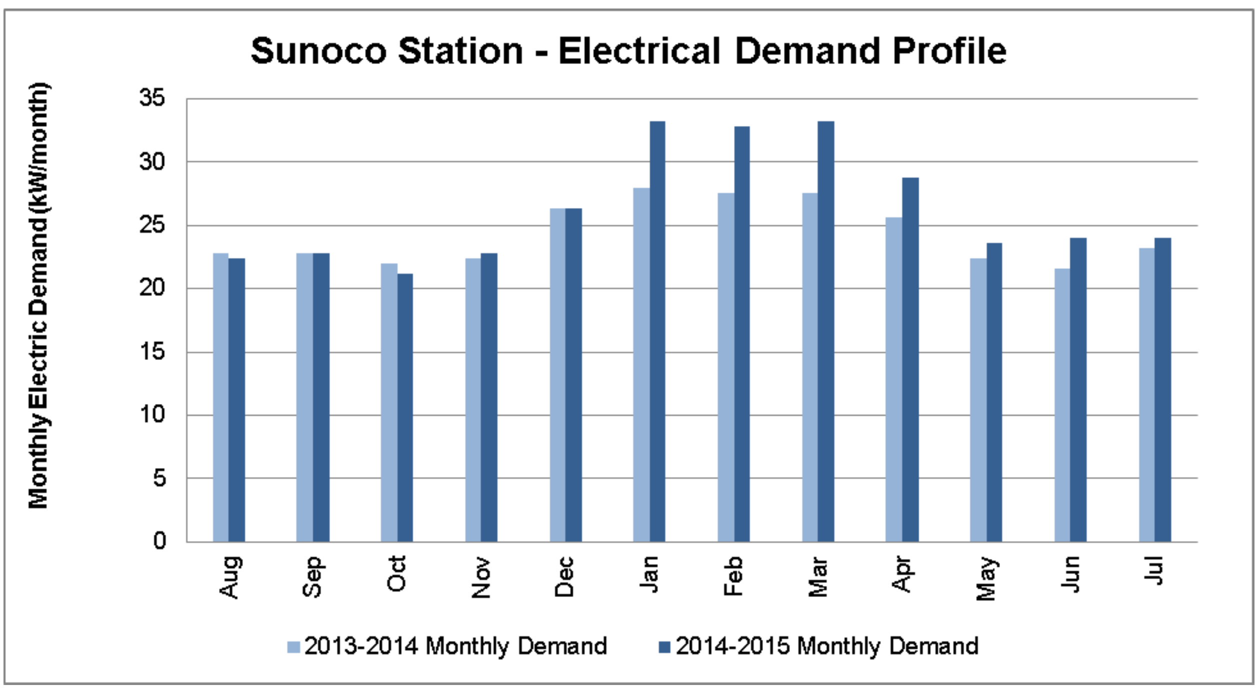

Figure 49. Electrical Demand Profile: Sunoco Station

Appendix C Utility Line Diagrams from Con Edison

