6 - Town of Brookhaven

Notice

NY Prize Stage I
Feasibility Study
Independence Hill Microgrid
Final Report

prepared for

NYSERDA

energy & resource solutions

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April 2016

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EXECUTIVE SUMMARY

This feasibility study was conducted under an award from the NY Prize initiative and presents an assessment of an electric microgrid between the Town of Brookhaven (the Town) and the Sachem School District. This report has been prepared to document the proposed microgrid capabilities, and it fulfills the NY Prize Stage 1 Feasibility Study deliverable requirements. The facilities included in the final configuration of the feasibility study are the Brookhaven Town Hall (the Town Hall) at 1 Independence Hill Road, Farmingville, New York, and Sachem High School East at 177 Granny Road, Farmingville. The nearby Tecumseh Elementary School was also considered for inclusion in early versions of the microgrid configuration but was later ruled out as plans were revealed to close the facility.

This project fully encompasses the goals of the NY Prize program in identifying projects that incorporate resiliency, emergency power availability, and financial success. The project has the community support, technical merit, and financial viability to be a strong contender to move on to Stage 2 of the NY Prize program. This project bridges many of the stakeholder gaps that exist in developing successful microgrid projects that can be replicated at other locations statewide. There are many towns across New York that could look to this project as a model to develop similar microgrids and structure relationships with town and community agencies that can bring substantial benefits to their communities.

This Stage 1 project examines the installation of an islandable microgrid encompassing the Brookhaven Town Hall and Sachem High School East. This microgrid would be used under normal conditions to provide power and available waste heat to both buildings and under emergency conditions to provide power to support a Red Cross emergency shelter at Sachem High School East and the Town's emergency response center within Town Hall. To assess the microgrid's technical and financial feasibility and ability to meet the New York Reforming the Energy Vision (NY REV) goals, the Stage 1 study has completed the following:

- An evaluation of the technical viability of distributed energy resources for the Town Hall and Sachem High School East
- An evaluation of the financial feasibility of developing a microgrid encompassing the facilities
- Identification of the performance and energy savings reduction opportunities in terms of the operation, maintenance, and control of the base building systems
- Development of an understanding of the roadblocks to project success and determination of possible workarounds or identifying potential solutions

The Microgrid Vision

The Town of Brookhaven is the second-largest town in New York State by population (486,040 residents) and the fifth-largest by land area (531.5 square miles). It has over 150 miles of Atlantic Ocean and Long Island Sound coastline. Because of its size, population, and coastal location, it is vulnerable to rises in sea level and storm damage related to climate change; the Town's services and operations were directly impacted by Hurricane Sandy. Brookhaven has developed a strategic energy plan driving investment in renewables and energy efficiency to reduce greenhouse gas (GHG) emissions, the primary driver of climate change. The intent of the microgrid, named the "Independence Hill" microgrid, is to reduce overall GHG emissions, improve local electrical distribution system performance during normal operations, and increase resiliency during grid outages.

The Independence Hill Microgrid includes the Town Hall, which is an emergency operations center, and the adjacent Sachem High School East, which serves as a Red Cross emergency shelter and emergency supply distribution center. On-site generation within the microgrid includes gas-fired combined heat and power (CHP) installed at the Town Hall and Sachem High School East, where there are substantial uses for waste heat, a large photovoltaic (PV) installation at the Town Hall (currently in planning as a lease arrangement), battery storage, two existing wind turbines, and bio gas-driven generation from a municipal water treatment plant. Buried cable will interconnect the two buildings. Controlled in concert, the components will lower GHG emissions through zero GHG generation (PV and wind turbines), reduce GHG generation (CHP and bio gas from an anaerobic digester), reduce the demand on the grid, and provide emergency power during grid outages (primarily natural gas CHP along with diesel back-up generators).

Increased grid resiliency is an important goal. The Town has experienced significant outages during recent storms and, along with its community, has struggled with a lack of grid resiliency and stability during emergencies. Brookhaven has an urgent need for a more reliable grid and better preparedness for changing climatic conditions. Table ES-1 presents a list of outages experienced in recent years.

Table ES-1. Power Outage by Facility

Facilities	Issue	Duration (Days)	Cause of Issues
Town Hall	Power outage	2.5, partial power	Hurricane Irene (August 2011)
Town Hall	Power outage	2.5, partial power	Hurricane Sandy (October 2012)
Sachem High School East	Power outages/schools closed	5, no power	Hurricane Sandy (October 2012)
Tecumseh Elementary School	Power outages/schools closed	5, no power	Hurricane Sandy (October 2012)
Town Hall	Power outage	2, no power	Winter Storm Nemo (February 2013)
Town Hall	Power outage	5, partial power	Cable failure (June 2014)
Total	**N/A**	**22**	**N/A**

N/A = Not applicable

One of the Town's main goals is to reduce GHG emissions by incorporating green, or low-emission, power generation. The Town also wants to include tangible benefits from a town-wide perspective, including grid resiliency, job creation, benefits from the Town and the Sachem School District partnership, and the maximization of taxpayer money.

The Town and school each have an existing 10 kW wind turbine; both are included in this report. Plans for the private development of photovoltaics (PV) at the Town Hall are, in part, being considered for inclusion in the microgrid with battery backup. The PV array's power will be discussed with the Public Service Enterprise Group Incorporated Long Island (PSEG-LI) to see where power can be used during emergencies.

Behind-the-meter efficiency will play a large role in the reduction of peak demand needs and annual energy usage as it lowers GHG emissions. The Town Hall is planning multiple energy efficiency and controls upgrades over the next 2–3 years based on a recent energy study and with a current allocation over $300,000 to spend on system upgrades.

The Sachem School District is undergoing a district-wide performance contract that will substantially lower the energy usage of the school facilities, including those of Sachem High School East. The impacts of the planned energy measures and any newly developed measures ascertained through this study will be used in the microgrid's final power requirement assessment. With the support of the Brookhaven National Laboratory, the Town will be looking to incorporate new software technology into the project to assess and manage the complexity of the power generation and potential storage for the microgrid.

This project will leverage existing and planned private development activities, including the Sachem School District's energy performance contract. This combination of technology and public/private development makes it a good project in which to demonstrate a different strategy for enhancing system resiliency. The project will look to incorporate typical CHP generation and less-mainstream technologies, including fuel cells and/or microturbines powered by methane from the nearby wastewater treatment facility.

In conducting this microgrid feasibility study, Mr. Kurt Blemel, Ms. Sue Haselhorst, and Mr. George Sorin Ioan of ERS worked with Mr. Anthony Graves from the Town and Mr. Bruce Singer of the Sachem School District to coordinate site visits, clarify the system operation, and facilitate the introductions of other Town and Sachem School District staff for interviews and assistance with equipment access and data-logging equipment. The ERS team leveraged the expertise of Schneider Electric for identification and development of a control architecture to interface with existing PSEG-LI electric service to the facilities. The ERS team visited the facilities on multiple occasions to discuss the microgrid project's function and goals, perform facility walk-throughs, develop an understanding of the electrical services, and obtain information about the facilities from their staff.

Description of the Facilities

The proposed microgrid includes the two buildings as summarized in Table ES-2. Building-level information is summarized below, and additional information on the buildings is provided in Sections 1 and 2 of this report.

Table ES-2. Facility Information

Development Name	Winter/Summer Demand (kW)	Annual Usage	Emergency Requirements	Sq Ft	Population
Town Hall	800/1200	5 million kWh, 80,000 therms	350 kW	225,000	1,000
Sachem High School East	600/850	4.75 million kWh, 150,000 therms	500 kW	420,000	2,450

Brookhaven Town Hall

The Town Hall encompasses over 225,000 sq ft and three floors; on a daily basis, the Town Hall serves approximately 1,000 people during normal business hours, as this is a public building that houses public service sectors. The building space includes offices, an auditorium, a full kitchen, a data server room, a mechanical room, and an atrium. Its typical hours of operation are 8 a.m.–6 p.m. Monday–Friday and 8 a.m.–12 p.m. on Saturdays. The building uses central heating and cooling systems to deliver heating and cooling through ventilation units. The 10-year (2003–2013) peak demand recorded at the utility meter was 1,494 kW, but the typical annual peak load ranges from 800–1,200 kW. The electrical usage has steadily declined over a 3-year period due to the efficiency efforts of the Town.

During an emergency event, such as a hurricane, normal town functions are suspended and the Emergency Operations Center is activated to coordinate town emergency services.

Sachem High School East

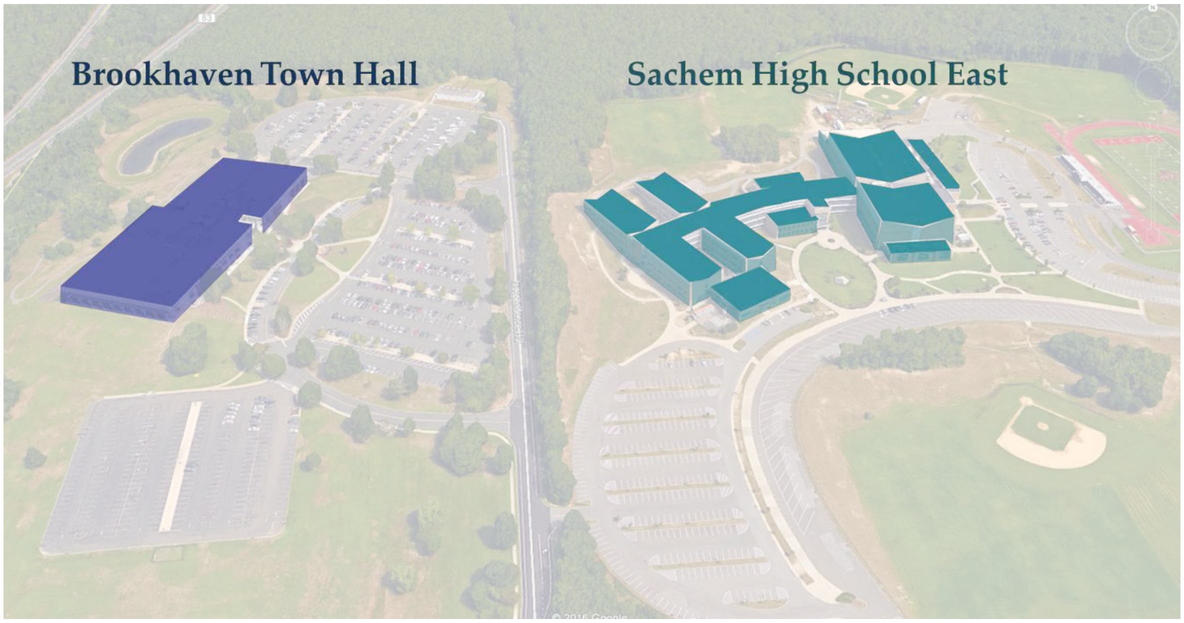
Sachem High School East has approximately 2,300 students and 150 faculty members. Its typical hours are 6 a.m.–6 p.m. Monday–Friday, 6 a.m.–4 p.m. on Saturday, and mostly closed on Sunday. Its typical monthly peak load ranges from 450–500 kW with a minimum monthly peak of 215 kW. The building uses central heating and cooling systems to deliver heating and cooling through air handling units.

During an emergency event, normal school functions are suspended and a Red Cross emergency shelter is activated.

Summary of Proposed Microgrid Capabilities

Figure ES-1 shows the facilities included within the microgrid. The two buildings would be connected by underground electrical wires at points close to what is shown on the map. The entry points are where the main electrical lines come into each facility from PSEG-LI.

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



The Independence Hill microgrid will include a new 1,148 kW combined heat and power (CHP) plant, a potential 50 kW battery backup, a potential solar array, and a potential bio-gas methane generator for the Town Hall. At Sachem High School, the microgrid will include one 383 kW CHP plant, which was already planned for installation prior to NY Prize. The microgrid configuration and operations are shown in Table ES-3. The sources listed will serve as the main microgrid generation units providing power during normal and emergency operations. There are additional generation resources already in place that will be utilized to provide normal and emergency generation depending on need and availability; these include two diesel back-up generators and two wind turbines.

Table ES-3. Current and Planned Power Generation Resources

Location	Generation Resource	Generation Capacity (kW)	Normal Operations	Emergency Operations	Emergency Operation Duration	Back-Up Generation
Town Hall	Natural gas CHP unit, new	1,148	X	X	7 days	
	Wind turbine, existing	10	X		N/A	
	Photovoltaic, in-planning	TBD		X		
	Battery storage, in-planning	50–150		X	N/A	
	Back-up diesel generator, existing	300		X	7 days	X
	Wastewater methane generator, in planning	TBD	X	X	N/A	

Location	Generation Resource	Generation Capacity (kW)	Normal Operations	Emergency Operations	Emergency Operation Duration	Back-Up Generation
Sachem High School East	Natural gas CHP unit, new	383	X	X	7 days	
	Wind turbine, existing	10	X		N/A	
	Back-up diesel generator, existing	500		X	7 days	X
Total generation capacity of microgrid		**2,451**				

N/A = Not applicable

Microgrid Operation

The Independence Hill Microgrid will run in parallel with the grid but will be largely power self-sufficient during normal operation. There is no plan to export power. The project's control systems will automatically island the microgrid during an emergency event and restore parallel operation after the event. The electrical infrastructure will be buried underground. The microgrid will primarily rely on the CHP plants at the Town Hall and Sachem High School East to deliver power and useable heat to each of the buildings, supplemented by the two existing wind turbines. It will act as a single coordinated power pool for the facilities running in parallel with the grid, drawing any deficit in power from the utility grid. During a non-emergency event when power from the grid is unavailable for a short period, the microgrid will automatically go into island mode. During an emergency event, the microgrid will automatically go into island mode at the first loss of power. The Town and School districts will suspend normal functions and activate emergency functions, greatly reducing the building electric loads. Sachem High School East runs a Red Cross emergency shelter, and the Town Hall is an emergency response center for the Town. Both of these facilities currently utilize their back-up generation units to handle the emergency power loads. With the microgrid configuration, the capacity of the new CHP units exceeds the emergency operation requirements of both buildings.

NY Prize Microgrid Criteria

The ERS team has assessed many desired features for integration into the microgrid, including two CHP plants powered by natural gas, one potential methane generation unit, two diesel back-up generators, two wind turbines, one solar array, and one battery back-up system. The microgrid will be isolated from the grid during normal operation, even though some utility power will be used, and it will be able to run islanded from the grid during an emergency event. The microgrid's control systems will be able to automatically separate from the grid during the event and restore the facilities to the grid after the event. The electrical infrastructure will be buried underground to protect the lines in case of emergencies, allowing the best level of protection to ensure the reliability of the microgrid during a storm or grid-level outage.

The configuration includes distributed generation resources at the Town Hall and Sachem High School East. The Sachem High School East resources are being installed under an energy performance contract through Johnson Controls. Some of the measures in the contract have been implemented, and the CHP system planned for the school is slated to be implemented by 2017. With significant components already in place, the CHP unit and battery back-up system at the Town Hall, together with the entire microgrid control systems, are the only newly planned components for the microgrid.

The Town has executed a contract with a third-party installer for a large solar power array at the Town Hall. The microgrid will utilize some of the available power from this array, along with a bank of battery backups for shorter-duration outages when the array is not available.

Microgrid Controls, Isolation, and Islanding

The controls, communications, islanding capabilities, and seamless operation of the microgrid will provide the Town Hall and Sachem High School East with the added resiliency and emergency operations they will need to provide Brookhaven with emergency services. ERS team member Schneider Electric has been providing equipment, controls, and communications for electrical infrastructure projects for many years and will be developing the infrastructure, operations, and communication requirements for this project.

The microgrid will go into isolation automatically if power is lost during grid-connected mode. During an event, the switch will open and the generation resources will be electrically isolated. The operation will be an open transition. The synchronous generators will be switched to voltage control mode and simultaneously closed onto the microgrid. The microgrid control system will manage the generation to ensure optimum voltage and frequency control.

Communication and interoperability with the local utility and the primary operator of the Independence Hill microgrid will be incorporated into the final project design.

Financial Feasibility

The Independence Hill microgrid has been evaluated based on electric and thermal load requirements for the two facilities and is currently within acceptable financial payback models for the Town of Brookhaven. The summary of the financial model is shown in Table ES-4.

Table ES-4. Energy Balance and Costs Summary

Parameter	Town Hall	Sachem High School East
Existing Operation – without Microgrid		
Electric energy load (MWh/year)	5,143	4,005
Peak demand (MW)	1.3	0.7
Thermal energy load (therms/year)	79,995	150,237
Electric energy cost ($/year)	$836,211	$590,413
Natural gas cost ($/year)	$68,489	$113,004
Total energy cost ($/year)	$904,700	$703,418
Proposed Operation – with Microgrid		
Electric energy supplied by the microgrid (MWh/year)	5,090.3	3,868.1
Demand supplied by the microgrid (MW)	1.148	0.383
Electric energy supplied by the utility (MWh/year)	53.5	136.5
Demand supplied by the utility (MW)	0.153	0.284
Thermal energy supplied by the microgrid (therms/year)	68,283	64,391
Natural gas used by the microgrid (therms/year)	478,553	416,255

Electric energy cost ($/year)	$21,103	$53,844
Cost of natural gas used by the microgrid ($/year)	$409,721	$313,098
Total energy cost ($/year)	$430,824	$366,942

Based on the project pricing and annual fees associated with the project, the simple payback for the project is 15 years, using a total project cost of $10,260,000, annual savings of $810,352, and annual maintenance fees of $140,000. Further financial details are included in Section 4 of the report and also in the Industrial Economics, Incorporated (IEC) analysis.

Please note: The IEc model and analysis was designed to characterize the societal impacts of the proposed microgrid on the electric grid and on the community, while the ERS analysis reflects the costs and benefits to the individual microgrid customers. For example, the IEc model used the location based marginal price (LBMP) for local NYISO zones to price electricity at $0.038 per kWh; the ERS analysis was based on actual billing data for the sites and used an electricity supply price of approximately $0.08 per kWh, plus additional demand charges, to estimate project benefits. Thus, the economic feasibility shown in the results of the IEc model does not reflect the actual value to the Town of Brookhaven and the Sachem School District.

Alternative Microgrid Configuration Options

Multiple options were reviewed for the Independence Hill microgrid. ERS developed energy models for a wide range of energy generation sizing and technologies. The project configuration shown in Table ES-3, above, is the best economic and emergency load setup for servicing the two buildings and their emergency requirements under normal and emergency operation. The internal combustion engine that has been selected as the main power generation during normal and emergency operation provides the Town of Brookhaven with the most economical system. Sizes evaluated ranged from 500 kW to 2 MW, with the optimum size for both buildings resulting in a microgrid with a size of 1.5 MW. Some of these alternative configurations, such as incorporating fuel cells as generation units, were omitted due to high costs; fuel cells would reduce the overall emissions of the project significantly, but would increase the payback by over 7 years. These technologies may be further considered as the project prepares for Stage 2 of NY Prize.

Microgrid Roadblocks, Challenges, and Potential Solutions

While the potential for microgrids to increase resiliency and provide complementary services to Brookhaven is great, the ERS team identified several roadblocks and challenges throughout the course of the feasibility study. Some of these roadblocks are likely faced by many of the NY Prize projects currently under analysis. The primary roadblocks and challenges are presented below, along with the potential solution under consideration at the end of the feasibility study. The ERS team is engaged with many stakeholders in discussing these roadblocks and expects to continue these conversations in preparation for and during Stage 2 of the NY Prize program. Table ES-5 highlights the primary roadblocks pertaining to the Independence Hill microgrid and the potential workarounds and solutions under consideration.

Table ES-5. Primary Challenges and Their Solutions

Roadblock/Challenge Faced by the Microgrid	Potential Workaround or Solution
There are unresolved right-of-way issues when connecting multiple electrical meters across a public street.	This is a known challenge affecting all NY Prize projects under consideration. This is a regulatory hurdle that should be addressed with the utilities and PSC. For Independence Hill, additional cable can be laid to circumvent the road between the Town Hall and Sachem High School since the road is a dead end; however, this adds additional costs for burying extra cable.
School building regulations require that all new electrical cabling be installed underground and not overhead.	While this requirement adds significant additional infrastructure and installation costs to the project, underground cabling also has additional resiliency benefits to the facilities.
Sachem School District has an existing energy performance contract in place for district-wide energy efficiency and distributed generation projects, including the CHP unit at Sachem High School included in the microgrid.	This is a challenge for the microgrid because it requires that an additional stakeholder be engaged in the project. This may also restrict opportunities for additional energy efficiency work, and the installation timing of the CHP unit could potentially be affected. The ERS team has made initial inquiries to engage the ESCO and this effort will be pursued further in Stage 2.
Town of Brookhaven is separately pursuing installation of a third-party owned PV array on Town Hall property for PSEG-LI load relief.	This presents an opportunity for the microgrid to incorporate battery storage into the design, potentially harnessing a portion of the PV generation capacity during outages and emergency scenarios.

Conclusions and Next Steps

The ERS team has evaluated the microgrid project, including a full technical analysis and review of the infrastructure requirements and utility and stakeholder involvement. The microgrid provides multiple benefits to both the town hall and high school, including electricity and thermal production at lower costs per kWh and MMBtu than current cost, and resiliency to support the town's emergency operations center and shelter. Further, the infrastructure that will connect the facilities will provide a central backbone for future expansion. This expansion could incorporate additional renewable resources, and surrounding residential neighborhoods could also be incorporated to strengthen resiliency and emergency services in the future.

Next Steps

There are several activities that the project team will need to complete as the proposal for Stage 2 is developed, many of which have already begun:

- ❑ The project team will continue to engage the town and school district stakeholders. These conversations will focus on processing the results of this feasibility study and considering any additional configuration options.
- ❑ The project team will continue to hold conversations with PSEG-LI to discuss the cable routing, the proposed third-party PV array, and other interconnect issues.

- As the microgrid moves into Stage 2, which contains a cost-share component, a partnership agreement between the Town and the school district will likely be required to outline the contributions and benefits that each party will receive throughout the microgrid design phase.

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

INTRODUCTION

This report presents the final results of the Independence Hill Microgrid NY Prize feasibility study completed by the ERS team as outlined below:

- **Section 1: Summary of Microgrid Capabilities** – This section presents an overview of the microgrid facilities, outlining minimum and preferred capabilities considered during the feasibility study.
- **Section 2: Technical Design Costs and Considerations** – This section presents the preliminary assessment of the technical design and system configuration of the microgrid.
- **Section 3: Commercial and Financial Feasibility** – This section presents the assessment of commercial and financial feasibility of the microgrid.
- **Section 4: Technical Design Costs and Benefits** – This section presents the costs and benefits developed for the feasibility study.

1 Summary of Microgrid Capabilities

This section presents the minimum required and preferred capabilities for the Independence Hill Microgrid. The microgrid project configuration includes distributed generation resources at the Town Hall and Sachem High School East. These resources will provide on-site power in both grid-connected and islanded mode.

1.1 Description of the Facilities

The proposed microgrid includes the two buildings as summarized in Table 1-1.

Table 1-1. Facility Information

Development Name	Winter/Summer Demand (kW)	Annual Usage	Emergency Requirements	Sq Ft	Population
Town Hall	800/1200	5 million kWh, 80,000 therms	350 kW	225,000	1,000
Sachem High School East	600/850	4.75 million kWh, 150,000 therms	500 kW	420,000	2,450

1.1.1 Brookhaven Town Hall

The Town Hall encompasses over 225,000 sq ft and three floors; on a daily basis, the Town Hall serves approximately 1,000 people during normal business hours, as this is a public building that houses public service sectors. The building space includes offices, an auditorium, a full kitchen, a data server room, a mechanical room, and an atrium. Its typical hours of operation are 8 a.m.–6 p.m. Monday–Friday and 8 a.m.–12 p.m. on Saturdays. The building uses central heating and cooling systems to deliver heating and cooling through ventilation units. Three Weil-McLain main natural gas-fired steam boilers provide steam at 15 psi and 5,238 KBtu/hr. Air is delivered through eight air handling units (AHUs 1–8), most of which have 30 hp supply fans and 10 hp return fans; AHU-3 is the only unit with a 15 hp supply fan. Cooling is supplied to the AHUs by two 400-ton centrifugal Carrier chillers using three 50 hp chilled water pumps. The cooling system has a free cooling exchanger to take advantage of free cooling during the colder months.

The building is served by 480 V three-phase secondary services that enter the building and feed three 2,500 A service entrance switches. The three services are common-metered at a master meter for the building. The building formerly used all electric heat and was converted in the 1990s to natural gas. The service entrance switches are original to the building and are oversized for the current load. The 10-year (2003–2013) peak demand recorded at the utility meter was 1,494 kW (see the electric consumption utility information included as an appendix to the application); the typical annual peak load ranges from 800–1,200 kW. The electrical usage has steadily declined over a 3-year period due to the efficiency efforts of the Town.

During an emergency event, such as a hurricane, normal town functions are suspended and the Emergency Operations Center is activated to coordinate town emergency services.

1.1.2 Sachem High School East

Sachem High School East has approximately 2,300 students and 150 faculty members. Its typical hours are 6 a.m.–6 p.m. Monday–Friday, 6 a.m.–4 p.m. on Saturday; it is mostly closed on Sunday. Its typical monthly peak load ranges from 450–500 kW with a minimum monthly peak of 215 kW. The building uses central heating and cooling systems to deliver heating and cooling through ventilation units. Twelve modular boilers provide hot water to the AHUs and perimeter unit ventilators. Cooling is supplied from one central chiller. The school operates year-round, serving a variety of functions through the summer and maintaining a constant building load through the year.

During an emergency event, normal school functions are suspended and a Red Cross emergency shelter is activated.

1.1.3 Facility Layout

Photo 1-1 shows the facilities included within the microgrid. The Town Hall and high school will be connected by underground electrical wires entering each facility at the same point of entry as the PSEG-LI main electrical lines.

Photo 1-1. Overview Map of the Two Facilities Included in the Microgrid

1.2 Power Generation Mix

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

Table 1-2. Current and Planned Power Generation Resources

Location	Generation Resource	Generation Capacity (kW)	Normal Operations	Emergency Operations	Emergency Operation Duration	Back-Up Generation
Town Hall	Natural gas CHP unit, new	1,148	X	X	7 days	
	Wind turbine, existing	10	X		N/A	
	Photovoltaic, in-planning	TBD		X		
	Battery storage, in-planning	50–150		X	N/A	
	Back-up diesel generator, existing	300		X	7 days	X
	Wastewater methane generator, in planning	TBD	X	X	N/A	
Sachem High School East	Natural gas CHP unit, new	383	X	X	7 days	
	Wind turbine, existing	10	X		N/A	
	Back-up diesel generator, existing	500		X	7 days	X
Total generation capacity of microgrid		**2,451**				

TBD = To be determined
N/A = Not applicable

The ERS team has analyzed several power generation scenarios for integration into the microgrid, including two CHP plants powered by natural gas, one potential methane generation unit, two existing diesel back-up generators, two existing wind turbines, one potential solar array, and one potential battery back-up system.

The Sachem High School resources are being installed under an energy performance contract through Johnson Controls, which is a source of funding for the microgrid. The high school CHP system is slated to be implemented by 2017. The Town has executed a contract with a third-party installer for a large solar power array at the Town Hall. The microgrid will likely utilize some of the available power from this array, along with a bank of battery backups for shorter-duration outages when the array is not available. Discussions are underway with PSEG-LI to see if this array can feed the microgrid during emergency events.

1.3 Microgrid Controls, Isolation, and Islanding

The controls, communications, islanding capabilities, and seamless operation of the microgrid will provide the Town Hall and Sachem High School East with the added resiliency and emergency operations they will need to provide the Brookhaven with emergency services.

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

During an event, the switch will open and the generation resources will be electrically isolated. The operation will be an open transition. The synchronous generators will be switched to voltage control mode and simultaneously closed onto the microgrid. The microgrid control system will manage the generation to ensure optimum voltage and frequency control. The loads will be evaluated for real and reactive requirements as part of the synchronous generators' sizing plus a generous margin. These measures will help ensure that the requirements of ANSI C84.1 are met. The benefits and costs for the N+1 generator fuel storage will be evaluated to ensure that the microgrid has a level of redundancy and resiliency to make it successful for the Town Hall and Sachem High School East.

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

1.4 Additional Capabilities

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

- **Leveraging existing and planned development –**The microgrid project will leverage existing and planned private development activities, including the school district energy performance contract. This combination of technology and public/private development makes it a good project in which to demonstrate a different strategy for enhancing system resiliency. The project will look to incorporate CHP generation units alongside intermittent generation resources, as well as specialized components such as a wastewater methane generator at the on-site wastewater treatment facility.
- **Extensive demand-side management to minimize generation requirements –** Behind-the-meter efficiency will play a large role in the reduction of peak demand needs and annual energy usage as it lowers GHG emissions. The Town Hall is planning multiple energy efficiency and controls upgrades over the next 2–3 years based on a recent energy study and with a current allocation over $300,000 to spend on system upgrades. Likewise, the Sachem School District is undergoing a district-wide performance contract that will substantially lower the energy usage of the school facilities, including those of Sachem High School East. The impacts of the planned energy measures and any newly developed measures ascertained through this study will be used in the microgrid's final power requirement assessment. With the support of the Brookhaven National Laboratory, the Town will be looking to incorporate new software technology into the project to assess and manage the complexity of the power generation and potential storage for the microgrid.

- **Greenhouse gas reductions and community benefits** – One of the Town's main goals is to reduce GHG emissions by incorporating green power, or low-emission power, generation. The Town also wants to include tangible benefits from a town-wide perspective, including grid resiliency, job creation, benefits from the Town and the Sachem School District partnership, and the maximizing of taxpayer money for the best interests of the Town.

2 TECHNICAL DESIGN COSTS AND CONFIGURATION

ERS, along with The Town of Brookhaven, The Sachem School District, and ERS's partners, have conducted extensive analysis of multiple scenarios for the Independence Hall microgrid. The current microgrid design configuration that is discussed below is the final iteration of these scenarios that were studied, discussed, and analyzed.

2.1 Proposed Microgrid Infrastructure and Operations

The microgrid will serve Brookhaven Town Hall and Sachem High School East and will be operated continuously to provide electric energy and hot water. Section 1.1 provides a complete description of the facilities, summarized in Table 2-1.

Table 2-1. Facilities Served by the Microgrid

Facility	Facility Type	Area (Sq ft)
Brookhaven Town Hall	Office	225,000
Sachem High School East	School	420,000

Tecumseh Elementary School, with an occupied area of 75,000 sq ft, was originally included in the microgrid design but in the month of February the town informed ERS that the school will be decommissioned and closed, due to diminishing student population in the town. As a result of this decision, ERS removed the elementary school and its associated loads and generation capacities from the microgrid feasibility study.

2.1.1 Microgrid Equipment and Layout

The Independence Hill microgrid will include a new 1,148 kW combined heat and power (CHP) plant, a potential 50 kW battery backup, a potential solar array, and a potential bio-gas methane generator for the Town Hall. At Sachem High School, the microgrid will include one 383 kW CHP plant, which was already planned for installation prior to NY Prize. The microgrid configuration and operations are shown in Table 2-2. The sources listed will serve as the main microgrid generation units providing power during normal and emergency operations. There are additional generation resources already in place that will be utilized to provide normal and emergency generation depending on need and availability; these include two diesel back-up generators and two wind turbines. The microgrid will run in parallel to the grid during normal operation with a single feed and will be able to run islanded from the grid during emergency events, as described in the following sections.

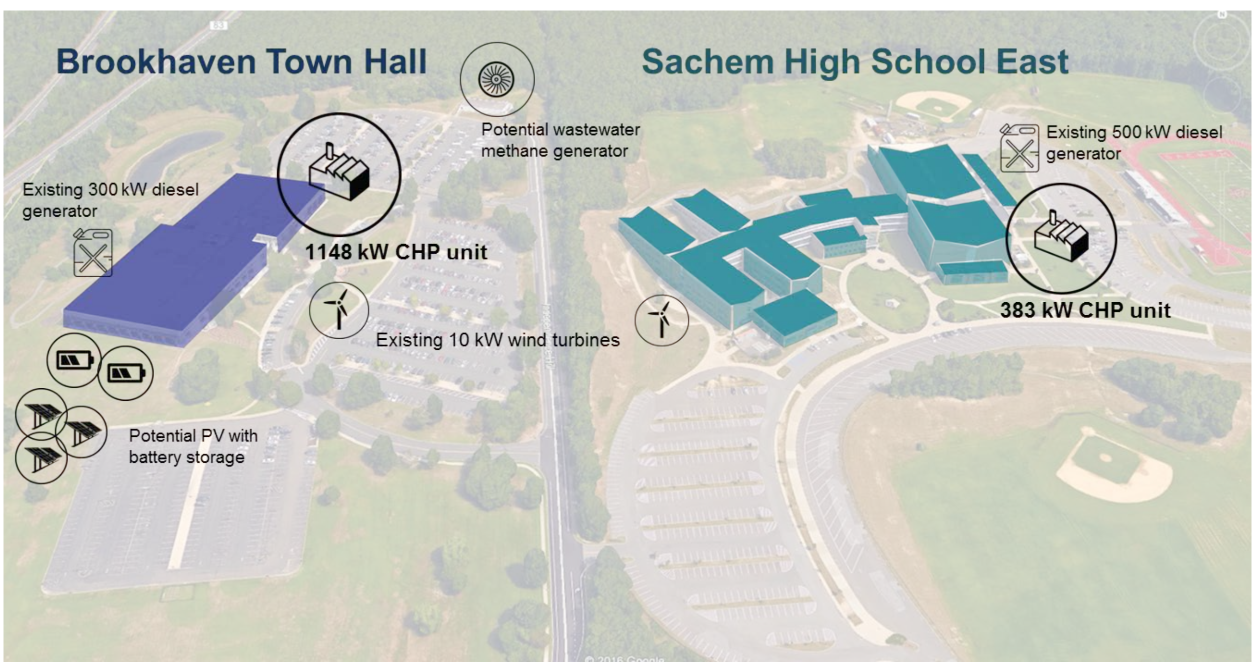
Table 2-2. Current and Planned Power Generation Resources

Location	Generation Resource	Generation Capacity (kW)	Normal Operations	Emergency Operations	Emergency Operation Duration	Back-Up Generation
Town Hall	Natural gas CHP unit, new	1,148	X	X	7 days	
	Wind turbine, existing	10	X		N/A	
	Photovoltaic, in planning	TBD		X		
	Battery storage, in planning	50–150		X	N/A	
	Back-up diesel generator, existing	300		X	7 days	X
	Wastewater methane generator, in planning	TBD	X	X	N/A	
Sachem High School East	Natural gas CHP unit, new	383	X	X	7 days	
	Wind turbine, existing	10	X		N/A	
	Back-up diesel generator, existing	500		X	7 days	X
Total generation capacity of microgrid		**2,451**				

TBD = To be determined

A one-line diagram of the proposed microgrid was created by the ERS team and is included for reference in Appendix A; this shows the microgrid connection between the Town Hall and Sachem High School East. The overview layout of the microgrid, with its likely connection points, is also shown in Photo 2-1. The individual facility infrastructure connections are presented in Section 2.4.

Photo 2-1. Overview of the Facilities Included in the Microgrid



The Town has executed a contract with a third-party installer for a large solar power array at the town hall. The microgrid will likely utilize some of the available power from this array, along with a bank of battery backups for shorter-duration outages when the array is not available. We are in discussions with PSEG-LI to see if this array can be used by PSEG-LI during emergencies if it is available.

2.1.2 Microgrid Operation

The microgrid will run in parallel with the grid, but will be largely power self-sufficient during normal operation. There is no plan to export power. The project's control systems will automatically island the microgrid during an emergency event and restore parallel operation after the event. The electrical infrastructure will be buried underground to provide the best level of protection against weather and other disruptions (i.e., tree falls and automobile strikes).

Normal Operation

The microgrid will primarily rely on the CHP plants at the Town Hall and Sachem High School East to deliver power and useable heat to each of the buildings, supplemented by the two existing wind turbines. Additional power from PV and methane CHP will be incorporated into the microgrid when and if they come online. The microgrid will act as a single coordinated power pool for the facilities running in parallel with the grid, drawing any deficit in power from the utility grid. There is no plan to export power. The control system will monitor the generation sources included within the microgrid to ensure that they are functioning and ready for an emergency event.

Grid Power Outage

During a non-emergency event when power from the grid is unavailable for a short period, the microgrid will automatically go into island mode. There is sufficient capacity between both of the new generators and the existing back-up generators to operate both buildings. This setup will take advantage of the available renewable resources first, using less fuel oil reserves and providing a cleaner option during these periods.

Emergency Operation

During an emergency event when power from the grid is unavailable for an extended period, the microgrid will automatically go into island mode at the first loss of power. The Town and School districts will suspend normal functions and activate emergency functions, greatly reducing the building electric loads. During an emergency operation, the microgrid generation provides N+1 redundancy. An N+1 redundancy means that each generation unit should have one fully independent, equal backup in case the main unit fails.

Sachem High School East runs a Red Cross emergency shelter, and the Town Hall is an emergency response center for the Town. Both of these facilities currently utilize their back-up generation units to handle the emergency power loads. With the microgrid configuration, the capacity of the new CHP units exceeds the emergency operation requirements of both buildings; therefore, the back-up diesel units provide N+1 redundancy to ensure operation during an event. While Town Hall and Sachem High School based emergency operations can run indefinitely using electricity from the CHP units, full N+1 redundancy will require a 7-day supply of fuel oil; currently, neither site stores enough fuel oil for 7 days of operation. This will be reviewed and storage sizes will be developed to provide N+1 redundancy for a 7-day period. Since wind and solar power are not necessarily available for all times and types of emergencies, these will not be counted on to deliver power during emergencies but will be included in the control software and hardware configurations to save fuel and prolong operational durations. The battery backup will only be used to handle a smaller set of emergency services for a short amount of time.

2.2 Load Characterization

The microgrid will serve separate facilities during both normal and emergency operating periods. Table 2-3 shows the two facilities served by the microgrid.

Table 2-3. Facilities Summary

Facility	Brookhaven Town Hall	Sachem High School East
Sq ft	225,000	420,000
Electric utility rate	Rate 285	Rate 285
Natural gas utility rate	Rate 170	Rate 170
Percentage of annual usage served by the microgrid	98%	98%
Economic sector	Large commercial	School
Annual electricity use (MWh)	5,143	4,005
Peak electric demand (MW)	1.3	0.7
Emergency operation demand (MW)	≤0.3	≤0.5
Percentage of emergency operations served by microgrid	100%	100%
Number of hours per day the facility requires electricity from the microgrid during major power outage	24	24

Table 2-4 presents the energy usage summaries for each of the buildings included in the microgrid.

Table 2-4. Building-by-Building Summary

Building	Sq Ft	Normal Maximum (kW)	Emergency Maximum (kW)	Thermal Load (MMBtu/hr)	Annual Usage Served by Microgrid
Brookhaven Town Hall	225,000	1,301	1,301	8,000	98%
Sachem High School East	420,000	667	667	15,000	98%

Energy efficiency is an important part of the overall microgrid project. The Town and the Sachem School District have a great track record on this front and each of the facilities has planned or ongoing energy efficiency projects, which will reduce their overall need for electrical energy. The summaries of these projects are shown in Table 2-5.

Table 2-5. Planned Energy Efficiency Improvements

Building	Critical Load (kW)	Energy Efficiency Reductions	EE Activities	Other Building Modifications
Brookhaven Town Hall	1,301	11% – percentage of kW 11% – percentage of kWh	Lighting retrofit, HVAC upgrades	N/A
Sachem High School East	700	3% – percentage of kW 11% – percentage of kWh	Lighting retrofit	N/A

2.2.1 Building Load Characterization

ERS calculated the electric energy and natural gas consumption for each facility using monthly utility bills provided by the town.

To determine the relationship between electric energy and natural gas monthly consumption with weather, the monthly billed electric energy and natural gas consumptions were plotted against the actual cooling degree days (CDD) and heating degree days (HDD) recorded at the nearby Islip (Long Island), NY, weather station.

ERS used the results of this analysis to calibrate the modeled consumption. To model the hourly electric energy and natural gas consumption, ERS made the following assumptions:

- The weekly electric energy and natural gas consumption are only dependent on outdoor conditions (CDD and HDD).
- The hourly electric energy and natural gas consumption are schedule dependent.

ERS compared the modeled annual consumption (electric energy and natural gas) with the weather-normalized consumption to ensure that the modeled consumption corroborates the weather-normalized utility bills.

2.2.2 Electric Energy – Monthly Weather-Normalized Billed Consumption

ERS regressed the billed monthly consumption against the CDD and HDD recorded at the nearby Islip weather station. Then, to eliminate any specific weather biases, we normalized the billed electric usage with the TMY3 weather data for the Islip weather station.

Table 2-6 shows the billing periods, the billed annual consumption, and the weather-normalized annual consumption that ERS calculated for each facility included in the microgrid.

Table 2-6. Microgrid Weather-Normalized Consumption Summary

Facility	Billing Period	Billed Annual Consumption (kWh/year)	Weather-Normalized Annual Consumption (kWh/year)
Brookhaven Town Hall	09/1/2012 – 5/31/2015	5,112,623	5,155,431
Sachem High School East	11/6/2013 – 8/12/2015	4,050,650	4,013,371

2.2.3 Electric Energy – Weekly Weather-Normalized Usage

An intermediate step in the load calculation was to model the weekly consumption. ERS modeled the weekly consumption using the equations, coefficients, and variables used to calculate the weather-normalized monthly consumption. Table 2-7 shows the summary of the loads calculated using the modeled weekly consumption.

Table 2-7. Microgrid Loads Summary

Facility	Weather-Normalized Annual Consumption (kWh/year)	Modeled Annual Consumption (kWh/year)
Brookhaven Town Hall	5,155,431	5,143,872
Sachem High School East	4,013,371	4,004,648

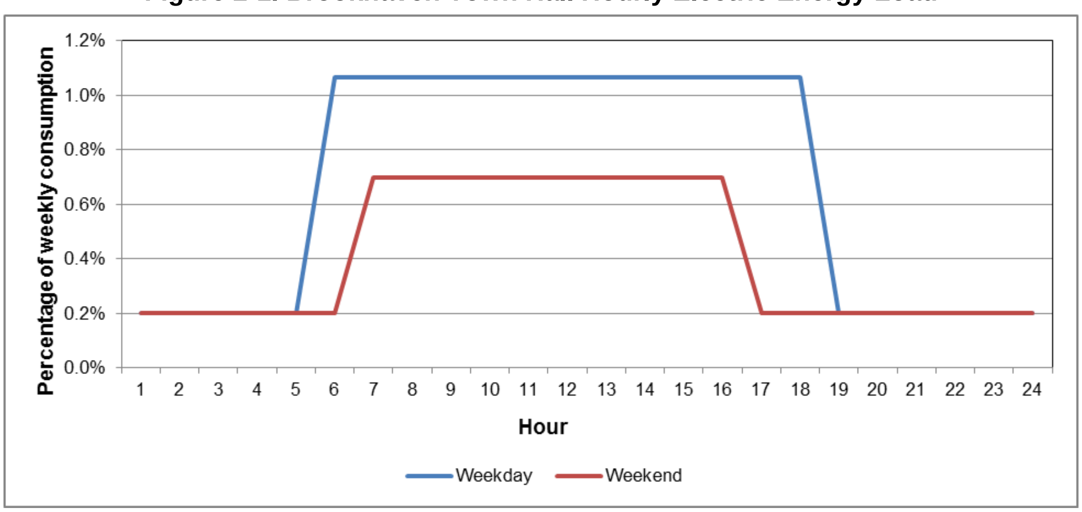
Modeled Hourly Consumption

To determine the hourly electric load for each facility, ERS made the following assumptions about the load at Brookhaven Town Hall:

- Defined two day types: weekday (Monday to Friday) and weekend (Saturday and Sunday)
- Defined four schedules: weekday occupied (6:00 to 18:00), weekday unoccupied (19:00 to 5:00), weekend occupied (7:00 to 16:00), and weekend unoccupied (17:00 to 6:00)

ERS modeled the hourly loading using the weekly usage and based on the load profile shown in Figure 2-1.

Figure 2-1. Brookhaven Town Hall Hourly Electric Energy Load



The Sachem High School East load assumptions are as follows:

- Defined two seasons: school in session (September 1 to June 30) and school not in session (July 1 to August 31)
- Defined two day types: weekday (Monday to Friday) and weekend (Saturday and Sunday)
- Defined eight schedules as shown in Table 2-8

Table 2-8. Sachem High School East Load Schedules

Schedules	School in Session	School Not in Session
Weekday occupied	06:00 to 19:00	09:00 to 16:00
Weekday unoccupied	20:00 to 05:00	17:00 to 08:00
Weekend occupied	09:00 to 16:00	10:00 to 15:00
Weekend unoccupied	17:00 to 08:00	16:00 to 09:00

ERS modeled the hourly loading using the weekly usage and based on the load profiles shown in Figures 2-2 and 2-3.