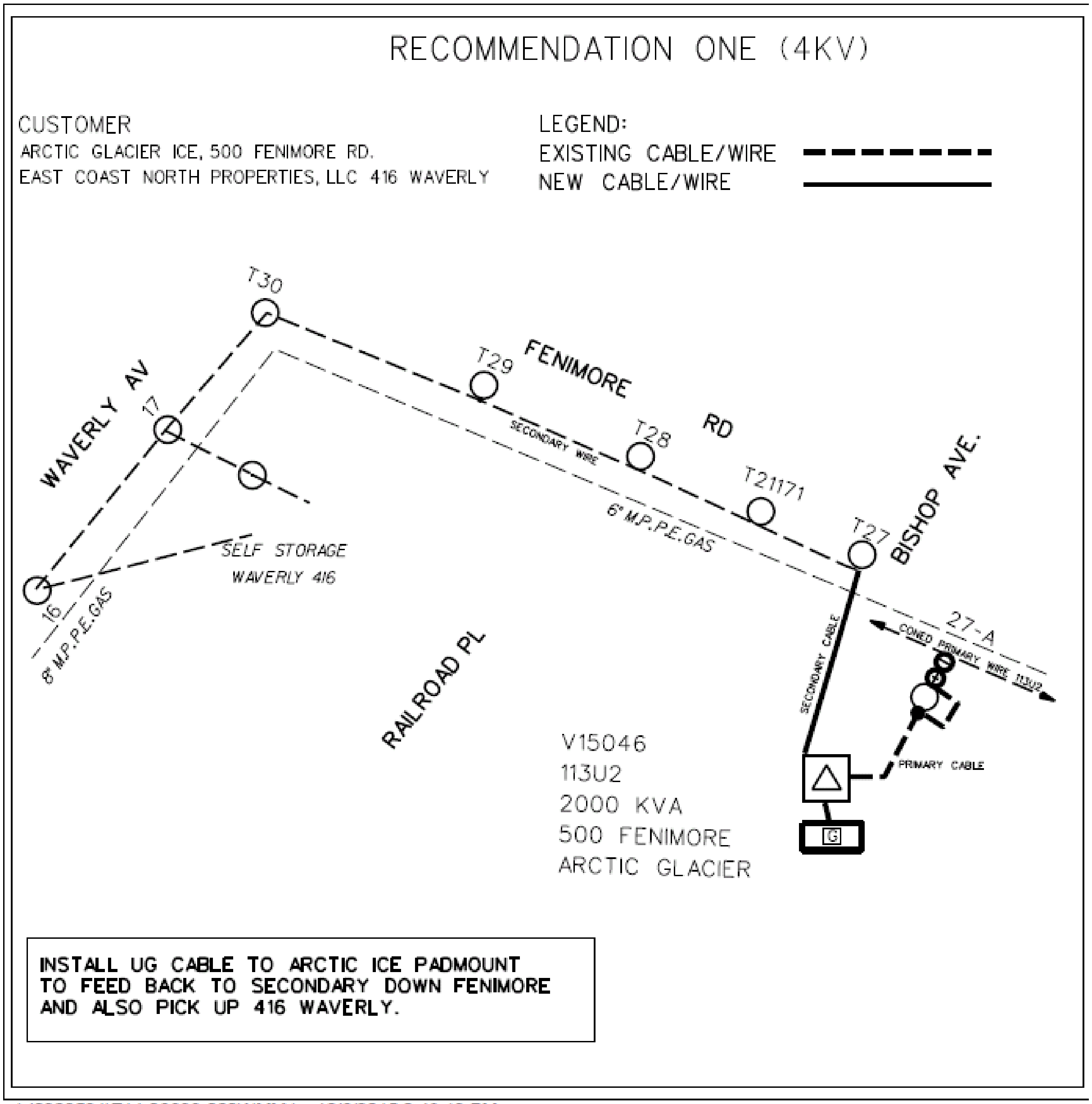

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Figure 50. Con Ed Recommendation One: Waverly-Fenimore Microgrid