Figure 2-2. Sachem High School East Hourly Electric Energy Load – School in Session

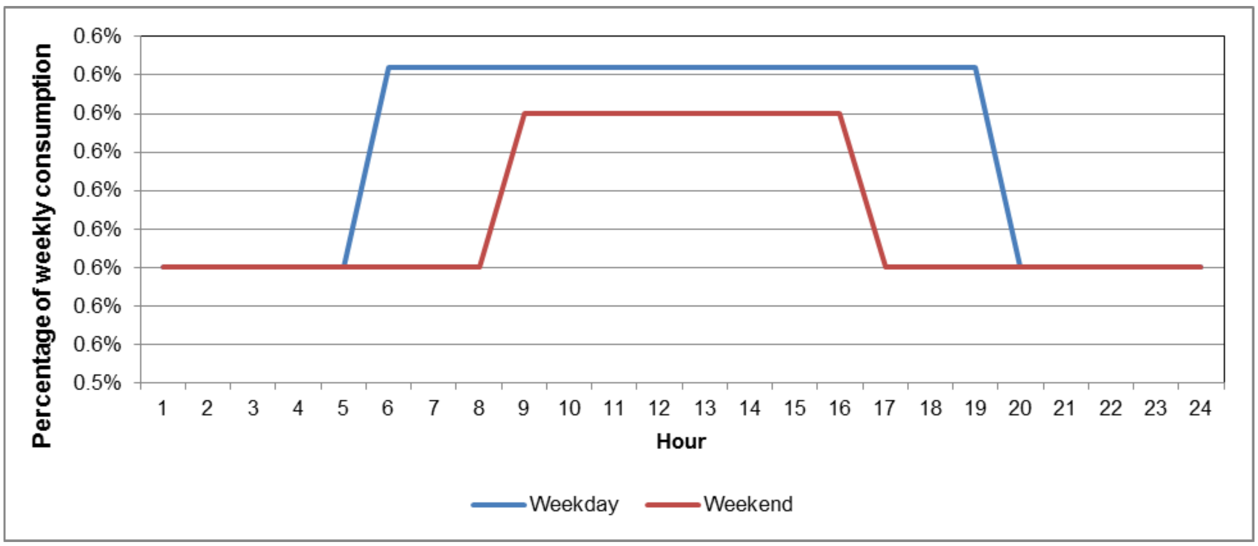
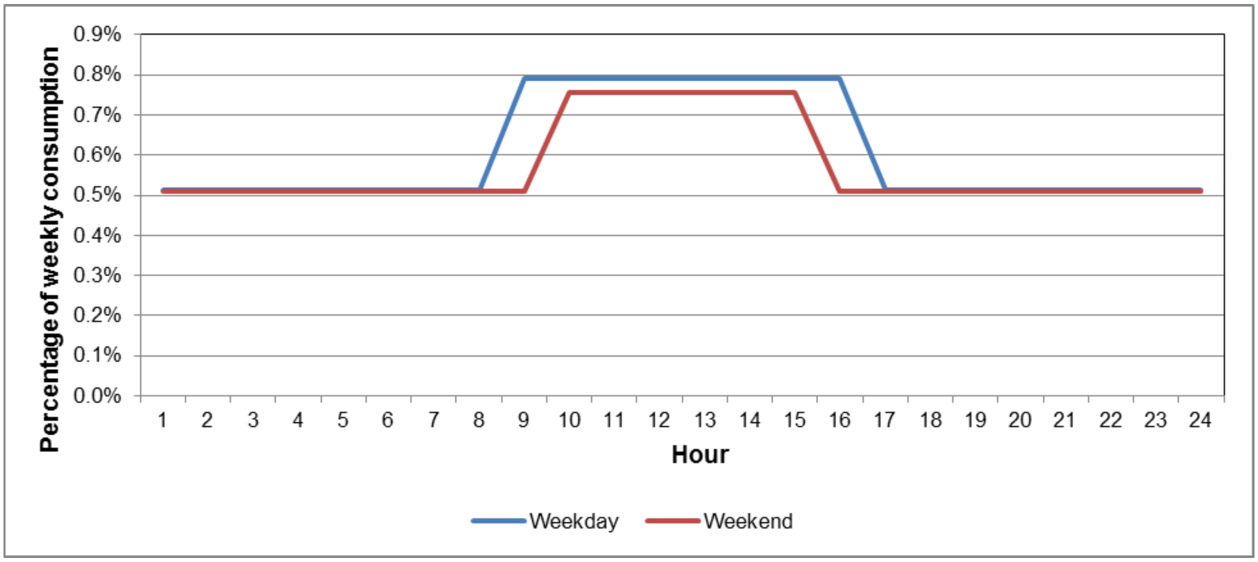


Figure 2-3. Sachem High School East Hourly Electric Energy Load – School Not in Session



The average electric demand load was calculated by averaging the modeled hourly consumption, while the maximum demand load was calculated by taking the maximum modeled hourly consumption.

2.2.4 Natural Gas – Monthly Weather-Normalized Billed Consumption

ERS regressed the billed monthly consumption against the HDD recorded at the nearby Islip NY weather station. Then, to eliminate any specific weather biases, ERS normalized the billed electric usage with the TMY3 weather data for the nearby Islip (Long Island) weather station.

Table 2-9 shows the billing periods, the billed annual consumption, and the weather-normalized annual consumption that ERS calculated for each facility included in the microgrid.

Table 2-9. Microgrid Weather-Normalized Consumption Summary

Facility	Billing Period	Billed Annual Consumption (Therms/year)	Weather-Normalized Annual Consumption (Therms/year)
Brookhaven Town Hall	01/1/2010 – 12/31/2012	76,332	76,964
Sachem High School East	06/36/2014 – 09/1/2015	141,350	151,241

2.2.5 Natural Gas – Weekly Weather-Normalized Usage

An intermediate step in the load calculation was to model the weekly consumption. ERS modeled the weekly consumption using the equations, coefficients, and variables used to calculate the weather-normalized monthly consumption. Table 2-10 shows the summary of the loads calculated using the modeled weekly consumption.

Table 2-10. Microgrid Loads Summary

Facility	Weather-Normalized Annual Consumption (Therms/year)	Modeled Annual Consumption (Therms/year)
Brookhaven Town Hall	76,964	79,995
Sachem High School East	151,241	150,237

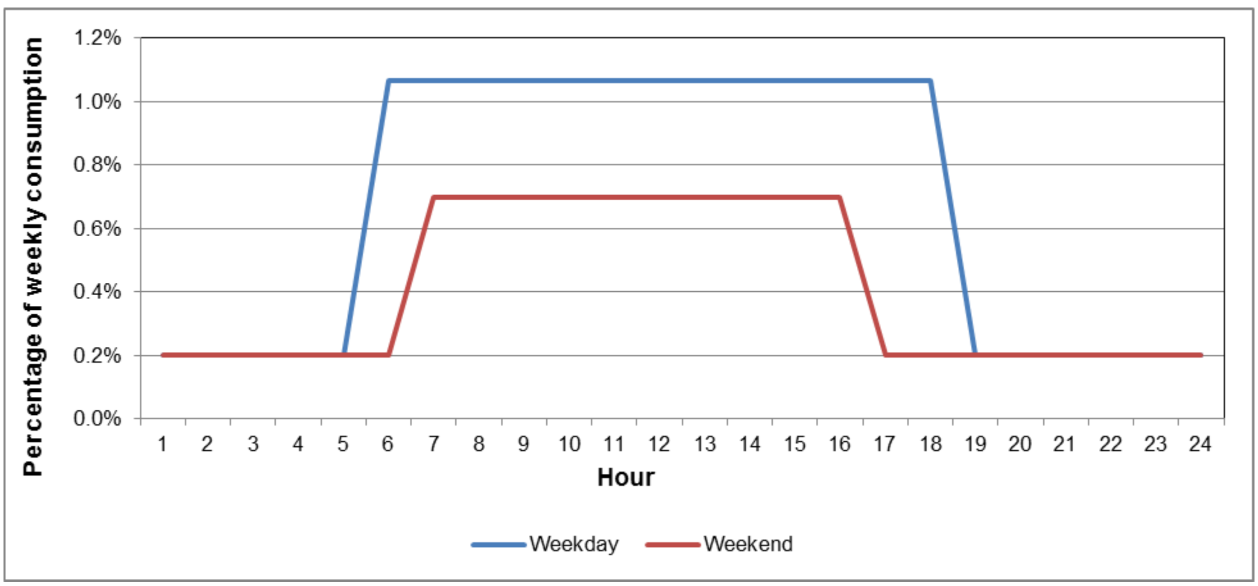
Modeled Hourly Consumption

To determine the hourly natural gas load for each facility, ERS made the following assumptions for Brookhaven Town Hall:

- Defined two day types: weekday (Monday to Friday) and weekend (Saturday and Sunday)
- Defined four schedules: weekday occupied (06:00 to 18:00), weekday unoccupied (19:00 to 05:00), weekend occupied (07:00 to 16:00), and weekend unoccupied (17:00 to 06:00)

ERS modeled the hourly loading using the weekly usage and based on the load profile shown in Figure 2-4.

Figure 2-4. Brookhaven Town Hall Hourly Natural Gas Load



The Sachem High School East load assumptions are as follows:

- Defined two seasons: school in session (September 1 to June 30) and school not in session (July 1 to August 31)
- Defined two day types: weekday (Monday to Friday) and weekend (Saturday and Sunday)
- Defined eight schedules as shown in Table 2-11

Table 2-11. Sachem High School East Load Schedules

Schedules	School in Session	School Not in Session
Weekday occupied	06:00 to 19:00	09:00 to 16:00
Weekday unoccupied	20:00 to 05:00	17:00 to 08:00
Weekend occupied	09:00 to 16:00	10:00 to 15:00
Weekend unoccupied	17:00 to 08:00	16:00 to 09:00

ERS modeled the hourly loading using the weekly usage and based on the load profiles shown in Figures 2-5 and 2-6.

Figure 2-5. Sachem High School East Hourly Natural Gas Load – School in Session

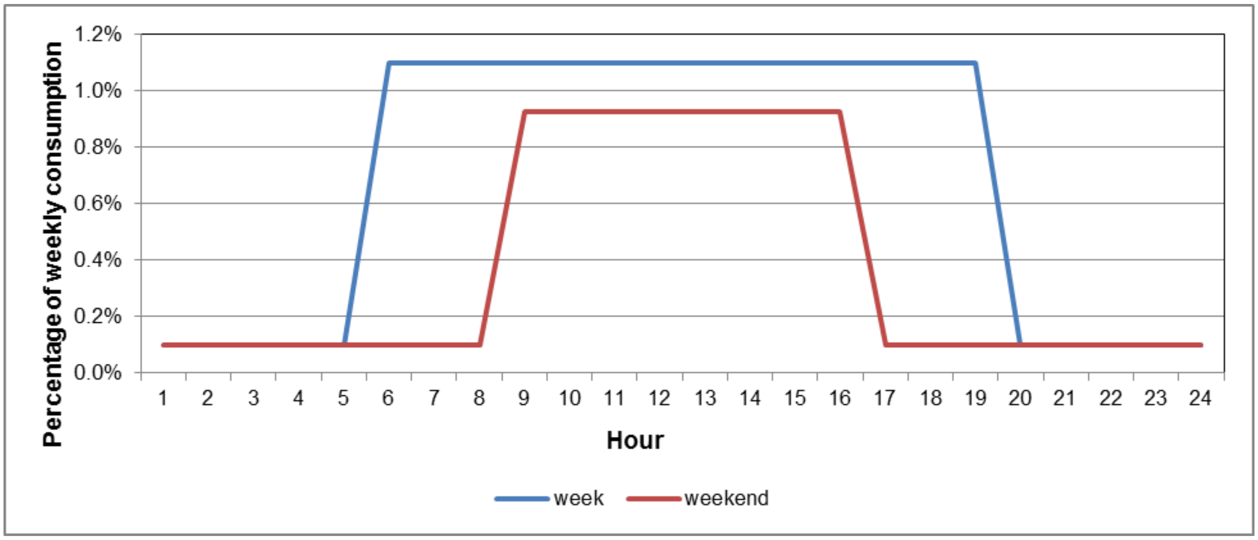
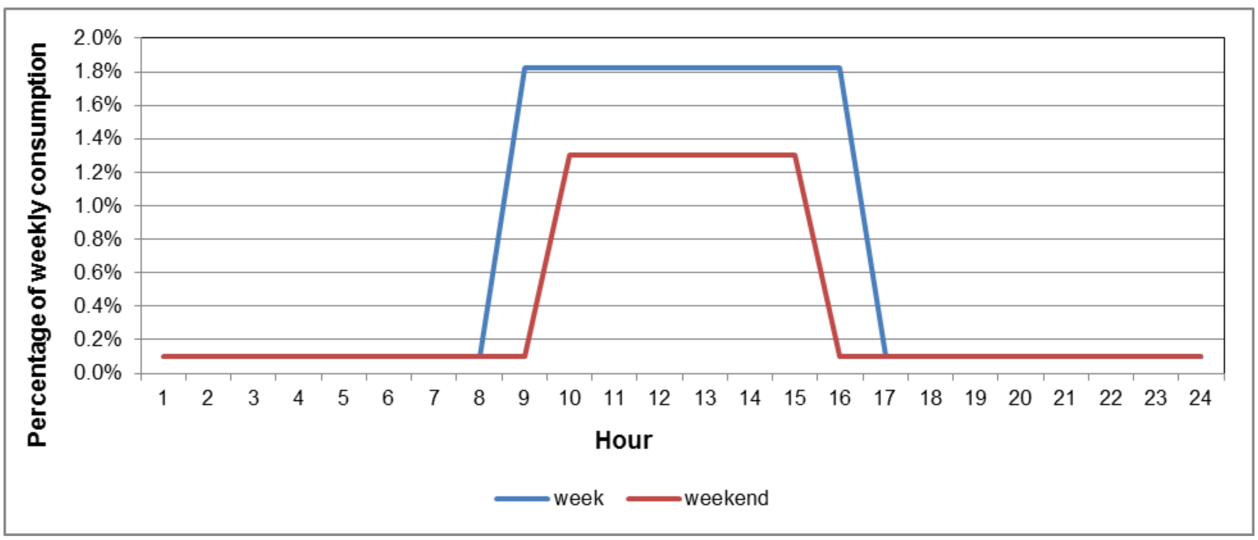


Figure 2-6. Sachem High School East Hourly Natural Gas Load – School Not in Session



2.3 Distributed Energy Resources Characterization

The design for the Independence Hill microgrid is based upon a 383 kW CHP installed at the high school and one 1,148 kW CHP installed at the town hall. These generators will be connected to a new low-voltage microgrid distribution tie switchboard. This switchboard will have feeder connections to three service tie switchboards – one for each incoming PSEG-LI electrical utility service. These switchboards will include paralleling controls and protection to enable parallel operation of the new microgrid generation units with the existing utility services.

The microgrid distribution tie switchboard will connect to a 480:13200 V step-up transformer and fused disconnect switch. New underground medium voltage cabling will be installed to connect the Brookhaven Town Hall complex to the neighboring Sachem High School complex. A new step-down transformer, microgrid distribution tie switchboard, and two service tie switchboards will be installed at the high school.

During a PSEG utility outage the utility service main breakers of the service tie switchboards will be opened at both the town hall and high school complexes. The microgrid tie breakers interconnecting the two complexes will then be closed, creating an island microgrid encompassing both locations. Electrical power will be provided for the island using the new microgrid generation.

The microgrid will be equipped with two electrically following CHP units. One 383 kW CHP will be installed at the high school and one 1,148 kW CHP will be installed at the town hall. The two existing 10 kW wind turbines (WTs) will also be included in the microgrid. Table 2-12 shows the summary of these installations.

Table 2-12. Proposed Microgrid Generation Sources

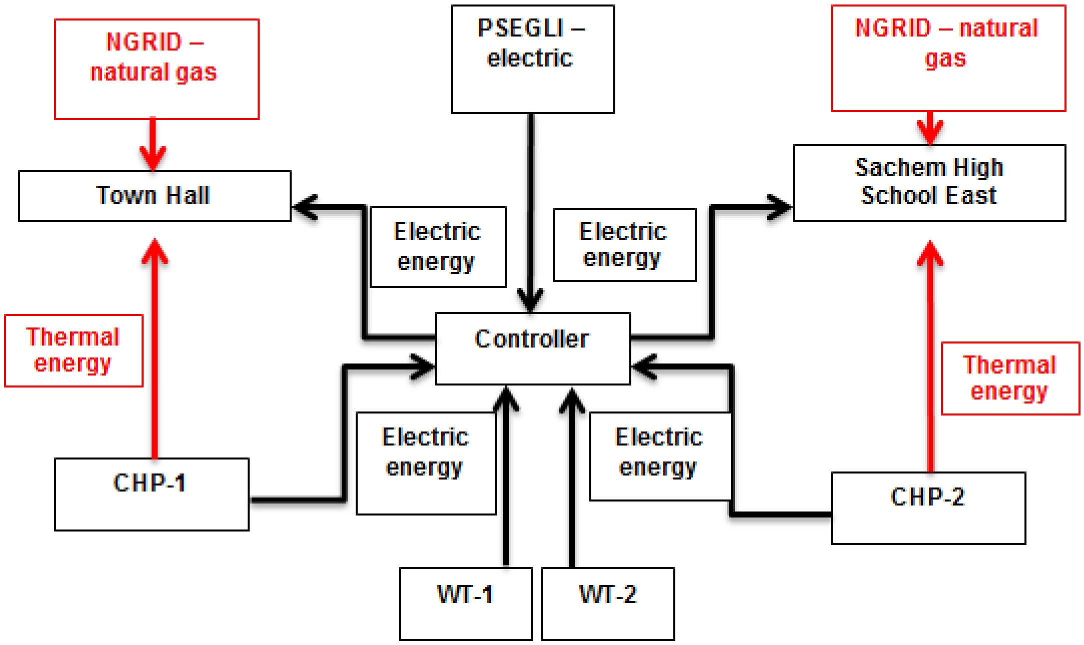
Unit	Location	Capacity (kW)	Prime Mover	Thermal Capacity (MMBtu/h)
CHP-1	Town hall	1,148	Natural gas-fired reciprocating engine	4.319
CHP-2	High school	383	Natural gas-fired reciprocating engine	1.859
WT-1	Town hall	10	Wind turbine	N/A
WT-2	High school	10	Wind turbine	N/A

The two CHP units that will be part of the microgrid will be located close to the end uses that they will serve. The 1,148 kW CHP will be located on the northwest side of the town hall building, by the loading dock, while the 383 kW CHP will be located on the southeast side of the high school building by the back-up diesel generator.

Using the modeled electric end thermal loads modeled for the town hall and the high school buildings and the performance data of the two CHP units that will be part of the microgrid, ERS determined that the CHP units will supply most of the electric energy as well as thermal energy loads for the town hall and the high school buildings.

By design, the two CHP units will supply the generated electric and thermal energy in conjunction with the existing wind turbines that are already operating, as shown in Figure 2-7.

Figure 2-7. Proposed Microgrid Energy Flows



The DER units supply electric energy into a single feed that connects the town hall and the high school buildings. Each CHP unit supplies thermal energy only to the closest building. Namely, CHP-1 supplies thermal energy to the town hall and CHP-2 supplies thermal energy to the high school.

Because the electric energy production of the wind turbines would be difficult to predict and because the capacity of the wind turbines is small when compared to the capacity of the CHP units, ERS chose not to model the energy production of the two wind turbines.

Table 2-13 shows the modeled loads and the CHP units' modeled production. Note that the electric energy produced by CHP-1 at the town hall will be consumed by both the town hall and the high school, as shown in Figure 2-7, above.

Table 2-13. Proposed Microgrid Annual Energy Balance

Facility	Electric Load (kWh)	Peak Demand (kW)	Thermal Load (Therms)	Unit	Electric Generation (kWh)	Peak Demand (kW)	Thermal Generation (Therms)
Town hall	5,143,872	1,301	79,995	CHP-1	5,608,776	1,148	68,283
High school	4,004,648	667	150,237	CHP-2	3,349,575	383	64,391
Total	**9,148,520**	**1,968**	**230,232**		**8,958,351**	**1,531**	**132,674**

The microgrid will require an additional 200,000 kWh/year from the power utility, assuming current usage patterns.

2.4 Electrical and Thermal Infrastructure Characterization

This section discusses the electrical and thermal characteristics of the proposed infrastructure for the project. Aerial photographs of the site are shown in Photo 2-2.

Photo 2-2. Brookhaven Microgrid Site Overview

2.4.1 Brookhaven Town Hall

The Brookhaven Town Hall is fed by the utility via underground electrical cables that travel up Independence Hill and down the driveway. The site was originally fed from three utility substations but is only powered through two substations in the current configuration. The utility lines are routed underground to a vault just outside the electric room to three transformers that step down the voltage from 13.8 kV to 480y/277 VAC. Photo 2-3 identifies these key features.

Photo 2-3. Brookhaven Town Hall

There are three service switchboards in the main electric room, as shown in Table 2-14. It should be noted that available space for the addition of an automatic transfer switch (ATS) is limited.

Table 2-14. Brookhaven Town Hall Service Switchboards

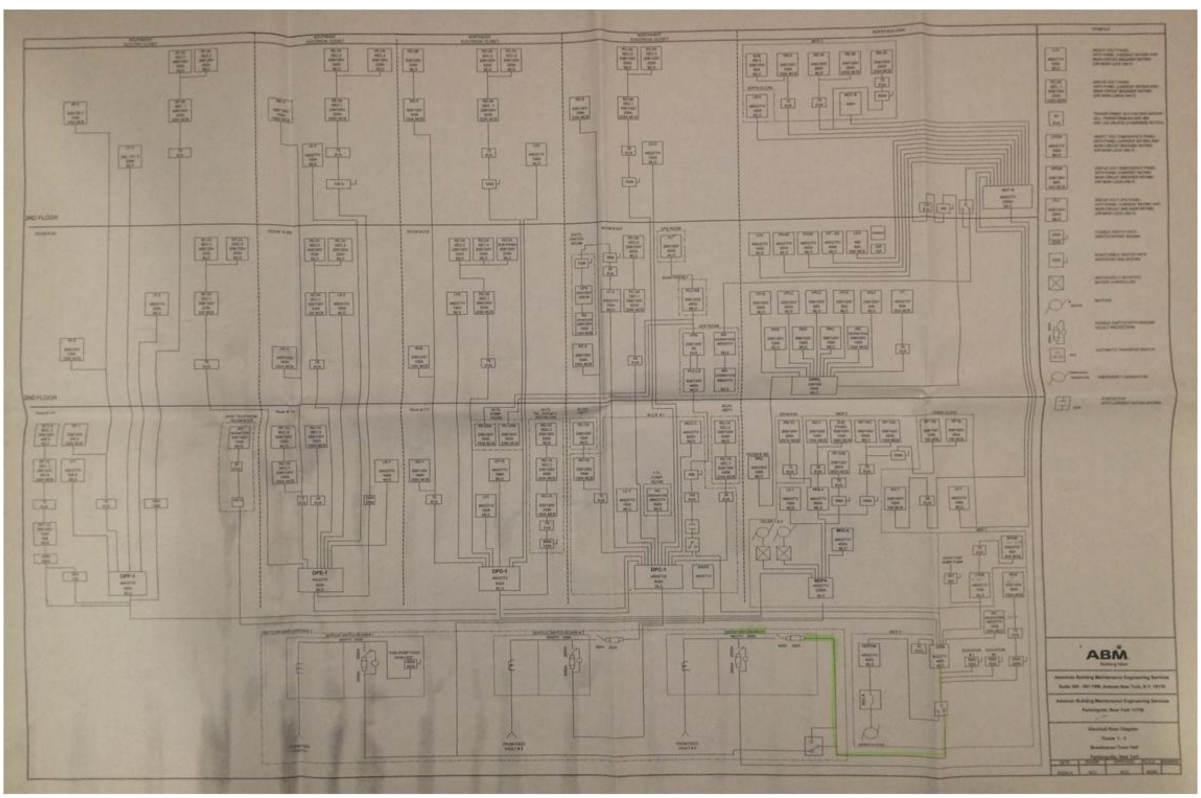
Service Switchboard	Voltage	Bus Ratings	Feeder
Service switchboard #1	480/277 VAC	2500 A bus rating	Fed from PSEG Vault 1
Main switch		2500 AS / 2500 AF	
Fire pump		600 AS / 400 AF	
Service switchboard #3	480/277 VAC	2500 A bus rating	Fed from PSEG Vault 3
Main switch		2500 AS / 2000 AF	
Computer room		200 AS / 200 AF	
Service switchboard #2	480/277 VAC	2500 A bus rating	Fed from PSEG Vault 2
Main switch		2500 AS / 2000 AF	
Second normal feed		400 AS / 400 AF	Feeds DPEM through ATS

Photo 2-4 shows the service switchboards at Brookhaven Town Hall.

Photo 2-4. Brookhaven Town Hall Service Switchboards

The building mechanical room is located adjacent to the electrical room and contains the town hall's 375 kVA emergency standby diesel generator feeding the MDPEM panel, which feeds the DPEM panelboard. The generator is primarily for life safety and elevators. The electrical riser diagram is up to date and is shown in Figure 2-8.

Figure 2-8. Brookhaven Town Hall Electric Riser Diagram

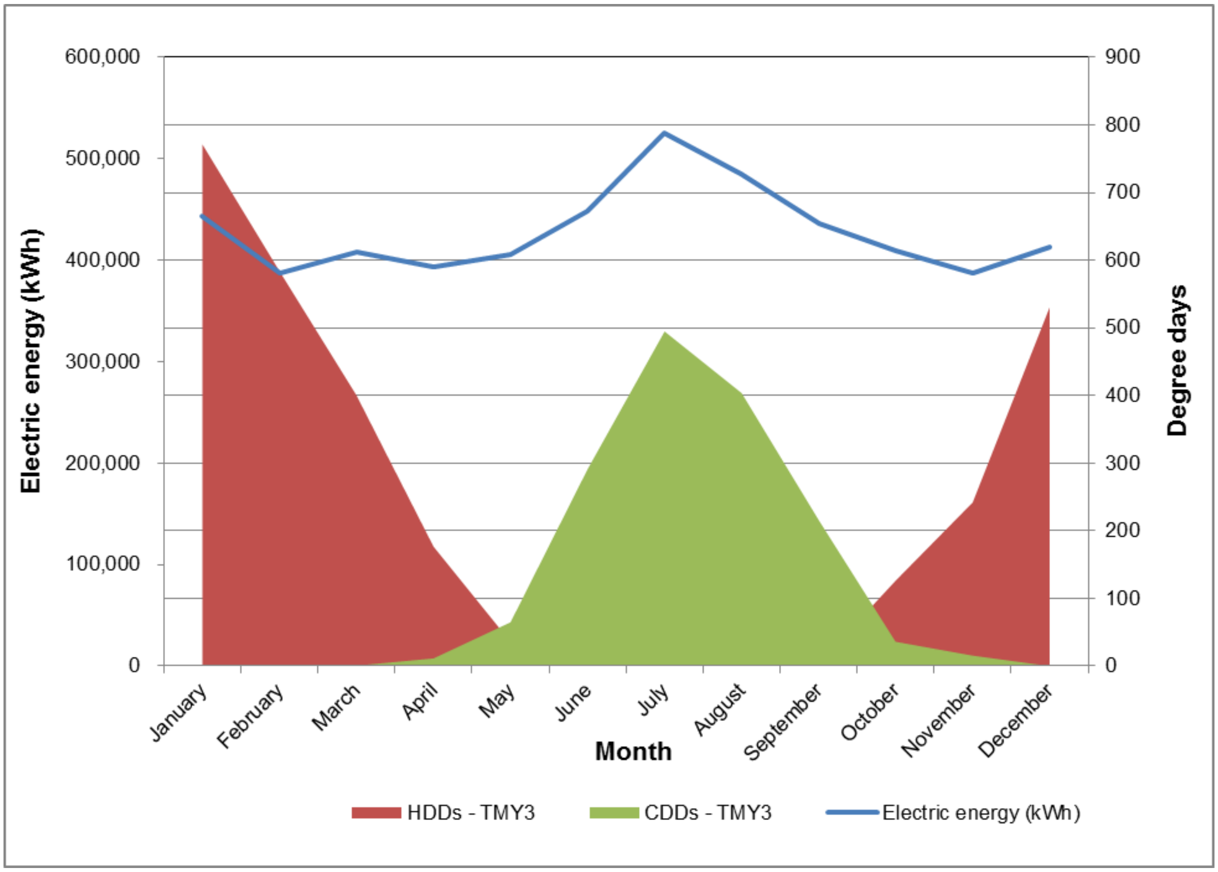


Conversations with town facility manager suggest that it is not possible to load shed within the building, as services are distributed throughout the building. The peak demand of 1301 kW (from monthly data) occurs in August. Table 2-15 and Figure 2-9 show the weather-normalized electric consumption for the town hall.

Table 2-15. Town Hall – Weather-Normalized Electric Energy Consumption

Month	CDDs – TMY3	HDDs – TMY3	Electric Energy (kWh)
January	0	771	443,259
February	0	584	387,667
March	1	400	407,855
April	11	177	393,636
May	65	36	405,660
June	291	2	448,990
July	495	0	525,170
August	404	0	485,147
September	216	3	436,242
October	36	126	409,532
November	15	242	387,319
December	0	531	413,394
Total	**1,534**	**2,872**	**5,143,872**

Figure 2-9. Town Hall – Weather-Normalized Electric Energy Consumption

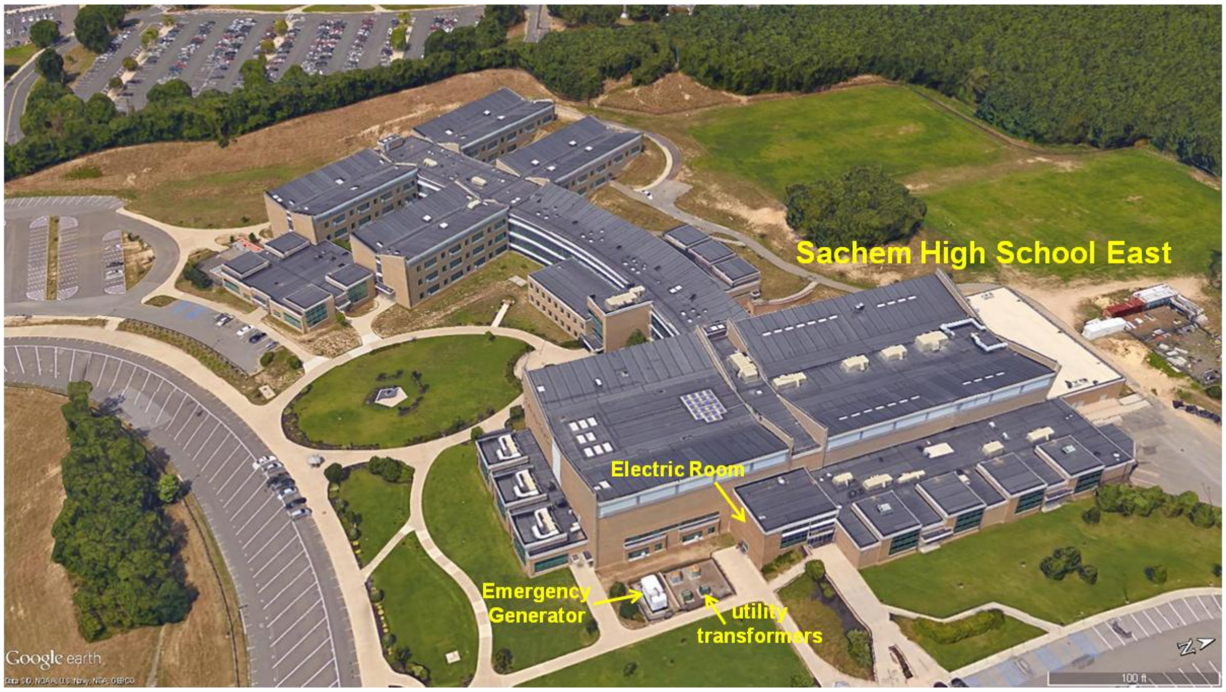


This load information includes the small wastewater treatment plant (WWTP) that is located on the property. The main disconnect in the WWTP is through a 400-ampere 600 V ac switch (fuse rating unknown). The plant is oversized for the current building activity and runs in batches, mostly at night. There is a small wind turbine that is on a pole outside the WWTP that it is connected into a 100-ampere 208Y/277 V ac panelboard. The wind turbine feeds the panelboard by back-feeding a two-pole breaker on the board.

2.4.2 Sachem High School East

The Sachem High School East building is just over 10 years old and was constructed during 2003 and 2004. Photo 2-5 shows an aerial view of the site.

Photo 2-5. Sachem High School East



There are two utility feeders to the high school switchboards: MSB-H1 and MSB-H2; both are rated 408Y/277V ac and 3,000A. These switchboards QED2 by Schneider Electric have NW main breakers with 3,000 A trip units. The maximum 667 kW demand (monthly data) occurs in July.

There is a 500 kW standby emergency diesel generator outside the electric room on a pad next to the utility transformers. There is a 2,700-gallon fuel storage tank. The generator is exercised weekly and uses a load bank for these exercises. There are three automatic transfer switches (ATS-1, ATS-3, and ATS-4 (no ATS-2)). ATS-1 is rated 800 A, ATS-3 is rated 100 A, and ATS-4 is 400 A.

Figures 2-10 and 2-11 show snapshots of the electrical riser diagram (as-built) E-401.

Figure 2-10. Sachem High School East Electric Riser Diagram

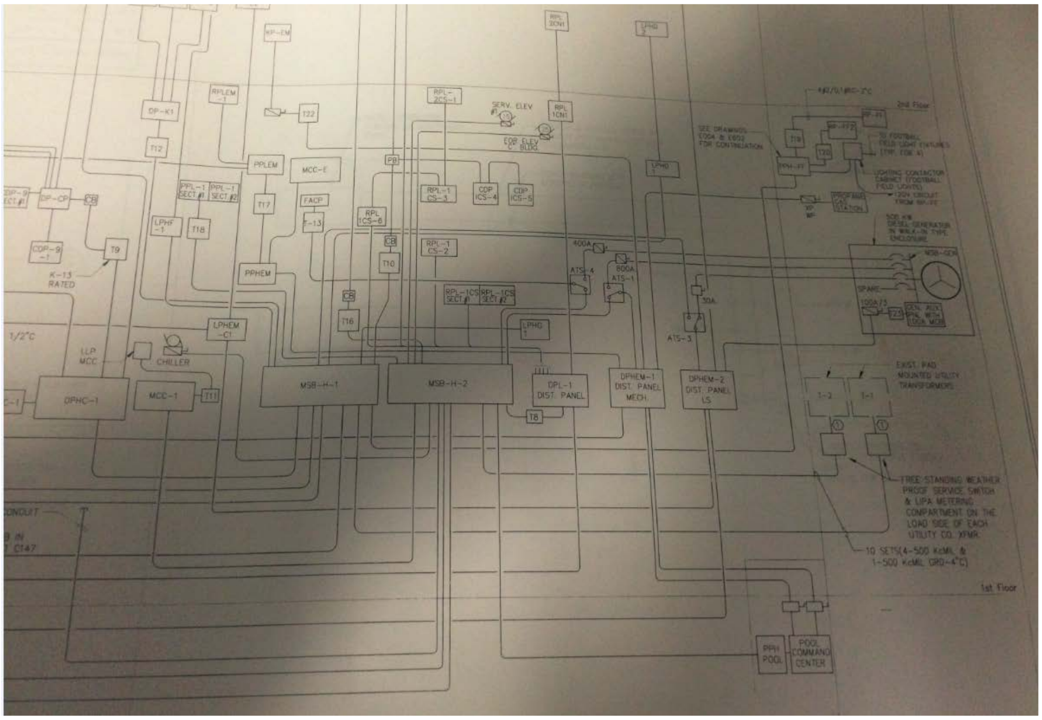


Figure 2-11. Sachem High School East Electric Riser Diagram

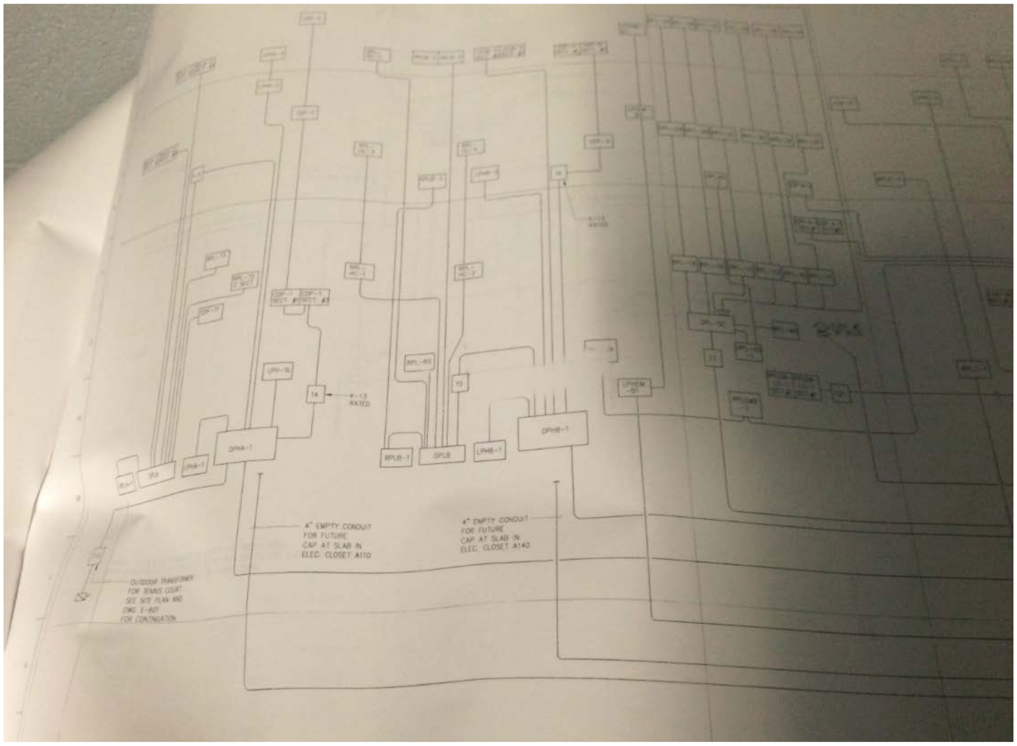
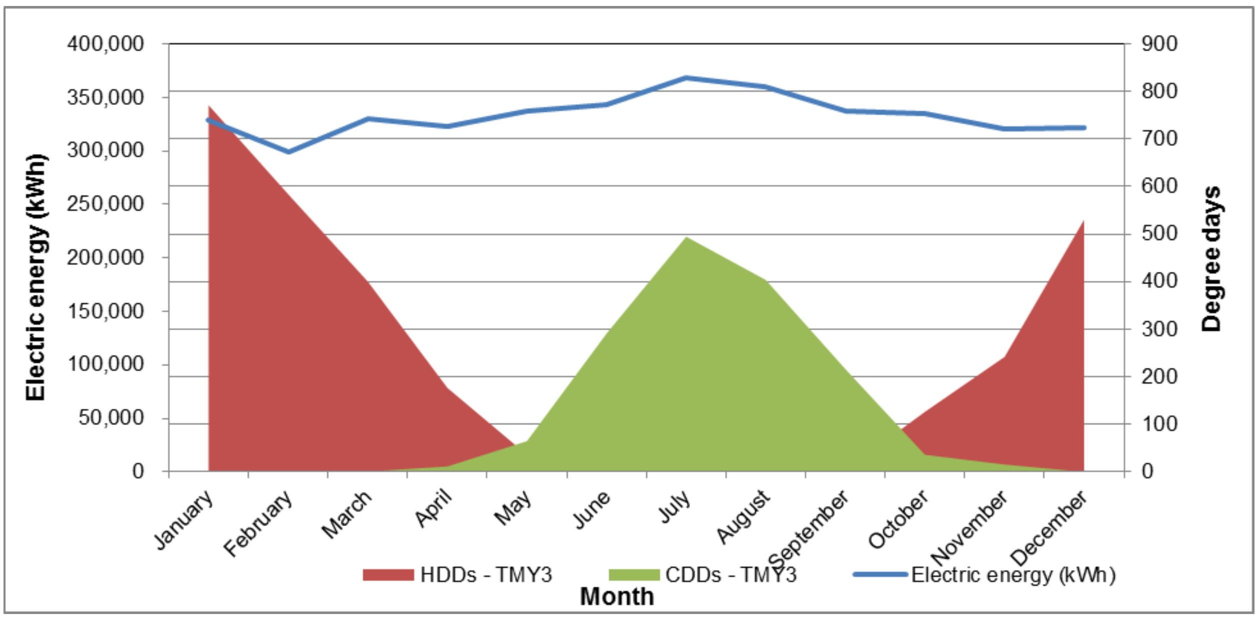


Table 2-16 and Figure 2-12 show the weather-normalized electric consumption for the Sachem High School East. The school's electric load is not reduced during the summer months, as the school hosts activities year-round at its swimming pool and other facilities.

Table 2-16. Sachem High School East – Weather-Normalized Electric Energy Consumption

Month	CDDs – TMY3	HDDs – TMY3	Electric Energy (kWh)
January	0	771	329,341
February	0	584	298,574
March	1	400	330,150
April	11	177	322,356
May	65	36	336,889
June	291	2	342,977
July	495	0	368,905
August	404	0	360,546
September	216	3	337,701
October	36	126	335,015
November	15	242	320,902
December	0	531	321,290
Total	**1,534**	**2,872**	**4,004,648**

Figure 2-12. Sachem High School East – Weather-Normalized Electric Energy Consumption



The planned microgrid configuration is slated to utilize multiple distributed energy resources (DERs) in two locations. One alternative configuration for the microgrid would be to house all of the DERs at the high school, since it has the largest thermal load, and distribute from there to the town hall. This would allow more of the waste heat generated to be used, making the system more efficient and more cost-effective. Since the CHP system is already planned at the high school through an energy performance contract, this option has some additional contractual issues that would need to be worked out if both parties wanted to configure the generation this way. Both configurations would require underground cabling (approximately 2,000 to 2,500 feet), as shown in red in Photo 2-6. This option will be further explored in preparation for Stage 2 of NY Prize.

Photo 2-6. Underground Cabling Between Town Hall and High School

2.5 Microgrid and Building Controls Characterization

The controls, communications, islanding capabilities, and seamless operation of the microgrid will provide the town hall and Sachem High School East with the added resiliency and emergency operations they will need to provide the town of Brookhaven with emergency services.

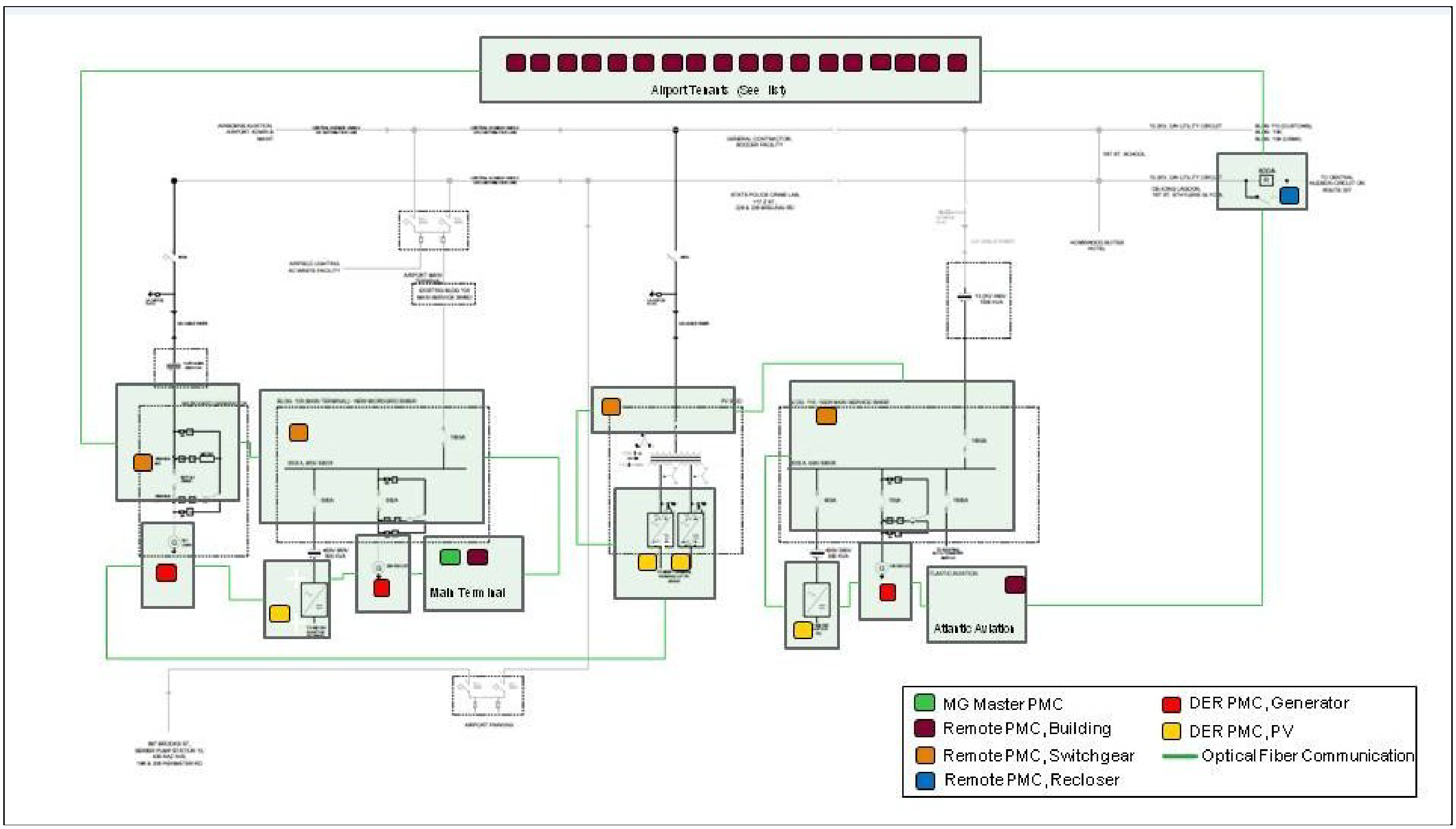
The microgrid will go into isolation automatically if power is lost during grid-connected mode. This utility loss will be detected by the IEEE 1547 protective relaying at the isolation point of the circuit. A remotely controlled recloser will isolate the microgrid circuit from the utility. All of the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

A distributed microgrid controller system will be provided to govern the operation of the microgrid. This controller consists of two components: the PowerLogic Microgrid Controller

(PMC), a real-time controller that is operating on the millisecond and second time scale and Struxureware Demand Side Operation (SDSO) software, a predictive controller that provides optimized DER schedules in 15-minute windows for the day ahead. While the PMC maintains responsibility for balancing of generation with loads and islanding/reconnection events, SDSO utilizes outside information in the form of weather and load forecasts, energy tariff data such as time-of-use rates, demand response commands, and user-imposed system constraints.