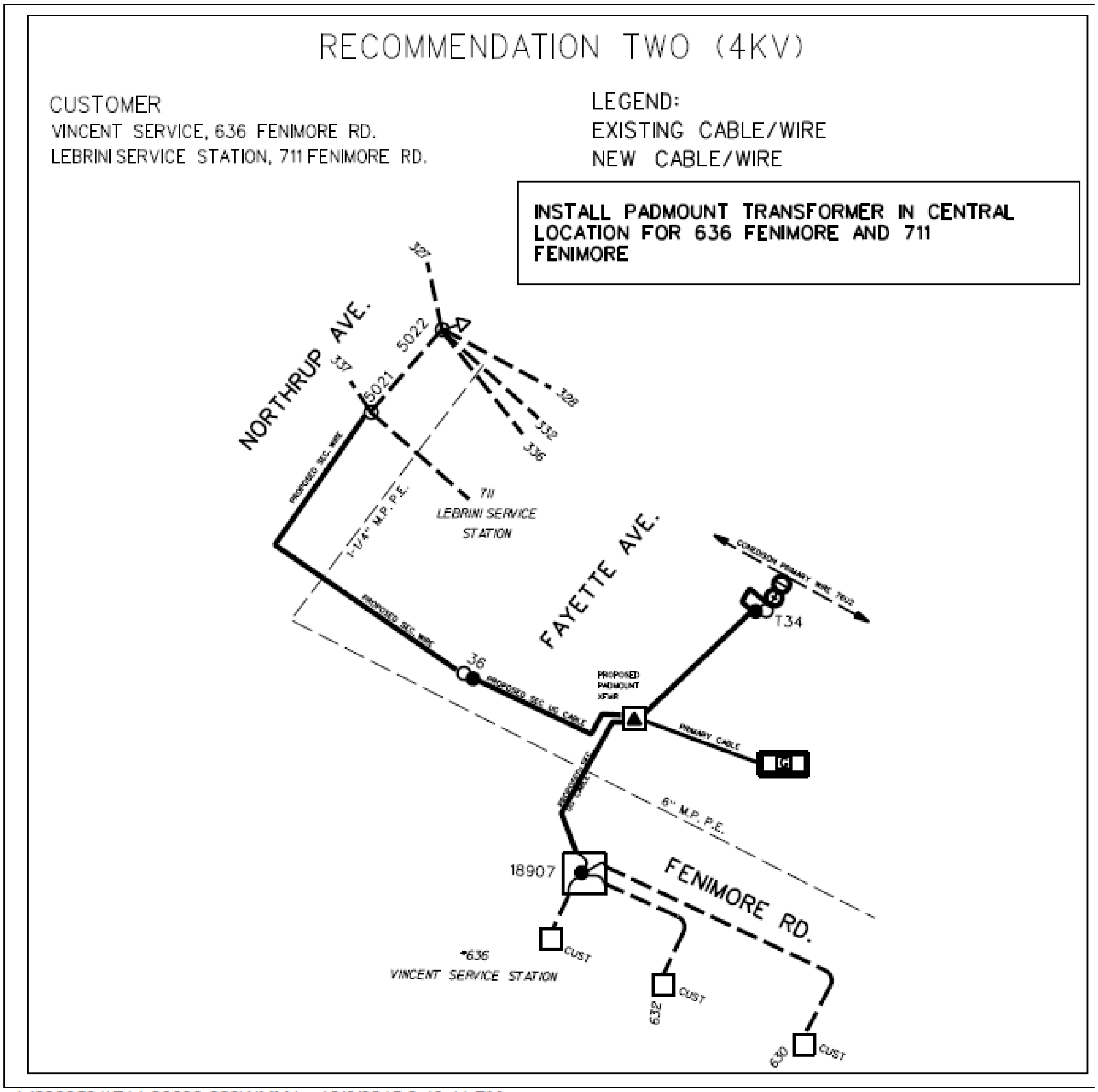

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Figure 51. Con Ed Recommendation Two: Northrup-Fayette Microgrid