The PMC will be capable of interfacing with the local controllers provided by the DER vendors. These local DER controllers will be responsible for the most basic operation of the DER, i.e., maintaining the required voltage and frequency output for system stability. The PMC will provide a level of coordination above these local controllers, such that the site load is shared between DER and the utility grid (when connected) at an optimal level. Figure 2-13 shows an example of the microgrid control architecture that will be fully designed in Stage 2 of NY Prize.

Figure 2-13. Microgrid Control Architecture Example



2.5.1 Proposed Control System Layout

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

A modular architecture provides an optimized solution today and can be easily expanded to control additional equipment in the future. The flexibility of the I/O and communications architecture allows it to be easily adapted to a wide range of DERs and microgrid equipment.

During operation in normal grid-connected (parallel) mode all utility voltage and frequency reference will be from the new utility recloser. If there is an outage, the recloser will open and all DER sources will isolate from the grid at their connection points.

The PMC will then initiate black start of the anchor generator, bringing it online and creating a microgrid voltage and frequency reference for the other DER sources.

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

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

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

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

It should be noted that the microgrid will also incorporate sophisticated monitoring software operated by Brookhaven National Laboratory that would provide information to maximize the cost-benefit of the electrical generation and storage capacity components of the microgrid.

2.6 Information Technology/Telecommunications Infrastructure Characterization

During an event, the switch will open and the generation resources will be electrically isolated. The operation will be an open transition. The synchronous generators will be switched to voltage control mode and simultaneously closed onto the microgrid. The microgrid control system will manage the generation to ensure optimum voltage and frequency control. The loads will be evaluated for real and reactive requirements as part of the synchronous generators’ sizing plus a generous margin. These measures will help ensure that the requirements of ANSI C84.1 are met. The benefits and costs for the N+1 generator(s) will be evaluated to ensure that the microgrid has a level of redundancy and resiliency to make it successful for the town hall and Sachem High School East.

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

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

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

2.7 Microgrid Cost Estimates

The cost estimates presented in Table 2-17 reflect the initial estimates based on the proposed configuration set forth in this report. Capital cost estimates include generation equipment, as well as the distribution, control infrastructure, and cabling and trenching needed to bury wires throughout the microgrid. All capital equipment has an expected life span of 20 years.

Table 2-17. Capital Cost Estimates for Brookhaven Microgrid

Location	Capital Component	Installed Cost ($)	Description of Component
Brookhaven Town Hall	CHP-1	$4,902,534	1.148 MW CHP unit
	Distribution equipment	$975,000	Switchboards, transformers, existing equipment modifications, installation
	Control & IT hardware	$244,000	Control panels, controllers, software
Sachem High School East	CHP-2	$1,635,602	0.383 MW CHP unit
	Distribution equipment	$702,000	Switchboards, transformers, existing equipment modifications, installation
	Control & IT hardware	$160,000	Control panels, controllers, software
Cabling	Cabling & trenching	$1,030,000	Fiber, cabling, and trenching between sites
Total capital costs		**$9,649,136**	

In addition to the capital costs, we estimate annual maintenance costs of $140,000 per year for the microgrid. These costs include maintenance of CHP-1, the distribution equipment, and control hardware. Maintenance costs for CHP-2 are not included here, as this equipment is already included in a separate contract with the Sachem School District.

3 Brookhaven Microgrid Commercial and Financial Feasibility

This section outlines the primary stakeholders and customers served by the Independence Hill Microgrid and the assessment of commercial and financial feasibility of the project.

3.1 Customer Relationships

The microgrid will serve two customers – the Town of Brookhaven and the Sachem Central School District – and include two buildings: Brookhaven Town Hall and Sachem High School East. The Town Hall serves the Town's population of 500,000 residents, hosting an emergency response center that needs to remain operational during emergencies and a wastewater treatment facility. Sachem High School East operates a 200-occupant capacity Red Cross shelter in the gymnasium during emergency events. The residents of the Town of Brookhaven are additional stakeholders in the microgrid project, and they benefit from the increased reliability of these essential town services in emergency situations.

The primary generation resources for the microgrid are CHP plants at the Town Hall and Sachem High School East as detailed in Sections 1 and 2 of this report. These plants, along with power from the two existing 10 kW wind turbines, will deliver power and usable heat to each of the buildings. The microgrid will act as a single power point for the two facilities, pulling in additional power needs from the utility grid. During normal operation, the microgrid generation resources will operate together to provide power to the facilities. During grid power outages, including emergency events, the microgrid will provide power to cover the emergency operational needs for both the Town Hall and Sachem High School East.

The Independence Hill microgrid can serve as a replicable model for other towns. The microgrid necessitates a partnership between the Town Hall and school district; with many towns in New York and in the region co-locating facilities such as town halls, police stations, fire facilities, and schools in close proximity, the model can be replicated across the state. Further, future iterations could address scalability by incorporating abutting residential and/or commercial neighborhoods and creating future public/private partnerships that extend further into the community. The design of this project would allow for such expansion in the future. And while direct revenue benefits would be small, since this is a relationship amongst the residents, all savings generated would be tax-dollar savings and would accrue to the public as a whole.

3.2 Value Proposition

The microgrid will provide value to the participants, community, and stakeholders in a variety of ways. Benefits delivered by the project include cost savings for electricity delivered and in the form of heat recovered from the CHP units and reduced transmission losses from local generation. In addition, each participant will yield greenhouse gas (GHG) reductions year-round, and all members of the larger community of Brookhaven will benefit from the increased resiliency delivered by the system. Sachem High School East runs a Red Cross emergency shelter, and the Town Hall serves as an emergency response center for the Town. This system will allow critical operations at both facilities to remain operational during extended outages.

Because of its size, population, and coastal location, Brookhaven is vulnerable to sea level rise, storm damage, and other disruptions related to climate change. The Town has experienced significant outages during recent storms and, along with its community, has struggled with a lack of grid resiliency and stability in emergencies.

On the cost side the equation, by tying this project together with existing equipment and generation projects currently planned by both the school district and the town, the overall cost burden has been mitigated to the greatest extent possible. Assuming that all components of the system can be pulled together, costs and risks will be spread across multiple projects and cash flows, thereby providing an added level of protection for the project. Additional direct costs for the construction and operation of the project will be borne by the Town and the school district under the terms described above.

The project business model pulls together the Town and the school district into a partnership to generate lower-cost and lower-emission power for each and to provide resiliency for emergency services for residents during extended outages. While each entity has separate controlling bodies and differing missions, they both ultimately answer to the residents, which adds strength to the value proposition. Further strengths include the fact that each party will reduce costs for delivered power proportional to the power units located at their facilities, and both locations will leverage the CHP units to use the waste heat on their respective sites. Operating from different budgets creates the opportunity to issue bonds separately or incorporate the private developers already working with each entity at several levels of the project. Town staff members have indicated that they anticipate issuing bonds to finance the microgrid, while the School District is able to fund a portion of the capital costs through a performance contract vehicle. Approaches to take advantage of opportunities and mitigate threats will be a focus of Stage 2.

The Independence Hill microgrid has been designed to allow critical operations (services and shelter described above) at both facilities to remain operational for a period of 7 days or more during extended outages to address the community's urgent need for a more reliable grid and better preparedness for future storm events.

3.3 Project Team

The ownership of the microgrid will be split between the Town Hall and the Sachem High School East and will depend on how much electricity the generation units at each facility produce. The Town Hall and Sachem High School East will enter into a contractual agreement outlining the ownership structure and power purchasing scenarios. The details of this agreement will be further specified during the microgrid design phase. The CHP units at each of the facilities will use the waste heat generated to provide thermal energy to their buildings. This thermal energy will be used at the generating site and will not be shared between the Town Hall and Sachem High School East.

The Town is in excellent financial condition for the microgrid project. Sachem High School East is currently undergoing a restructuring of facilities through an engineering, procurement, and construction contract, and their current financial state is unknown, but the majority of the financial responsibilities will fall to the Town. Each has the ability to float bonds or muster other financial and legal resources as necessary to build the project. The Mayor's Office is committed to making this happen, and the Sachem School District has an extensive track record of addressing energy concerns with a performance contract already in place.

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

3.4 Commercial Viability – Creating and Delivering Value

To ensure that the proposed microgrid will deliver value to the participants as described in the prior sections, ERS conducted an extensive analysis of building loads for both project sites, as well as an inventory of existing resources that could be leveraged for the microgrid. ERS calculated electric energy and natural gas consumption for both the Town Hall and Sachem High School East, calibrating consumption with weather data and estimated load profiles unique to each facility. A detailed description of the loads and this characterization exercise was presented in the Task 2 report. ERS incorporated planned energy efficiency upgrades into the load estimates to project future electric and natural gas needs. Through multiple interviews and site visits, ERS engineers inventoried existing and planned equipment that could be leveraged for the microgrid. Both the Town Hall and Sachem High School have 10 kW wind turbines, as well as diesel back-up generators that are currently used to provide emergency power during outages. ERS incorporated these existing technologies into the microgrid to provide resiliency and a renewable component. The Sachem School District has previously entered into an energy performance contract for energy efficiency. This contract includes the 383 kW CHP unit that will be installed at Sachem High School East. Design and permitting for the unit have already been completed, and the next step is installation under the performance contract. The CHP unit at the Town Hall will need to go through a similar design and permitting process.

The project team explored a variety of generation scenarios to provide the necessary loads under normal and emergency generation scenarios, including solar PV, wind, battery storage, CHP, and wastewater methane generators. A solar PV system was initially included for nearby Tecumseh Elementary School, but once the project team learned of this school's planned closure, this element was removed from the feasibility design. The technologies planned for this microgrid, including generation, storage, and controls, have all been used previously in projects with NYSERDA and the utilities throughout and beyond New York.

In terms of benefits to the utility, the Independence Hill microgrid will provide increased power quality and improved reliability at the site, augmented peak shaving opportunities year-round, and true resilience in times of emergencies, allowing PSEG-LI to focus efforts on other areas in such burdensome periods.

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

3.5 Financial Viability

The Independence Hill microgrid between the Town of Brookhaven and Sachem High School East has been developed to be mutually beneficial under normal operation and during emergencies. Table 3-1 shows the simplified economics behind the project; the value reflects the microgrid's lifetime financial feasibility, including the emergency system redundancy benefits. The revenue streams will be relatively fixed on an annual basis over the life of the equipment and contracts.

Table 3-1. Energy Balance and Costs Summary

Parameter	Town Hall	Sachem High School East
Existing Operation – without Microgrid		
Electric energy load (MWh/year)	5,143	4,005
Peak demand (MW)	1.3	0.7
Thermal energy load (therms/year)	79,995	150,237
Electric energy cost ($/year)	$836,211	$590,413
Natural gas cost ($/year)	$68,489	$113,004
Total energy cost ($/year)	$904,700	$703,418
Proposed Operation – with Microgrid		
Electric energy supplied by the microgrid (MWh/year)	5,090	3,868
Demand supplied by the microgrid (MW)	1.148	0.383
Electric energy supplied by the utility (MWh/year)	53.5	136.5
Demand supplied by the utility (MW)	0.153	0.284
Thermal energy supplied by the microgrid (therms/year)	68,283	64,391
Natural gas used by the microgrid (therms/year)	478,553	416,255
Electric energy cost ($/year)	$21,103	$53,844
Cost of natural gas used by the microgrid ($/year)	$409,721	$313,098
Total energy cost ($/year)	$430,824	$366,942

Since the Town and School District are incurring a substantial cost to set up the microgrid, the current payback of approximately 15 years without incentives, while it is financially feasible, is likely outside of an acceptable return. Additional incentives that would allow the project to bring the payback to less than 12 years would likely keep both parties interested.

In addition to the capital costs, we estimate annual maintenance costs of $140,000 per year for the microgrid. These costs include maintenance of CHP-1 (Town Hall), the distribution equipment, and control hardware. Maintenance costs for CHP-2 (Sachem High School East) are not included here, as this equipment is already included in a separate contract with the Sachem School District. Based on the project pricing and annual fees associated with the project the simple payback for the project is 15 years, on a total project cost of $10,260,000, an annual savings of $810,352, and annual maintenance fees of $140,000.

The Town is planning to finance the project using either currently allocated money that was not spent on another project or through a bond. The Town has a good credit rating and utilizing a bond would be one of the lowest costs of obtaining the funding to develop the project.

3.6 Legal Viability

As discussed above, the project owner is the Town of Brookhaven, and the project will be located within the Town Hall property, which is owned and operated by the Town. The Town of Brookhaven is the applicant and will remain the applicant throughout the rest of the NY Prize program. Depending on how much involvement it would like to have in the ownership of the project, the Sachem High School East could potentially be a part owner in the microgrid instead of paying the Town for the power it receives from the microgrid.

The local utility PSEG-LI has expressed an interest in the microgrid and even potentially owning the microgrid depending on their needs, which will be worked through in Stage 2 of NY Prize. There are no actual regulatory hurdles except for the current ownership of the road between the Town Hall and Sachem High School East. While the project can go around the dead-end road if necessary by adding a couple of hundred feet to the buried power lines, it would be preferable to go under the road. The workaround is actually fairly easy since the road ends, but it would take extra capital to bury the additional 200 feet or so of wiring.

4 Technical Design Costs and Benefits

This section presents the analysis of benefits and costs of the Independence Hill Microgrid. The benefits and costs presented below primarily reflect the perspective of the Town Hall and high school; they incorporate actual load profiles and existing rate structures for the facilities. An additional benefit/cost analysis was conducted by Industrial Economics (IEc) to evaluate the societal benefits of the project; while this analysis is presented in Appendix C, it does not include actual site rates for the electrical and thermal costs from the grid, and thus the economic feasibility shown in the model does not reflect the actual value to the Town of Brookhaven and the Sachem School District.

4.1 Facility and Customer Description

The Independence Hill microgrid will serve two single-ratepayer facilities – the Brookhaven Town Hall and Sachem High School East – and will be operated continuously to provide electric energy and hot water. The Town Hall encompasses over 225,000 sq ft and serves approximately 1,000 people during normal business hours, providing a variety of municipal and public services. The three-floor Town Hall building includes offices, an auditorium, a full kitchen, a data server room, a mechanical room, and an atrium. Sachem High School East is approximately 420,000 sq ft and has about 2,300 students and 150 faculty, operating Monday through Friday with additional programming and recreational activities on Saturdays.

Both facilities provide critical services during emergency events: the Town Hall is the emergency response center for the Town of Brookhaven, and Sachem High School East operates a Red Cross emergency shelter. Electricity is needed to provide these services throughout a major power outage. A summary of the electric energy load and the microgrid potential is provided in Table 4-1.

Table 4-1. Electric Energy Loads and Microgrid Potential Summary

Indicator	Town Hall	Sachem High School East
Rate class	Large commercial/industrial (>50 annual MWh)	Large commercial/industrial (>50 annual MWh)
Facility type	Office building	K–12
Electric energy consumption (MWh/year)	5,143	4,005
Peak electric demand (MW)	1.3	0.7
Percentage of average usage microgrid could support during major power outage	98%	98%
Hours of electricity supply required per day during major power outage	24	24

4.2 Characterization of Distributed Energy Resources

The Independence Hill microgrid will consist of a new 1,148 kW combined heat and power (CHP) plant and a 383 kW CHP plant at Sachem High School East. These sources will serve as the main microgrid generation units providing power during normal and emergency operations. Additional generation resources are already in place and will be integrated into the microgrid to provide normal and emergency generation depending on need and availability; these include two diesel back-up generators (BGs) and two wind turbines (WTs). Other renewable resources are at some stage of planning and may be added to the microgrid, including PV arrays at the Town Hall, and a bio-gas generator. The microgrid will run in parallel with the grid during normal operation with a single feed and will be able to run islanded from the grid during emergency events, as described in the following sections.

Table 4-2 shows the distributed energy resources (DER) that constitute the configuration analyzed in this study. Note that the BGs will only operate during a major power outage.

Table 4-2. Distributed Energy Resources Summary

DER	Location	Energy Source	Nameplate Capacity (MW)	Production under Normal Conditions (MWh/year)	Production during Major Power Outage (MWh/day)	Fuel Consumption (MMBtu/MWh)
CHP-1	Town Hall	Natural gas	1.148	5,608	18.53	10.1
CHP-2	Sachem High School East	Natural gas	0.383	3,350	9.19	10.1
WT-1	Town Hall	Wind	0.010	22	0.00	0
WT-2	Sachem High School East	Wind	0.010	22	0.00	0
BG-1	Town Hall	Diesel fuel	0.300	0	7.200	6.594
BG-2	Sachem High School East	Diesel fuel	0.300	0	7.200	6.594

4.3 Capacity Impacts and Ancillary Services

The Independence Hill microgrid would be implemented at the end of a distribution feeder in an area of the grid that has consistently had power issues because of the nature of the existing grid configuration. The microgrid would alleviate some of the issues related to the additional power generation that may be needed in the near future. Based on over 1.5 MW of new power generation systems that would be implemented with the microgrid (see Table 4-2, above), this system will provide relief to the already taxed delivery system that is currently in place. The microgrid will provide peak load support in the area and reduce the power generation requirements of the utility by 1.5 MW. The microgrid would also reduce the need for additional distribution or transmission capacity, which may potentially reduce the utility's need to increase generation or transmission capacity in the area. However, it will not have additional capacity other than the BGs to provide demand response.

The microgrid will impact the transmission and distribution utility grid in the area. The system will be capable of black start, which means it will not need to have the utility grid available to start, but it will not provide any additional ancillary services for the utility.

One of the Town's main goals is to reduce greenhouse gas emissions by incorporating green power, or low-emission power, generation. The Town also wants to include tangible benefits from a town-wide perspective, including grid resiliency, job creation, benefits from the Town and the Sachem School District partnership, and the maximization of taxpayer money for the best interest of the Town. The additional preferred capabilities that will be included in the feasibility study are performing a comprehensive cost/benefit analysis and identifying potential financial options such as private-public partnerships, utility co-ownership, and third-party developers. The system size will fall under the natural gas CHP generation sizing requirements and will require minimum environmental permitting. Table 4-3 shows the values for the emission rates associated with the electric energy consumption at the site using the NY Prize assumptions.

Table 4-3. Emission Rates and Modeled Emission Values

Component	CO_2	SO_2	NO_X	PM
Natural gas emmision rates (ton/MMBtu)	0.058	0.00000029	0.000049	0.000004
Power utility emmision rates (ton/MWh)	0.538456	0.000290	0.000281	0
Proposed microgrid emmision rates (ton/MWh)	0.531227	0.000003	0.00080	0.000034
Existing operation – without microgrid				
Town Hall emissions (ton/year)	3,233	1.494	1.837	0.032
Sachem High School East emissions (ton/year)	3,027	1.166	1.861	0.060
Proposed Operation – with microgrid				
Town Hall emissions (ton/year)	2,804	0.029	2.360	0.191
Sachem High School East emissions (ton/year)	2,487	0.052	2.078	0.167

Note that the values for CO_2, SO_2, and PM emission rates shown for the microgrid are for the uncontrolled burning of natural gas. It is likely that the CHPs have catalytic converters to capture these pollutants, and the actual emissions will be less.

4.4 Project Costs

ERS, with Schneider Electric, developed the project costs for the microgrid utilizing partner vendor quotes, RSMeans, and cost information gathered by ERS during CHP outreach efforts. Table 4-4 provides the capital cost estimates for the microgrid.

Table 4-4. Capital Cost Estimates for Independence Hill Microgrid

Location	Capital Component	Installed Cost ($)	Description of Component
Town Hall	CHP-1	$4,902,534	1.148 MW CHP unit
	Distribution equipment	$975,000	Switchboards, transformers, existing equipment modifications, installation
	Control and IT hardware	$244,000	Control panels, controllers, software
Sachem High School East	CHP-2	$1,635,602	0.383 MW CHP unit
	Distribution equipment	$702,000	Switchboards, transformers, existing equipment modifications, installation
	Control and IT hardware	$160,000	Control panels, controllers, software
Cabling	Cabling and trenching	$1,030,000	Fiber, cabling, and trenching between sites
Total capital costs		**$9,649,136**	

Table 4-5 incorporates estimated design and maintenance costs for the proposed microgrid.

Table 4-5. Independence Hill Microgrid Design and Maintenance Costs

Indicator	Cost ($)
Fully installed costs and engineering lifespan of all capital equipment ($)	9,649,136
Initial planning and design costs ($)	611,000
Fixed operations and maintenance (O&M) costs ($/year)	140,000
Variable O&M costs, excluding fuel costs ($/MWh)	0

The DERs will meet 98% of the electric annual energy usage of the facilities and will provide 100% of normal operation power for short-duration outages and 100% of emergency operations power for virtually an indefinite period of time. Table 4-6 provides details on the periods during which each DER will operate in islanded mode without replenishing the fuel supply and the fuel consumption. ERS has assumed that natural gas would still be available during an emergency event.

Table 4-6. Islanded Mode Operation Summary

DER	Energy Source	Operating Hours in Islanded Mode	Fuel Consumption (MMBtu)
CHP-1	Natural gas	24 hrs/day, 7 days	14,646
CHP-2	Natural gas	24 hrs/day, 7 days	4,886
WT-1	Wind	0	0
WT-2	Wind	0	0
BG-1	Diesel fuel	24 hrs/day, 7 days	335
BG-2	Diesel fuel	24 hrs/day, 7 days	335

The Independence Hill microgrid between the Town of Brookhaven and Sachem High School East has been developed to be mutually beneficial under normal operation and during emergencies. Table 4-7 shows the simplified economics behind the project.

Table 4-7. Energy Balance and Costs Summary

Parameter	Town Hall	Sachem High School East
Existing Operation – without Microgrid		
Electric energy load (MWh/year)	5,143	4,005
Peak demand (MW)	1.3	0.7
Thermal energy load (Therms/year)	79,995	150,237
Electric energy cost ($/year)	$836,211	$590,413
Natural gas cost ($/year)	$68,489	$113,004
Total energy cost ($/year)	$904,700	$703,418
Proposed Operation – with Microgrid		
Electric energy supplied by the microgrid (MWh/year)	5,090.3	3,868.1
Demand supplied by the microgrid (MW)	1.148	0.383
Electric energy supplied by the utility (MWh/year)	53.5	136.5
Demand supplied by the utility (MW)	0.153	0.284
Thermal energy supplied by the microgrid (Therms/year)	68,283	64,391
Natural gas used by the microgrid (Therms/year)	478,553	416,255
Electric energy cost ($/year)	$21,103	$53,844
Cost of natural gas used by the microgrid ($/year)	$409,721	$313,098
Total energy cost ($/year)	$430,824	$366,942

In addition to the capital costs, estimated annual maintenance costs for the microgrid are $140,000 per year. These costs include maintenance of CHP-1 (Town Hall), the distribution equipment, and control hardware. Maintenance costs for CHP-2 (Sachem High School East) are not included here, as operations and maintenance are already included in a separate contract with the Sachem School District. Based on the project pricing and annual fees associated with the project, the simple payback for the project is 15 years, on a total project cost of $10,260,000, an annual savings of $810,352 and annual maintenance fees of $140,000.

4.5 Costs to Maintain Service during a Power Outage

The facilities included in the microgrid currently have small BGs at their respective facilities. Because these systems are already in place and connected to the existing back-up loads, there would be no additional cost to have them operational during an emergency if the microgrid were to go down. The only costs incurred for these back-up units would be the cost of the fuel and the staff overtime needed for startup if the emergency happens outside of normal work hours.