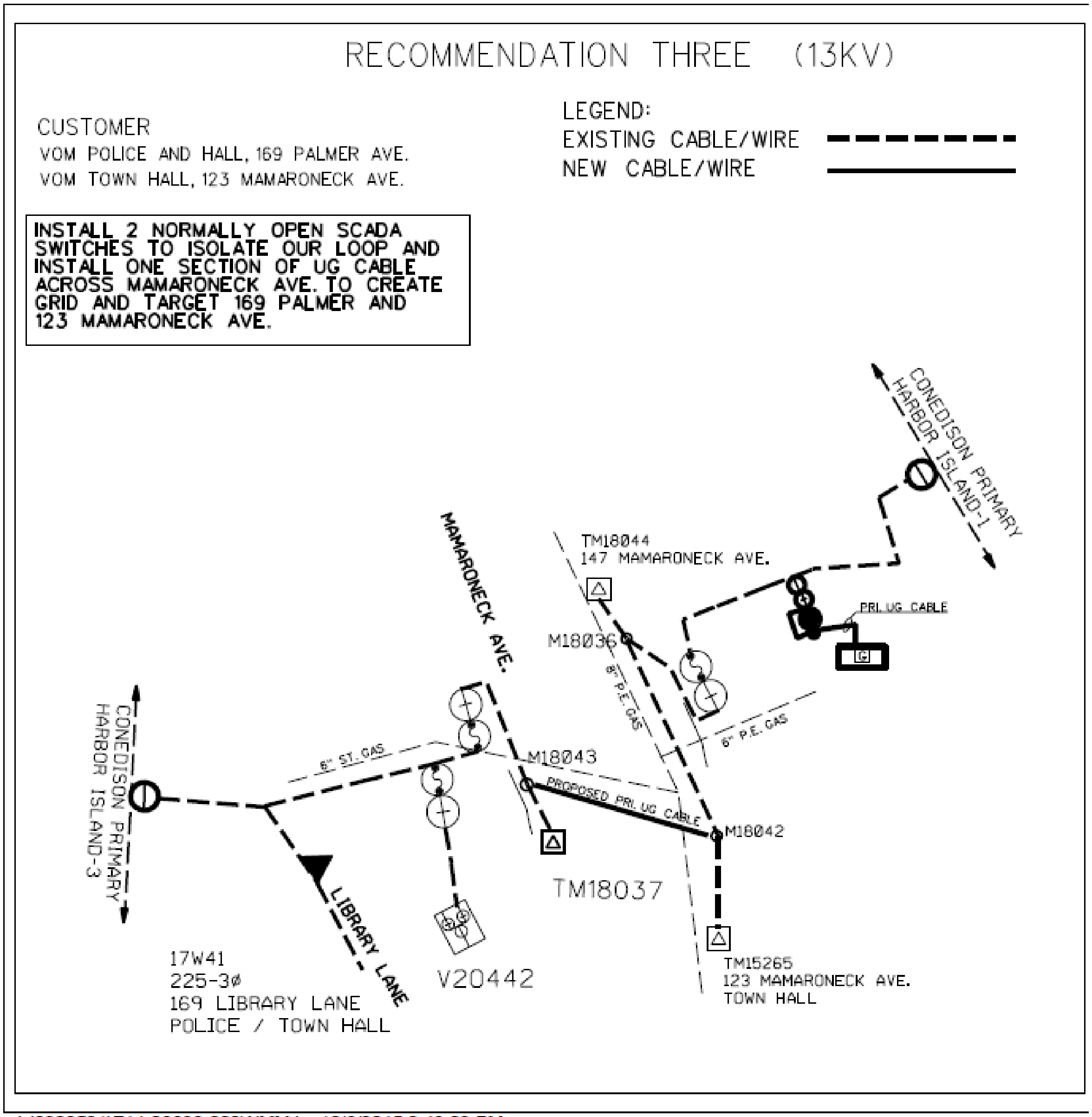

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Figure 52. Con Ed Recommendation Three: Mamaroneck Ave Microgrid

Appendix D: Supplemental Media

Figure 53. Images showing aftermath of Hurricane Irene at Fenimore-Waverly area

Figure 54. Members of VOM Microgrid Team celebrate after Kick-Off meeting in front of Phase One of Mamaroneck Self Storage

Figure 55. At VOM Village Hall with Mayor Norm Rosenblum, Village Manager Richard Slingerlands, Police Chief Christopher Leahy, Assist Fire Chief Tracy Schmalling, community business men and members of the VOM Microgrid team

Figure 56. Sean and Chris Murphy join VOM Microgrid team member Sal Cona, from Intelligen, and Mick Gilbert from Con Edison for a tour of a large Co-Gen installation in midtown Manhattan

Figure 57. VOM Microgrid Team members meet with Con Edison to study the existing VOM Industrial Area Grid

The following list provides links to video content that supplement topics discussed in this report:

The VOM microgrid team held a presentation at Mamaroneck public library to educate the community on the NY Prize initiative and what was being considered in the Village.
https://www.youtube.com/watch?v=9Bv1At6MtNE

The Army Corps of Engineers presented their Flood Risk Management Report findings to the Village of Mamaroneck government officials and residents.
http://lmctv.org/videos_list/village-of-mamaroneck-us-army-corps-of-engineers-presentation-22516/

Michael Murphy, Murphy Brothers Contracting, Village Mayor Rosenblum and community business man Jim Bilotta, Bilotta Kitchens, talk about the community Microgrid study, the massive flood problems and the future of the Village of Mamaroneck
http://lmctv.org/videos_list/murphy-brothers-contracting-10-steps-for-ensuring-those-beautiful-custom-homes/