During a power outage, when the electric energy provided by the utility is lost, the two BGs will come online to supplement the electric energy supplied by the two CHPs that are part of the microgrid. Table 4-8 shows the main features of the two BGs.

Table 4-8. Back-up Generators Summary

Indicator	BG-1	BG-2
Energy source	Diesel fuel	Diesel fuel
Nameplate capacity (MW)	0.300	0.300
Loading during an extended power outage	100%	100%
Production during major power outage (MWh/day)	7.200	7.200
Fuel consumption (MMBtu/MWh)	47.478	47.478
One-time cost associated with connecting and starting each BG ($)	0	0
Daily cost (excluding fuel) associated with operating each BG ($/day)	0	0
Emergency measures cost (during a widespread power outage; BGs available) ($/day)	0	0
Emergency measures cost (during a widespread power outage; BGs not available) ($/day)	0	0

Since the microgrid is expected to be available during an event where the electric grid is not available, there are no additional costs necessary to operate it and the BGs other than fuel oil and someone to physically start them up. Since the BGs are supplemental, they would only be needed during specific summer hour when the loading on the microgrid is pulling power from the utility grid.

4.6 Services Supported by the Microgrid

The Independence Hill microgrid will provide electric and thermal energy to Brookhaven Town Hall and Sachem High School East. During normal operations, the microgrid will offset utility purchases through on-site generation. During emergencies, the microgrid will increase resiliency at both facilities.

Brookhaven Town Hall operates an emergency call center during storm or emergency events; this center takes in calls from town residents and removes some of the burden on the 911 call center. In emergency situations, the Town currently relies on a back-up generator that can only handle a small portion of the load. This in essence shuts down the majority of the building and makes it difficult for Town employees to aid in relief or emergency efforts outside of the call center. The Town Hall is a central hub, so if it had power during emergency events it would be a crucial place to go for people looking for help, shelter, or an understanding of the effects of the emergency.

Sachem High School East is used as a Red Cross emergency center during emergency events. It covers a substantial amount of the populated area, since there are only three designated Red Cross shelters, with two more at other school locations. During emergency events, a significant portion of the school shuts down, since the current back-up generator does not provide the school with all of its necessary power. The microgrid will allow the school and the Town Hall to operate at higher capacity, and it will have better resiliency, since it would be unlikely that the electric and natural gas grids would be unavailable at the same time.

5 Conclusions and Recommendations

The ERS team evaluated the microgrid project, conducting a full technical analysis and review of the infrastructure requirements, stakeholder interests, and PSEG-LI distribution needs and perspectives. This section outlines the benefits and value streams from the Independence Hill Microgrid, discusses the primary roadblocks and challenges encountered throughout the feasibility study, along with their potential solutions, and suggests next steps for continuing into the engineering design for Stage 2 of NY Prize.

5.1 Independence Hill Microgrid Benefits and Value

The operation of the Independence Hill microgrid will generate many value streams, including the following:

- ❑ Electricity production at lower cost per kWh than either the Town Hall or the High School's current costs
- ❑ An infrastructure backbone for incorporating existing (the two wind turbines) and proposed renewable resources such as the PV array and bio-gas generator at the Town Hall.
- ❑ Thermal production at a lower cost per MMBtu than the Town Hall and the high school's current costs
- ❑ The combined operation reduces GHG with CHP efficiency of about 56%
- ❑ Emergency electric back-up service for the town's emergency services, including the emergency center at Town Hall and the emergency shelter at Sachem High School East

  Additional electric capacity for PSEG-LI electrical distribution

5.2 Microgrid Roadblocks, Challenges, and Potential Solutions

While the potential for microgrids to increase resiliency and provide complementary services to Brookhaven is great, the ERS team identified several roadblocks and challenges throughout the course of the feasibility study. Some of these roadblocks are likely faced by many of the NY Prize projects currently under analysis. The primary roadblocks and challenges are presented below, along with the potential solution under consideration at the end of the feasibility study. The ERS team is engaged with many stakeholders in discussing these roadblocks and expects to continue these conversations in preparation for and during Stage 2 of the NY Prize program. Table 5-1 highlights the primary roadblocks pertaining to the Independence Hill microgrid and the potential workarounds and solutions under consideration.

Table 5-1. Independence Hill Microgrid Roadblocks, Challenges, and Potential Solutions

Roadblock/Challenge Faced by the Microgrid	Potential Workaround or Solution
There are unresolved right-of-way issues when connecting multiple electrical meters across a public street.	This is a known challenge affecting all NY Prize projects under consideration. This is a regulatory hurdle that should be addressed with the utilities and PSC. For Independence Hill, additional cable can be laid to circumvent the road between the Town Hall and Sachem High School since the road is a dead end; however, this adds additional costs for burying the extra cable.
Both partner sites will produce thermal and electricity and will contribute to the funding of the microgrid	This challenge affects the revenue structure of the project. A partnership will be structured between the two parties to balance the flow of benefits and the investments including O&M.
School building regulations require that all new electrical cabling be installed underground and not overhead.	While this requirement adds significant additional infrastructure and installation costs to the project, underground cabling also has additional resiliency benefits to the facilities.
Sachem School District has an existing energy performance contract in place for district-wide energy efficiency and distributed generation projects, including the CHP unit at Sachem High School included in the microgrid	This is a challenge for the microgrid because it requires that an additional stakeholder be engaged in the project. This may also restrict opportunities for additional energy efficiency work, and the installation timing of the CHP unit could potentially be affected. The ERS team has made initial inquiries to engage the ESCO and this effort will be pursued further in Stage 2.
Town of Brookhaven is separately pursuing installation of third-party owned PV array on Town Hall property for PSEG-LI load relief.	This presents an opportunity for the microgrid to incorporate battery storage into the design, potentially harnessing a portion of the PV generation capacity during outages and emergency scenarios.

5.3 Recommendation and Next Steps

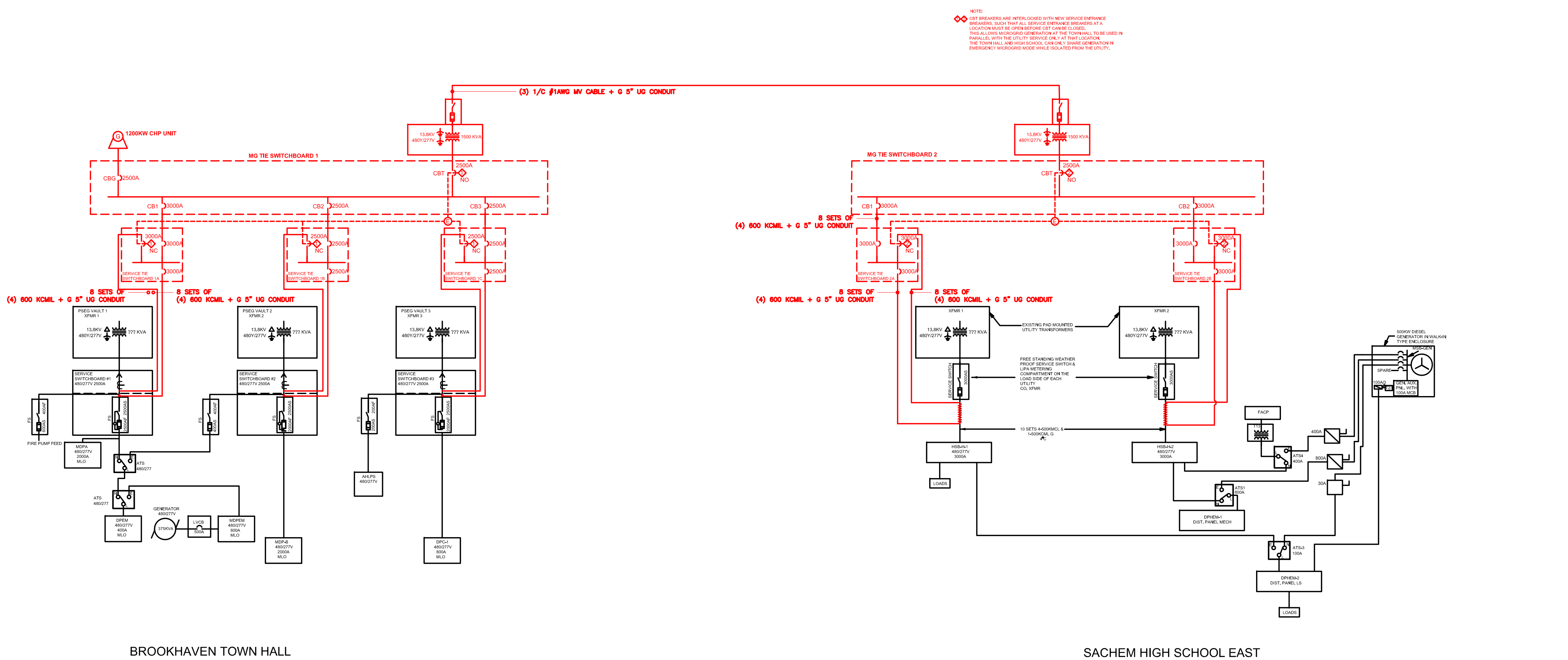
The Independence Hill microgrid has the stakeholder support and technical merit to be a feasible project that should continue to seek support during Stage 2 of the NY Prize program. There are several activities that the project team will need to complete as the proposal for Stage 2 is developed, many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

- The project team will continue to engage the town and school district stakeholders. These conversations will focus on processing the results of this feasibility study and considering any additional configuration options.
- The project team will continue to hold conversations with PSEG-LI to discuss the cable routing, the proposed third-party PV array, and other interconnection issues.
- As the microgrid moves into Stage 2, which contains a cost-share component, a partnership agreement between the Town and the school district will likely be required to outline the contributions and benefits that each party will receive throughout the microgrid design phase.

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

Appendix A

Conceptual One-Line Microgrid Design



COLOR LEGEND

EXISTING INFRASTRUCTURE

CONCEPTUAL ADDITIONS FOR MICROGRID

Schneider Electric

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

PROFESSIONAL SEALS

NOT FOR CONSTRUCTION

NO.	DESCRIPTION	DATE
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"TOWN OF BROOKHAVEN"

NY PRIZE FEASIBILITY

CONCEPTUAL MICROGRID DESIGN

ELECTRICAL ONE-LINE DIAGRAM

SEES PROJECT NO.	#########
CUSTOMER PROJECT NO.	########
DATE	1/25/2016
CURRENT REVISION DRAWN BY	BAP
CURRENT REVISION CHECKED BY	Checekd By
CURRENT REVISION APPROVED BY	Approved by

SK-1

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Appendix B

DER-CAM Analysis of the Independence Hill Microgrid

DER-CAM Analysis of a Proposed Microgrid in Town of Brookhaven, New York

J. Jung

September 30, 2015

1. Introduction

The New York State Energy Research and Development Authority (NYSERDA), in partnership with the Governor's Office of Storm Recovery (GOSR) announce the availability of up to $40,000,000, under the three-stage NY Prize Community Grid Competition (NY Prize), to support the development of community microgrids. The objective of NY Prize is to promote the design and build of community grids that improve local electrical distribution system performance and resiliency in both a normal operating configuration as well as during times of electrical grid outages. NY Prize objectives include empowering community leaders, encouraging broad private and public sector participation including local distribution utilities, local governments and third parties, protecting vulnerable populations and providing tools to build a cleaner more reliable energy system.

Governor Andrew M. Cuomo announced funding for the micorgids at Town of Brookhaven, proposed by Energy Resource Solutions (ERS), as part of the first phase of the NY Prize Community Microgrid Competition. Brookhaven National Laboratory (BNL) has teamed with ERS for its microgrid modeling expertise using the Distributed Energy Resources Customer Adoption Model (DER-CAM), which is an economic and environmental model of customer DER adoption to minimize cost and CO_2 emission. This report will show the DER-CAM analysis results of a proposed microgrid for Brookhaven Town Hall.

2. Overview of the proposed Town of Brookhaven community microgrid

The Town of Brookhaven and Sachem School District have suffered significant power outages from both warm-weather storms and winter nor'easters. The proposed microgrid would provide power to the town hall to enable it to act as an emergency operations center and for two adjacent Sachem schools to function as emergency shelters. Technology would include solar panels and two existing 10 kW wind turbines, fuel cells, battery storage, and/or microturbines powered by the onsite wastewater treatment plant. The project would also incorporate sophisticated monitoring software operated by Brookhaven National Laboratory that will maximize the cost-benefit of the electrical generation and storage capacity components of the microgrid.

3. Overview of DER-CAM

The DER-CAM is a tool that was developed by Lawrence Berkeley National Laboratory (LBNL) to help optimize the selection and operation of distributed energy resources on a utility distribution system. The DER-CAM tool has application in the design of microgrids and BNL is partnering with LBNL to make this capability available to interested stakeholders in the northeast.

The main objective of DER-CAM is to minimize either the annual costs or the CO_2 emissions of providing energy services to the modeled site, including utility electricity and natural gas purchases, plus amortized capital and maintenance costs for any distributed generation (DG) investments. The key inputs into the models are the customer's end-use energy loads, energy tariff structures and fuel prices, and a list of user-preferred equipment investment options, as shown in Figure 1. Additional information is available on BNL's DER-CAM website[1].

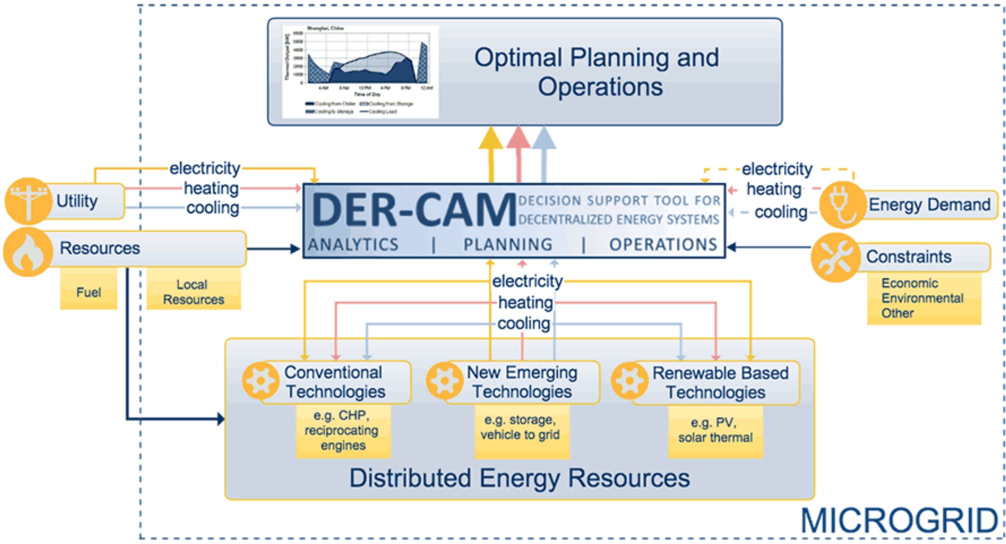

Figure 1 Schematic of information flow in DER-CAM

4. DER-CAM input data

- *Load profile*

It is required to input the specific load profile for the various buildings in the microgrid to obtain the variety of DER to be considered in the analysis. The loads include electricity, space-heating, water-heating, cooling, refrigeration, natural gas only (e.g. for cooking). However, the electricity, cooling, space-heating are only given for Brookhaven Town Hall. Therefore, the DER-CAM load profile template for a reference large office building was used to estimate the missing load profile. The template for Baltimore, MD was selected because Brookhaven is located in the same climate zones based on ASHRAE database. Furthermore, annual electricity and natural gas demand was used to scale the database load profiles to reflect the building.

- *Utility tariff*

DER-CAM allows only time-of-use electricity rates. For Brookhaven Town Hall it is $0.0496 per kwh during peak hours, $0.0406 per kwh for mid-peak hours, and $0.0268 per kwh for off-peak hours. Peak times are 10 a.m. to 10 p.m. Monday thru Saturday during summer. Mid-peak hours are 7 a.m. to 10 a.m. and 10 p.m. to 12 a.m. during summer and 7 a.m. to 12 a.m. during winter. Off-peak hours are 12 a.m. to 7 a.m. during summer and 12 a.m. to 7 a.m. during winter. Also, most utilities include a monthly fee, which is independent of the customer consumption. $10/day monthly fee was applied. Furthermore, the given natural gas price was applied.

- *Technologies investment.*

Since no practical investment price for each DER was available, the default price information provided by DER-CAM was used. No preference investment options were selected. The existing 300 kW diesel generator was included as a default.

- *Weather information*

The given hourly solar radiation, temperature and wind speed was applied for the DER-CAM simulation.

[1] https://www.bnl.gov/SET/DER-CAM.php

- *Global setting*

For this analysis, a 10 year maximum payback period was used based on ERS input. A multi-objective approach is used by considering the minimization of both the annual costs and CO_2 emissions. First, a base case without any investment was simulated to obtain the reference cost. Then, an investment case was simulated to see the investment economic and CO_2 emission benefits.

5. Detailed results for each critical building

Since the bulk electricity price at the town hall building is much lower than the local retail electricity rate, the analysis didn't show the variety of DER selection when considering economic benefit only. Therefore, a multi-objective approach was applied by considering the minimization of both the annual costs and CO_2 emissions. Every optimization run in the multi-objective frontier is a tradeoff between the cost and environmental functions, considering all possible DG technologies in the optimization.

Figure 2 shows the total annual energy costs and total annual CO_2 emission results by varying the weighting factor of annual costs. Total annual energy costs increase by decreasing the weighting factor of annual costs. This occurs because decreasing the weighting factor applied to annual energy costs (i.e., the relative importance of overall annual energy costs to the customer in comparison to the importance to him of decreasing annual CO_2 emissions) will open up the analysis to utilize greater investment in cleaner but more expensive DER options. Consequently, the total annual CO_2 emissions decrease by decreasing the weighting factor of annual costs. More investment of renewable energy generation will decrease the CO_2 emission but increase the annual energy cost. This is also shown in DER-CAM technology investment summary in Figure 3. Decreasing the weighting factor of total annual costs increases the investment of photovoltaic and energy storage in the multi-objective optimization analyses.

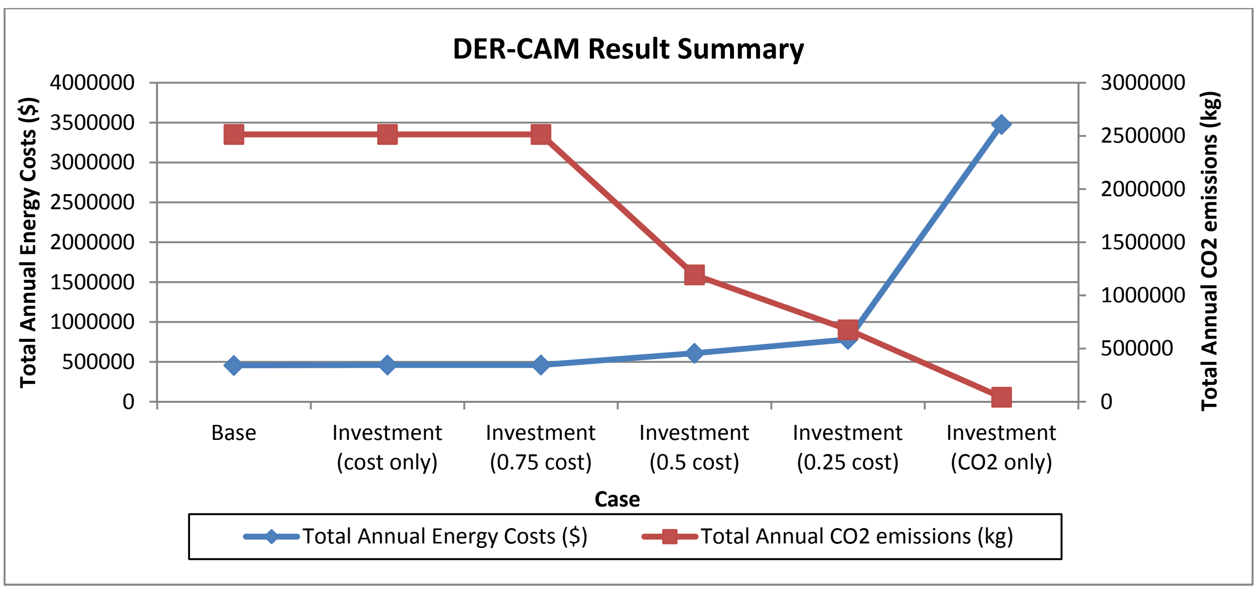

Figure 2 DER-CAM results summary

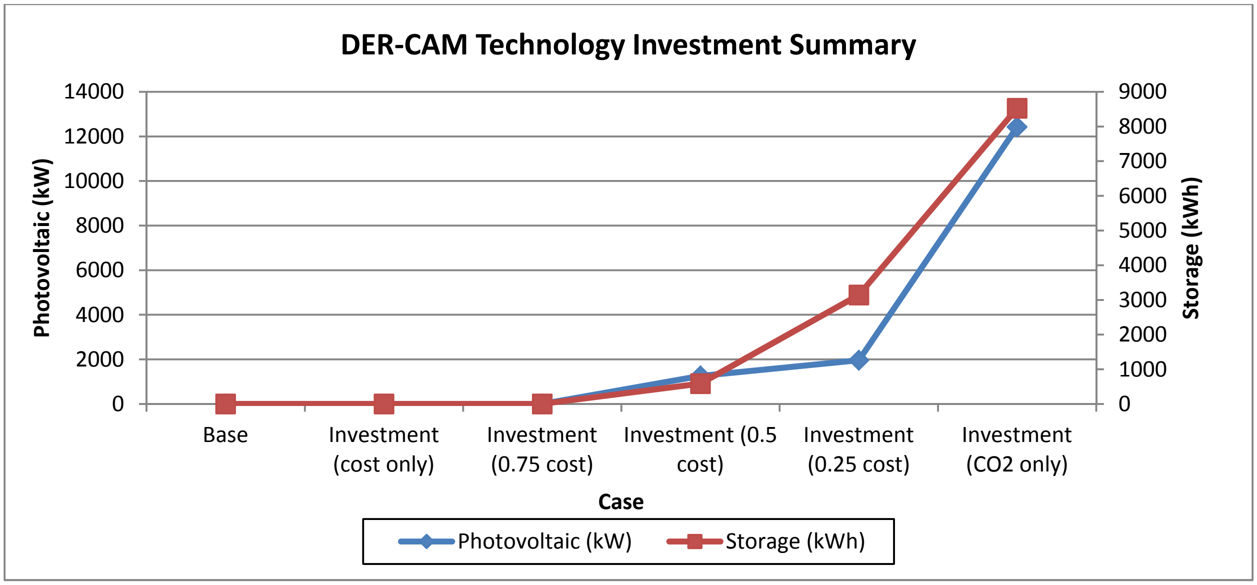

Figure 3 DER-CAM technology investment summary

The detail DER-CAM results for Brookhaven Town Hall is provided below.

a) Minimizing annual energy cost only

Table 1 the annual costs and CO_2 emissions savings by the investment – minimizing annual energy cost only

	Base Case (no investment)	Investment Case (investment)	Reduction
Total Annual Energy Costs ($)	$ 454,753	$ 460,500	*+ $ 5,747*
Total Annual CO_2 emissions (kg)	2,513,519 kg	2,513,519 kg	-

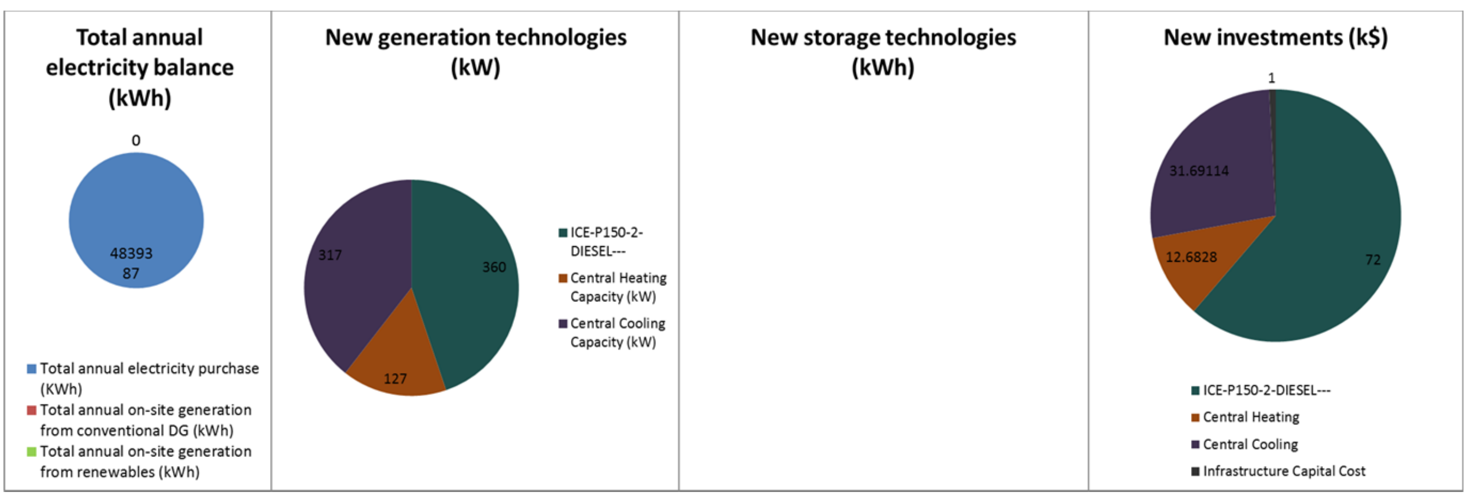

Figure 4 DER-CAM investment results – minimizing annual energy cost only

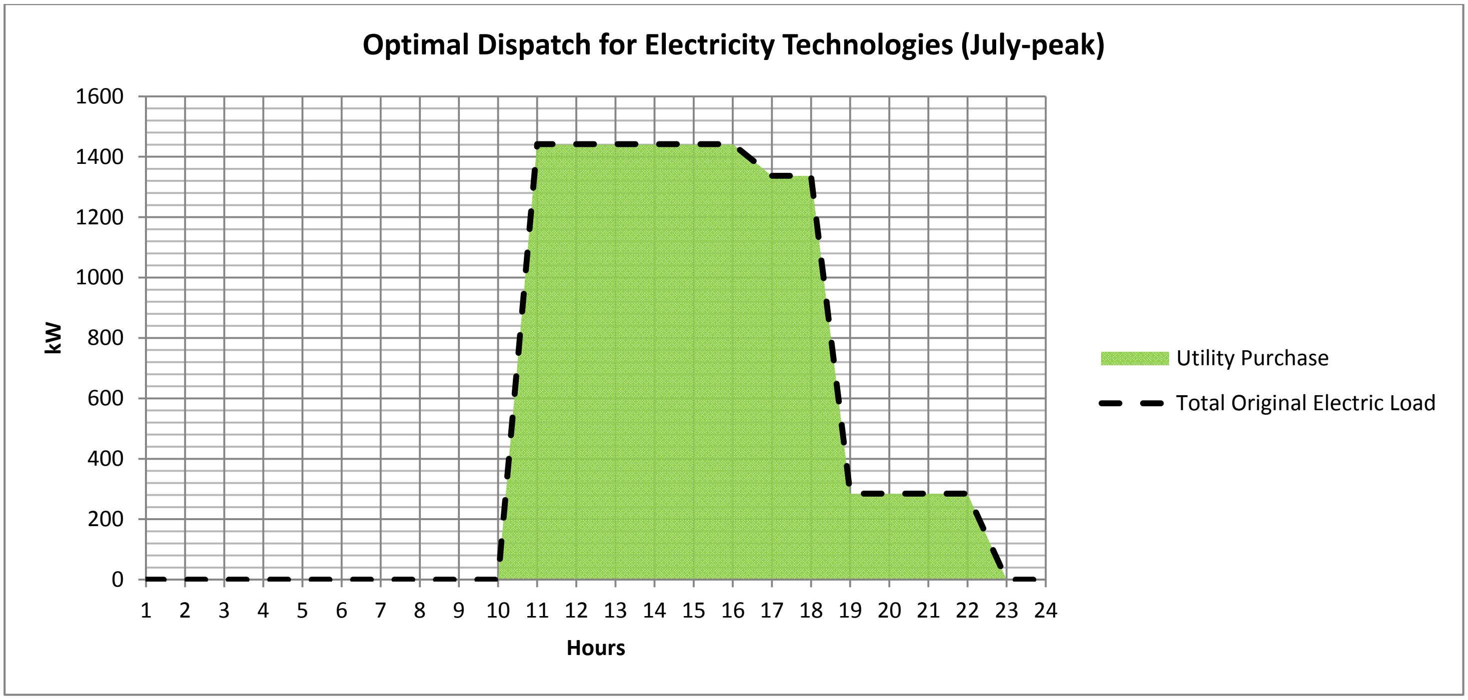

Figure 5 the detail electricity operation during peak day in July - minimizing annual energy cost only

DER-CAM output file - *BrookhavenTownHall (1.00Cost).xlsm*

b) Minimizing annual energy cost 0.75 weighting factor

Table 2 the annual costs and CO_2 emissions savings by the investment – minimizing annual energy cost 0.75 weighting factor

	Base Case (no investment)	Investment Case (investment)	Reduction
Total Annual Energy Costs ($)	$ 454,753	$ 460,500	*+ $ 5,747*
Total Annual CO_2 emissions (kg)	2,513,519 kg	2,513,519 kg	-

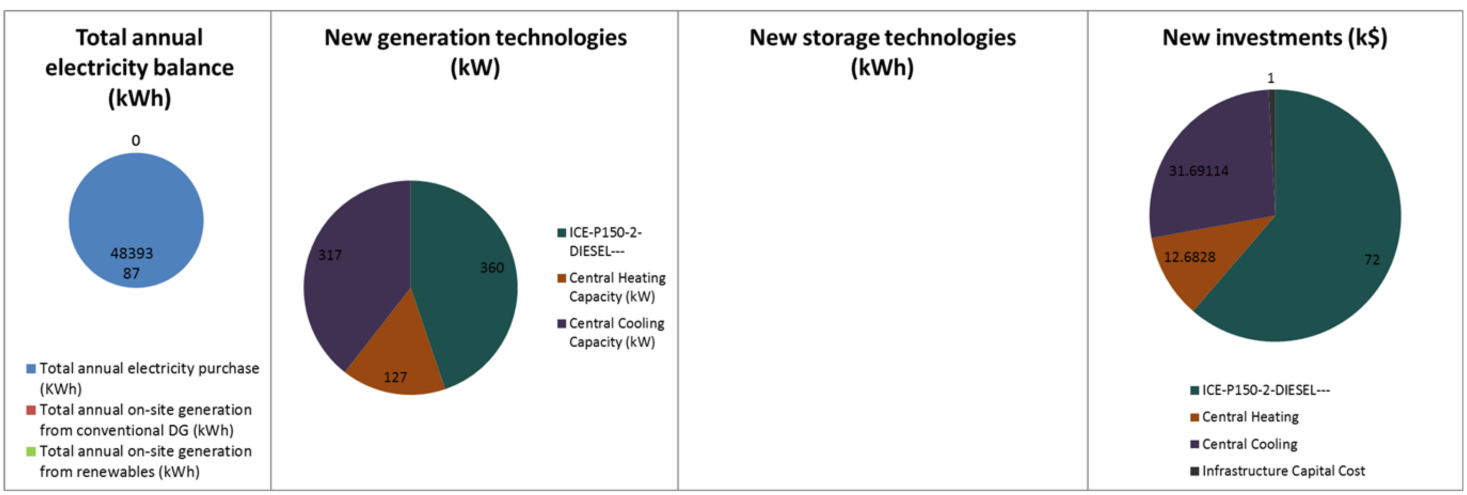

Figure 6 DER-CAM investment results – minimizing annual energy cost 0.75 weighting factor

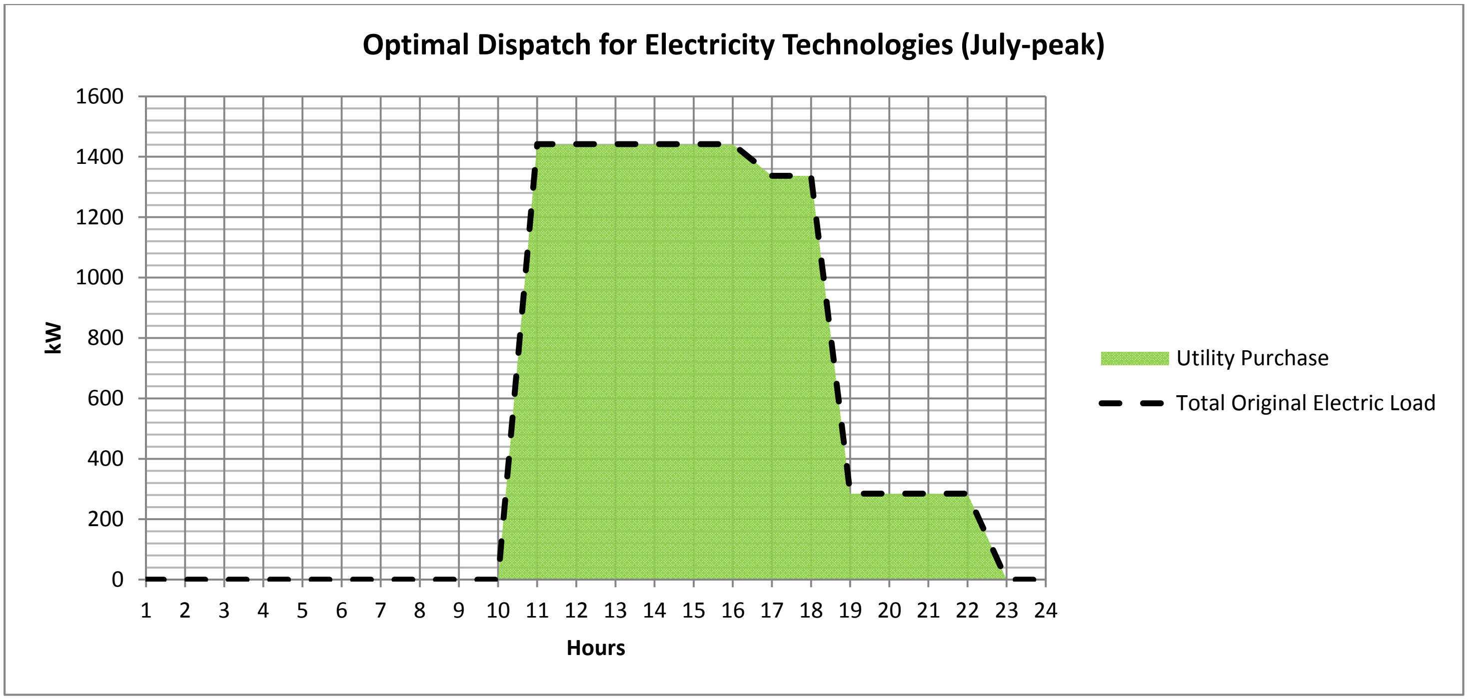

Figure 7 the detail electricity operation during peak day in July - minimizing annual energy cost 0.75 weighting factor

DER-CAM output file - *BrookhavenTownHall (0.75Cost).xlsm*

c) Minimizing annual energy cost 0.50 weighting factor

Table 3 the annual costs and CO_2 emissions savings by the investment – minimizing annual energy cost 0.50 weighting factor

	Base Case (no investment)	Investment Case (investment)	Reduction
Total Annual Energy Costs ($)	$ 454,753	$ 607,546	*+ $ 152,793*
Total Annual CO_2 emissions (kg)	2,513,519 kg	1,193,078 kg	*- 1,320,441 kg*

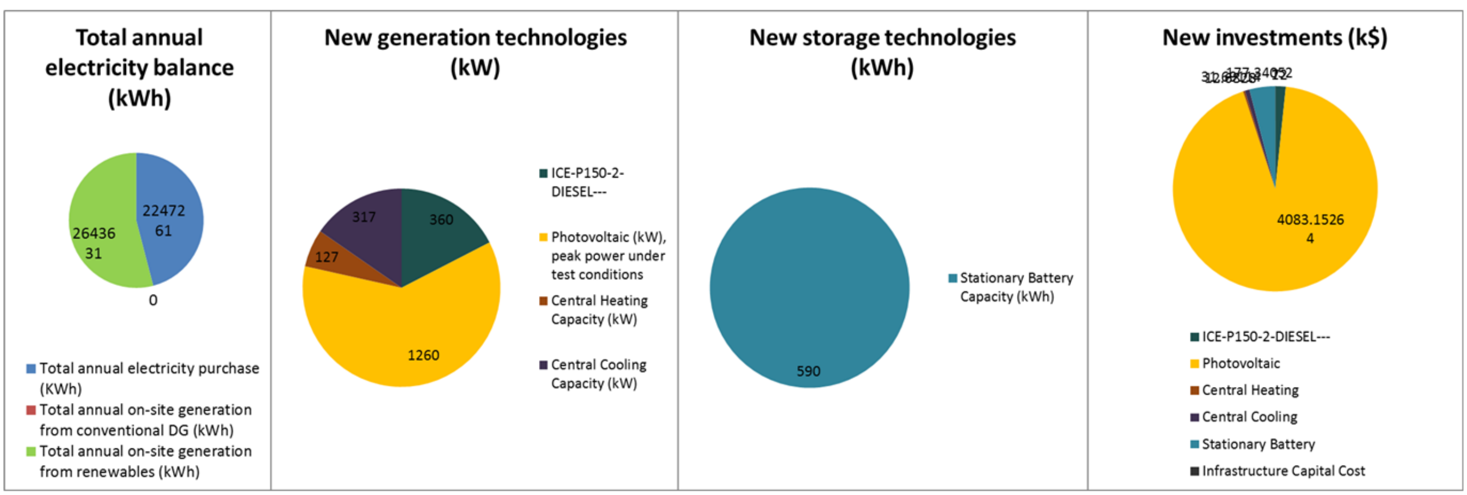

Figure 8 DER-CAM investment results – minimizing annual energy cost 0.50 weighting factor

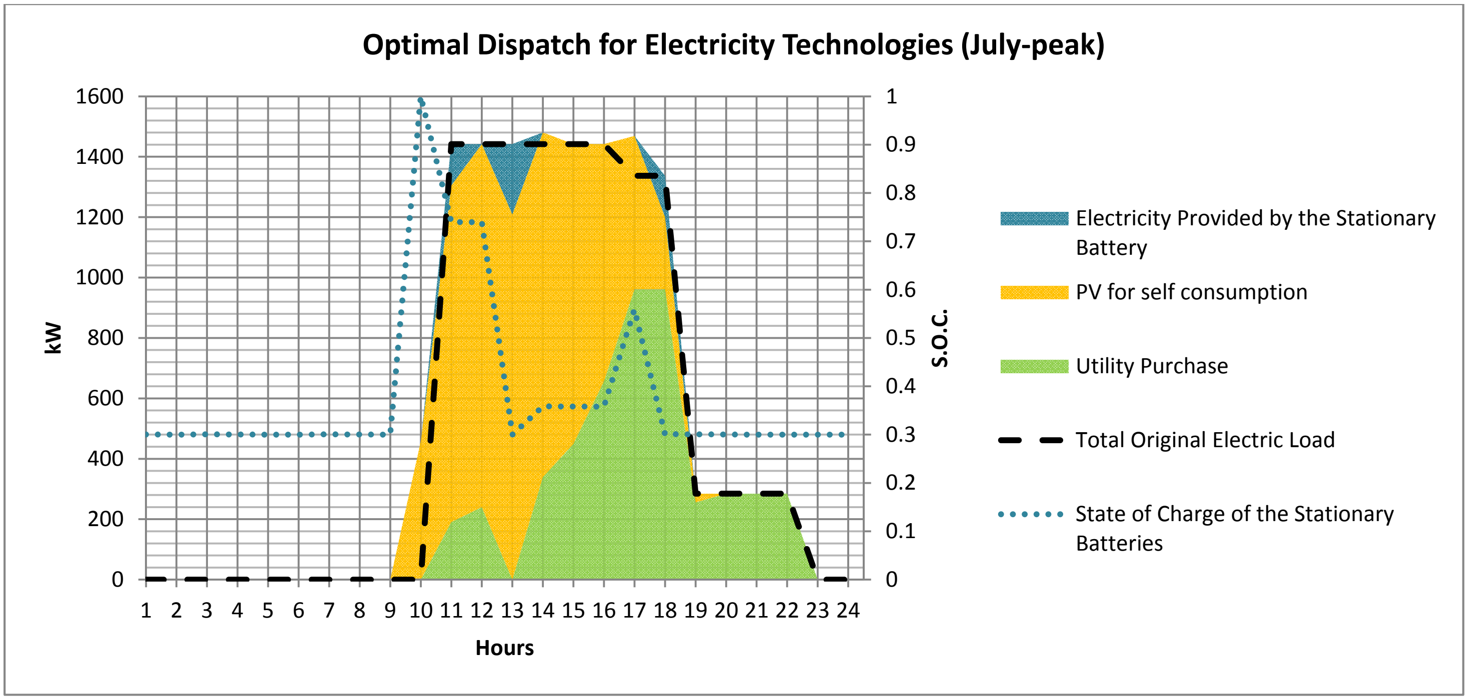

Figure 9 the detail electricity operation during peak day in July - minimizing annual energy cost 0.50 weighting factor

DER-CAM output file - *BrookhavenTownHall (0.50Cost).xlsm*

d) Minimizing annual energy cost 0.25 weighting factor

Table 4 the annual costs and CO_2 emissions savings by the investment – minimizing annual energy cost 0.25 weighting factor

	Base Case (no investment)	Investment Case (investment)	Reduction
Total Annual Energy Costs ($)	$ 454,753	$ 781,666	*+ $ 326,913*
Total Annual CO_2 emissions (kg)	2,513,519 kg	677,256 kg	*- 1,836,263 kg*

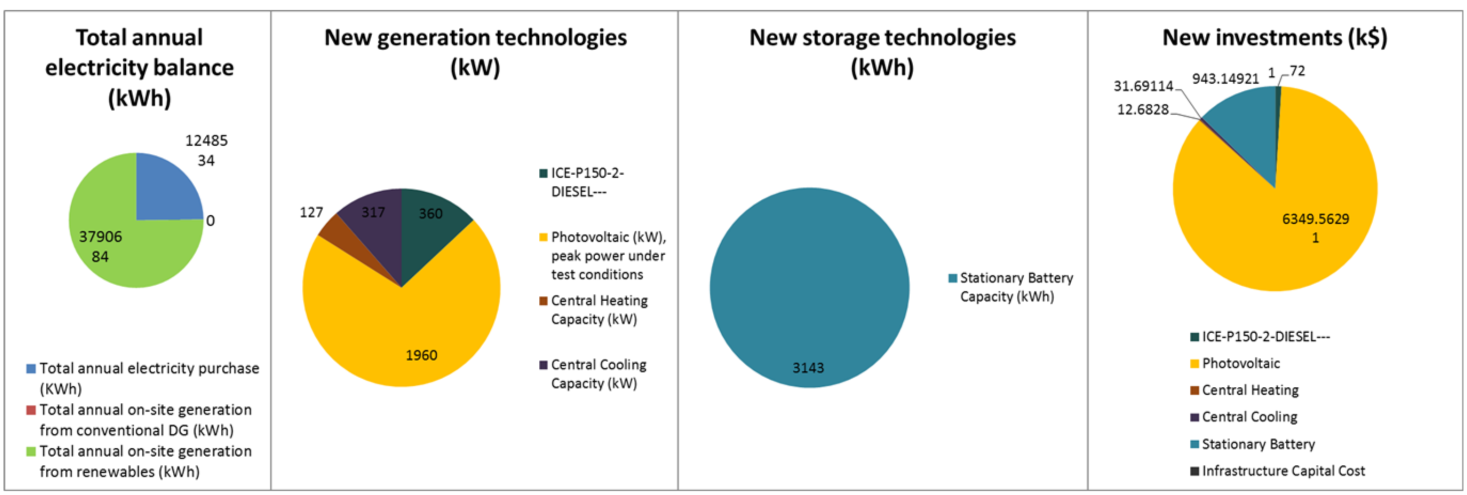

Figure 10 DER-CAM investment results – minimizing annual energy cost 0.25 weighting factor

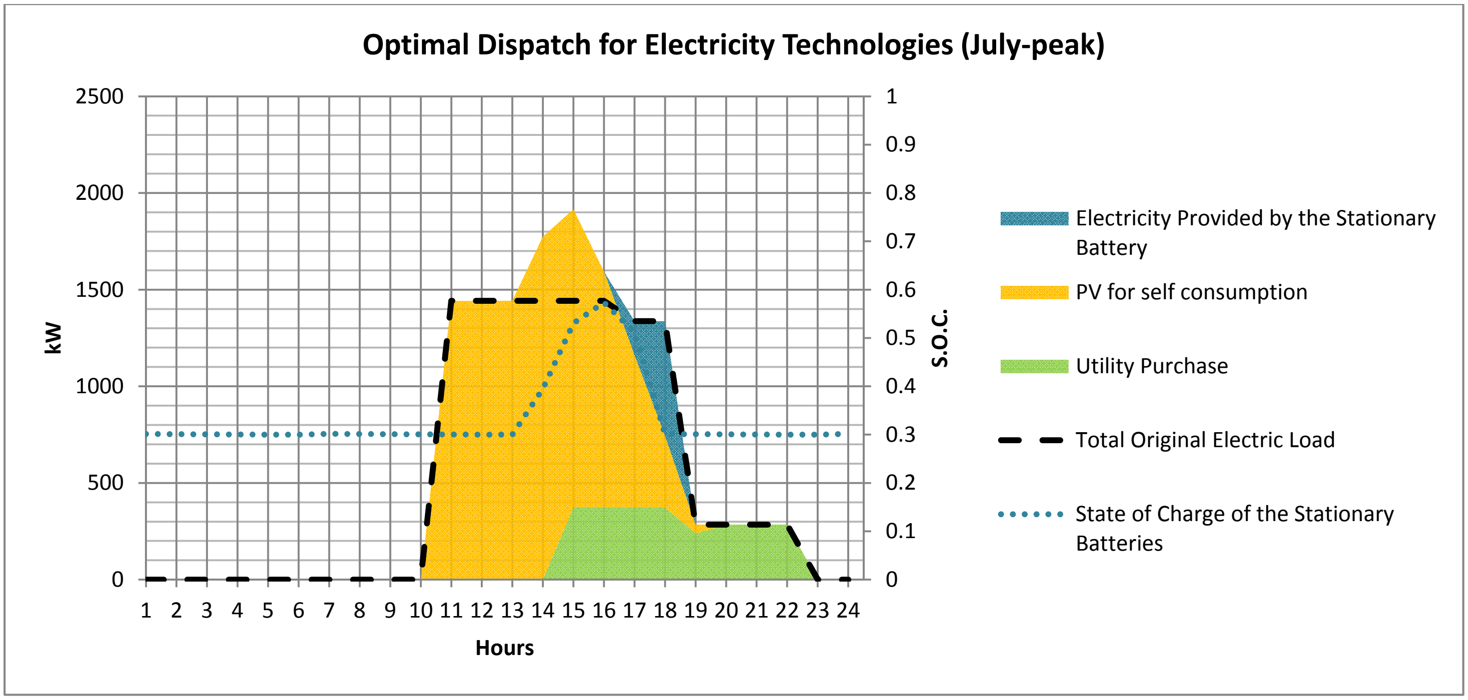

Figure 11 the detail electricity operation during peak day in July - minimizing annual energy cost 0.25 weighting factor

DER-CAM output file - *BrookhavenTownHall (0.25Cost).xlsm*

e) Minimizing annual CO_2 emission only

Table 5 the annual costs and CO_2 emissions savings by the investment – minimizing annual CO_2 emission only

	Base Case (no investment)	Investment Case (investment)	Reduction
Total Annual Energy Costs ($)	$ 454,753	$ 3,476,860	***+ $ 3,022,107***
Total Annual CO_2 emissions (kg)	2,513,519 kg	42,653 kg	***- 2,470,866 kg***

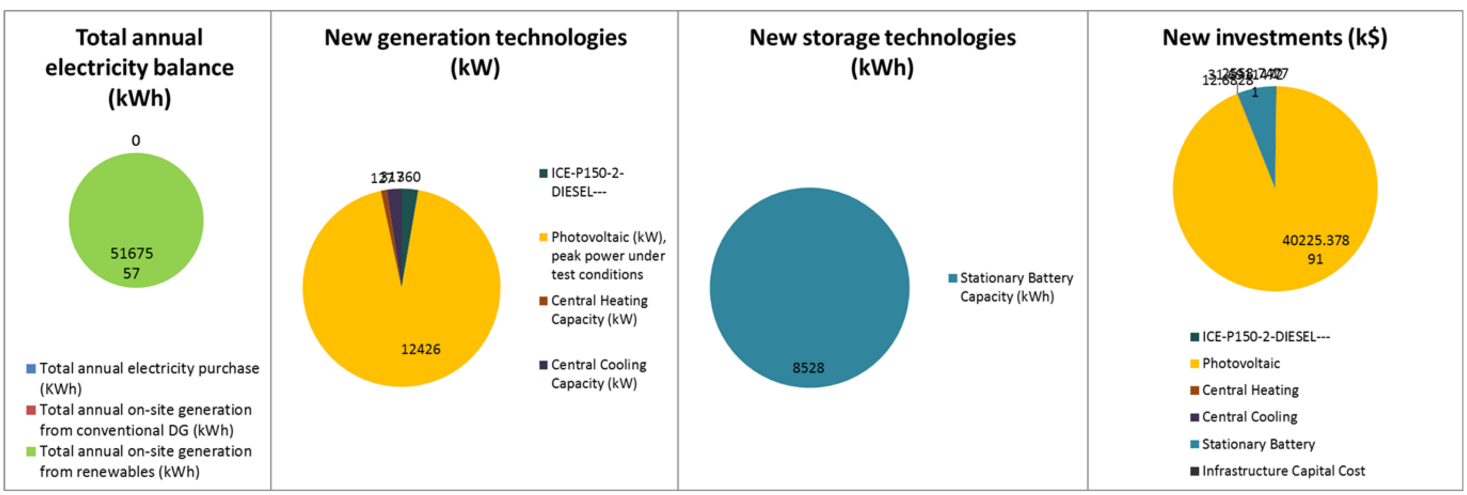

Figure 12 DER-CAM investment results – minimizing annual CO_2 emission only

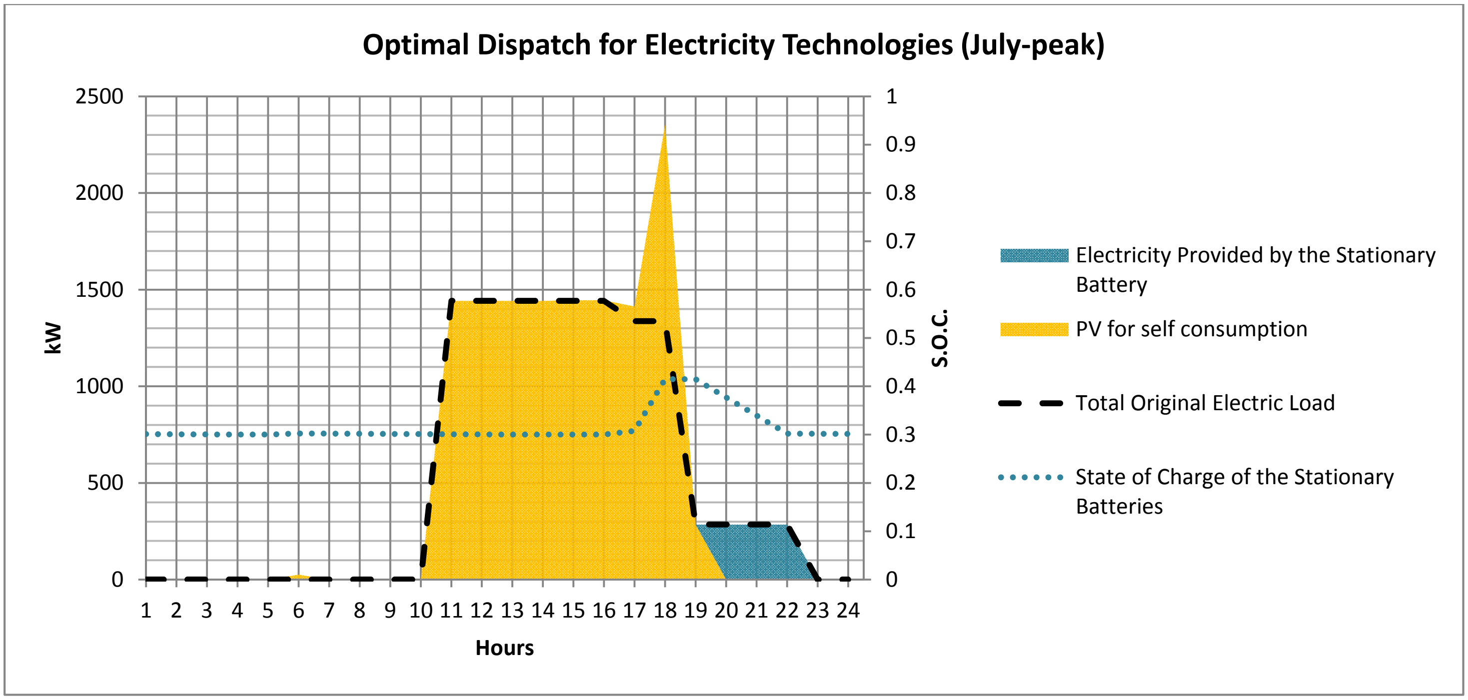

Figure 13 the detail electricity operation during peak day in July - minimizing annual CO_2 emission only

DER-CAM output file - *BrookhavenTownHall (0.00Cost).xlsm*

Appendix C

The Benefit-Cost Analysis Summary Report

Benefit-Cost Analysis Summary Report

Site 6 – Town of Brookhaven

PROJECT OVERVIEW

As part of NYSERDA's NY Prize community microgrid competition, the Town of Brookhaven – a community of approximately 500,000 residents in Suffolk County – has proposed development of a microgrid that would enhance electric service for two facilities:

- Brookhaven Town Hall, which provides office and meeting space for the town's elected and appointed officials and supports a number of municipal services, including an emergency call center.[1]
- Sachem High School East, one of the local school district's two high schools, with a student body of approximately 2,300 and a faculty of approximately 150 teachers.[2]

The primary source of power for the microgrid would be two new natural gas-fired combined heat and power (CHP) systems: a 1.148 MW unit that would be located at the town hall; and a 0.383 MW unit that would be located at the high school. The microgrid would also incorporate two 10 kW wind turbines and two 300 kW diesel backup generators that currently serve these facilities. The CHP units and the wind turbines would produce electricity during periods of normal operation. In contrast, the diesel generators would operate only during a major power outage, when the microgrid would operate in islanded mode.[3] During a major outage, the system would have sufficient generating capacity to keep the two facilities fully operational.

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.

[1] http://www.brookhaven.org/Departments/Town-Directory.

[2] http://www.usnews.com/education/best-high-schools/new-york/districts/sachem-central-school-district/sachem-high-school-east-14039.

[3] Because the wind turbines are already installed and operating, the energy they generate and the capacity they provide are not treated as benefits of the microgrid. Similarly, because the diesel generators would continue to operate solely on an emergency basis, neither the capacity nor the resiliency they provide is treated as a benefit of the microgrid.

- 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.[4] It also calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the ratio of project benefits to project costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2014 dollars.

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

The BCA considers costs and benefits for two scenarios:

- Scenario 1: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).

- Scenario 2: The average annual duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under Scenario 1.[5]

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

[5] 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

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

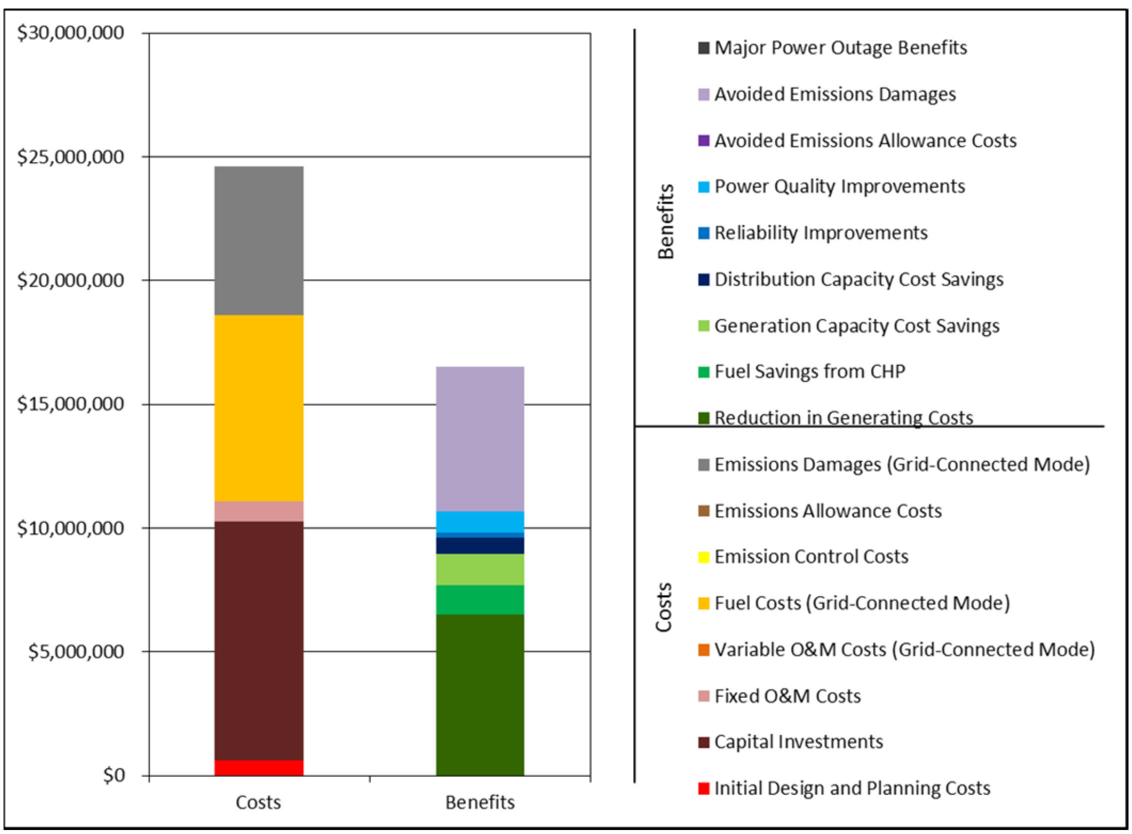
Table 1. BCA Results (Assuming 7 Percent Discount Rate)

	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
ECONOMIC MEASURE	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 1.8 DAYS/YEAR
Net Benefits - Present Value	-$8,120,000	$187,000
Benefit-Cost Ratio	0.7	1.0
Internal Rate of Return	-5.6%	7.3%

Scenario 1

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

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



caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

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

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$611,000	$53,900
Capital Investments	$9,650,000	$851,000
Fixed O&M	$816,000	$72,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$7,520,000	$663,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$6,030,000	$394,000
Total Costs	**$24,600,000**	
Benefits		
Reduction in Generating Costs	$6,520,000	$575,000
Fuel Savings from CHP	$1,150,000	$102,000
Generation Capacity Cost Savings	$1,300,000	$115,000
Distribution Capacity Cost Savings	$634,000	$55,900
Reliability Improvements	$200,000	$17,600
Power Quality Improvements	$855,000	$75,400
Avoided Emissions Allowance Costs	$3,270	$289
Avoided Emissions Damages	$5,830,000	$381,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$16,500,000**	
Net Benefits	**-$8,120,000**	
Benefit/Cost Ratio	**0.7**	
Internal Rate of Return	**-5.6%**	

Fixed Costs

The BCA relies on information provided by the project team to estimate the fixed costs of developing the microgrid. The project team's best estimate of initial design and planning costs is approximately $611,000. The present value of the project's capital costs is estimated at approximately $9.6 million, including costs associated with acquiring and installing the new CHP units; new distribution equipment (e.g., switchboards, transformers, and switches); controllers and other IT hardware and software; low and medium voltage cables; and the cost of trenching to bury the distribution lines. The project team estimates fixed operation and maintenance (O&M) costs for the system of approximately $72,000 per year. Over a 20-year operating period, the present value of O&M costs is estimated to be approximately $816,000.

Variable Costs

A significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's two CHP units. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the project team and projections of fuel costs from New York's 2015 State

Energy Plan (SEP), adjusted to reflect recent market prices.[6] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $7.5 million.

In addition, the analysis of variable costs considers the environmental damages associated with pollutant emissions from the distributed energy resources that serve the microgrid, based on the operating scenario and emissions rates provided by the project team and the understanding that none of the system's generators would be subject to emissions allowance requirements. In this case, the damages attributable to emissions from the microgrid's CHP units are estimated at approximately $394,000 annually. The majority of these damages are attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $6.0 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 Town of Brookhaven'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 $6.5 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. In addition, the new CHP systems would cut consumption of natural gas for heating purposes; the present value of these savings over the 20-year period analyzed is approximately $1.2 million. The reduction in demand for electricity from bulk energy suppliers and reduction in the amount of fuel needed to heat the school and town hall would also reduce emissions of air pollutants from these sources. The present value of these benefits is approximately $5.8 million.[7]

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.[8] The analysis estimates the impact of the project on generating capacity requirements based on the nameplate capacity of the two new CHP units; this approach yields annual benefits of approximately $115,000, with a present value of approximately $1.3 million over a 20-year period. The analysis estimates the impact of the project with respect to distribution capacity requirements on a similar basis, yielding annual benefits of approximately $55,900. Over a 20-year period, the present value of these benefits is approximately $634,000.

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 $17,600 per year, with a present value of $200,000 over a 20-year operating period. This estimate is calculated using

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

[7] 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.

[8] 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.

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:[9]

- System Average Interruption Frequency Index (SAIFI) – 0.72 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 81.6 minutes.[10]

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.[11] 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 0.7; i.e., the estimate of project benefits is approximately 70 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.[12,13]

As noted above, the Town of Brookhaven's microgrid project would serve two facilities during an extended outage: Brookhaven Town Hall and Sachem High School East, both of which are currently

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[9] www.icecalculator.com.

[10] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for PSEG Long Island.

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

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

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

equipped with 300 kW diesel backup generators. According to the project's consultants, however, neither of these units is large enough to keep the facilities they serve operational; the generator at the town hall can supply only 26 percent of the building's typical load, while the generator at the high school can supply only 37 percent. They indicate that both buildings would need to be evacuated in the event of outage, regardless of whether their backup generators function as designed. Thus, they anticipate that an outage would lead to a complete loss in the service capabilities of these facilities, both when relying on their backup generators and in the event that these units fail. They also indicate that a loss of power at the town hall would adversely affect the call center in the town hall that serves the Suffolk County Police Department.

The information provided above provides a baseline for evaluating the benefits of developing a microgrid. Specifically, the assessment of Scenario 2 relies on the following assumptions, as specified by the project's consultants, to characterize the impacts of a major power outage in the absence of a microgrid:

- Both Brookhaven Town Hall and Sachem High School East would be evacuated, regardless of the performance of their backup generators. In each case, the facility would experience a total loss in operating capabilities.

- The impact of the outage on the call center at the town hall would reduce the effectiveness of the Suffolk County Police Department in the Town of Brookhaven by approximately 15 percent.

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 relies on standard FEMA methods to calculate the cost of a 15 percent loss in service effectiveness for the Suffolk County Police Department. It employs the ICE Calculator to estimate the social benefit of keeping the town hall and school fully operational, based on the amount of electricity each facility uses. The calculator provides the following estimates:

- For Brookhaven Town Hall, a value of approximately $188,000 per day.

- For Sachem High School East, a value of approximately $169,000 per day.

Based on these values and the adverse impact on police services, the analysis estimates that the economic cost of a loss of power at the town hall and school is approximately $408,000 per day.[14]

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 1.8 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.

[14] The project's consultants indicate that a loss of power would also affect the wastewater pumping station that serves the town hall. Since the analysis of the impact of a major power outage assumes that the town hall would experience a total loss in operating capabilities, it does not separately consider the impact of a loss in wastewater services; to do so would result in double-counting. Similarly, the project's consultants indicate that in addition to serving the purposes for which they were designed, both the town hall and the high school can serve as emergency shelters. In the event of an emergency, each could accommodate approximately 200 residents. We estimate the value of each building when serving solely in this capacity as approximately $10,000 per day. This figure is based on each facility's shelter capacity (200 people) and American Red Cross data on the cost of providing overnight shelter ($50/person/day). It is our understanding, however, that in the event of an emergency neither facility would operate solely as a shelter. In the absence of additional information, we rely on the ICE Calculator to estimate the benefit of avoiding an interruption in electric service.

Figure 2. Present Value Results, Scenario 2 (Major Power Outages Averaging 1.8 Days/Year; 7 Percent Discount Rate)

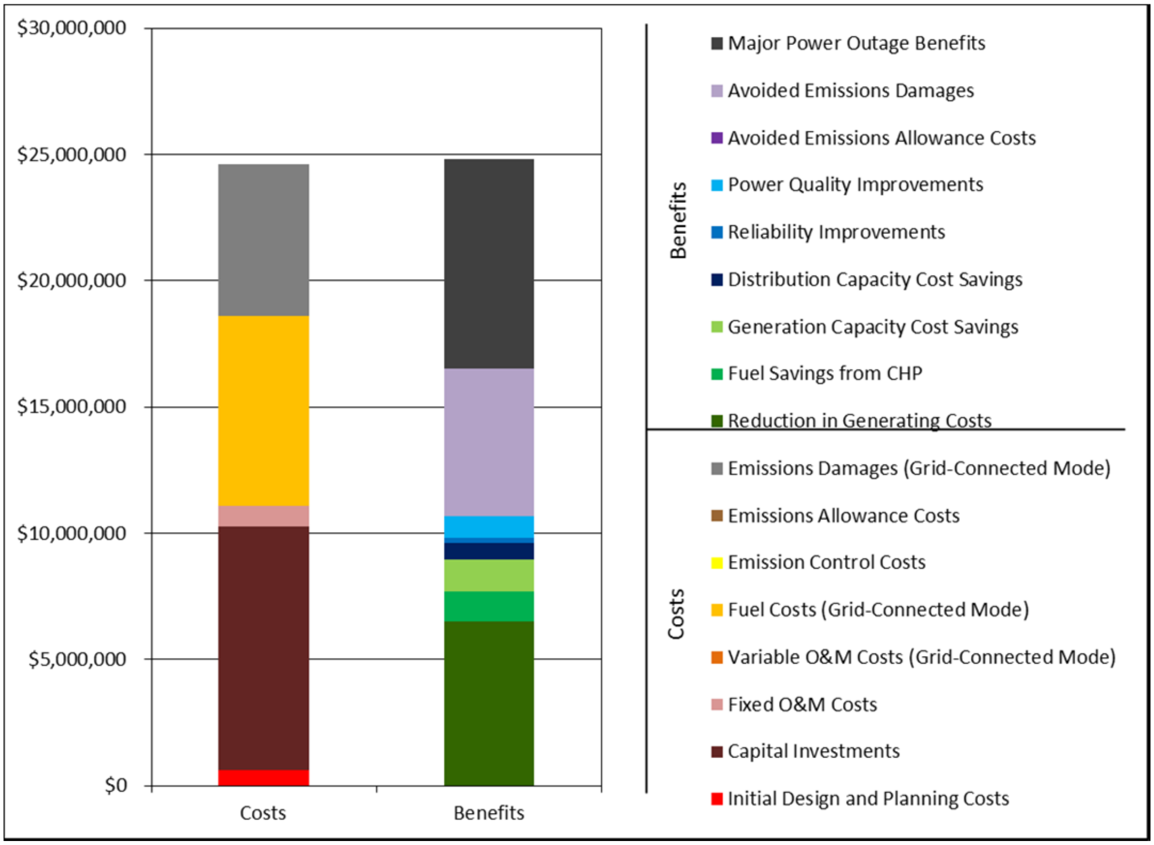

Table 3. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 1.8 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$611,000	$53,900
Capital Investments	$9,650,000	$851,000
Fixed O&M	$816,000	$72,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$7,520,000	$663,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$6,030,000	$394,000
Total Costs	**$24,600,000**	
Benefits		
Reduction in Generating Costs	$6,520,000	$575,000
Fuel Savings from CHP	$1,150,000	$102,000
Generation Capacity Cost Savings	$1,300,000	$115,000
Distribution Capacity Cost Savings	$634,000	$55,900
Reliability Improvements	$200,000	$17,600
Power Quality Improvements	$855,000	$75,400
Avoided Emissions Allowance Costs	$3,270	$289
Avoided Emissions Damages	$5,830,000	$381,000
Major Power Outage Benefits	$8,310,000	$734,000
Total Benefits	**$24,800,000**	
Net Benefits	**$187,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**7.3%**	