# 26 - Village of Sleepy Hollow

August 2016

# Notice

# NY Prize Task 5 Milestone Deliverable:

# Village of Sleepy Hollow Final Report



Submit to:
**NYSERDA**
New York State Energy Research and Development Authority

Submit by:
Willdan Energy Solutions
on behalf of the Villages of Tarrytown and Sleepy Hollow

# Table of Contents

## Tables

## Figures

# Executive Summary

The Village of Sleepy Hollow, located in Westchester County, New York, selected Willdan to perform a community microgrid feasibility study in response to the NY Prize solicitation by NYSERDA. Sleepy Hollow and Tarrytown, both Willdan NY Prize recipients, neighbor each other and share buildings, electrical infrastructure, and a joint authority that operates and maintains the cities' water resources along with nearby Briarcliff Manor.

Willdan has worked closely with its technology partners, community stakeholders, and the electric and gas utility, ConEd, to develop the best case microgrid application to address relatively high electricity prices, around $11.55 cents/kWh, to harden the electric and water utilities with long term generation resources, and to provide a robust solution for the communities in an emergency situation.

This study has resulted in the recommendation of 1,100 kW of natural gas fed generation resources shared between the two communities, with 450 kW of that being Combined Heat and Power (CHP) to provide electric backup and emergency heat to the communities' critical facilities. The critical facilities originally identified were separated based on their electric feeder configuration and utility recommendations into four load clusters as well as additional facilities that would not be in any cluster, but would be considered for behind the meter improvements.

The four clusters are: Sleepy Hollow Cluster 1, which includes Rescue Hose Fire Co, the Police, Village, and Fire Department building, Union Hose Fire Co, and North Tarrytown Housing Authority, Tarrytown Cluster 1, which includes the Police Department, Riverside Hose, and Tarrytown Municipal Housing Authority, Crossover Cluster 1, which includes the sleepy Hollow High School and the John Paulding School, and Crossover Cluster 2, which includes the three water pump stations for Sleepy Hollow, Tarrytown, and Briarcliff Manor. The recommended resources, along with existing backup generators and non-critical load shedding, prove technically and financially viable to support the clustered community microgrid as detailed in the following report.

## Recommendations

### Technical

#### *Phased Design Approach:*

1. Generation Assets: 1,100 kW Natural Gas Fed Generators
2. Load Control and Energy Conservation Measures: Smart Building and Sub-Building Controllers and Energy Management System
3. Wiring Reconfiguration: Four Clustered Microgrids that Maximize Existing Electrical Infrastructure
4. Communication Connectivity: Fiber Optic Backbone, Wireless Mesh Network Deployment
5. Microgrid Master Controller: Connect and Optimize Every Device in the System, Operator Friendly Interface

## Operations and Maintenance

1. Utilize equipment vendor warranties
2. Setup automatic notifications, remote monitoring, automated reporting
3. Train Maintenance Personnel

# Task 1: Description of Microgrid Capabilities

Willdan will demonstrate that the proposed microgrid has the minimum required capabilities:

*Table 1. Total System Community Microgrid Existing and Proposed Overview*[1]

| Category | Existing Resources | Proposed/Suggested Improvement | Justification |
|---|---|---|---|
| Load | • 18 public Critical facilities<br>• Over 1,670.6 kW coincident peak electrical demand<br>• Over 141.52 Therms/Hr peak gas demand | • Building Energy Efficiency<br>• LED Street lighting<br>• Load Curtailment<br>• Peak Shaving | • Resilience<br>• Cost Savings |
| Distributed Energy Resources (DERs) | • At least 8 Backup Diesel Generators with capacity totaling over 655[2] kW<br>• 2 backup Natural Gas Generators with capacity totaling 180 kW | • 150 kW Natural Gas Fired CHP for Sleepy Hollow Cluster 1<br>• 150kW Natural Gas Fired CHP for Tarrytown Cluster1<br>• 300kW Natural Gas Fired CHP for Crossover Cluster 1<br>• 500kW Natural Gas Fired Generator for Crossover Cluster 2 | • Demand Response Revenue<br>• Resilience<br>• Renewable Sources |
| Electrical and Thermal Infrastructure | • 13 kV Primary Feeder<br>• Underground Secondary Network<br>• Network of Natural Gas Mains | • High Reliability Distribution System<br>• Self-Healing | • Resilience<br>• Reliability |
| Master Controller and Building Controls | • Limited Building Controls | • Connected Master controller<br>• Upgraded building controls | • Resilience<br>• Optimal utilization of Microgrid Assets |
| IT/ Communication Infrastructure | • Manual Meters<br>• Some System Level Load metering | • Advanced Metering Infrastructure (AMI)<br>• 900 MHz mesh network<br>• Fiber optic backbone<br>• Control interface for DER | • Resilience<br>• Reliable real time information<br>• Remote Control |

[1] Estimation of the costs and benefits at this stage of the NY prize competition (Feasibility) is likely to be accurate within +/- 30%. The emphasis at this stage of analysis is on establishing a reasonable basis for competing for funding for a detailed, audit-grade engineering and business case analysis at a subsequent stage of the NY Prize Community Grid Competition.

[2] This number was obtained from the available information at the time; a reported 30 kW generator, 80 kW generator, and 175-200 kW generator (assumed to be 175 kW) and one confirmed generator with unreported capacity that was estimated to be 200 kW based on the ratio of the peak electric demand vs generator size of other buildings in Tarrytown.

## Introduction

The Village of Sleepy Hollow is proposing a feasibility study to implement a community microgrid ("Sleepy Hollow Community Microgrid"). Con Edison will act as the local electric distribution company and the gas distribution company during this feasibility study and will be joined by the Village of Sleepy Hollow participating as the Local Government.

The Village of Sleepy Hollow is an economically and culturally diverse community with a population of 10,000. Sleepy Hollow shares a public school system with Tarrytown (Public Schools of the Tarrytowns) as well as water resources and a large community border. The Lower Hudson Valley has been increasingly affected by severe weather with disruptions to basic services resulting from outages from major storms such as Lee, Sandy and the October 2011 Winter Storm and more localized severe weather related problems such as the 2006 Westchester County tornado which cut power to 10,000 people in the county. Willdan proposes a community microgrid for the Village, which will enhance the overall operational reliability of the electrical distribution system for all of the stakeholders, by providing a master controller which has the ability to perform, in real-time, reconfiguration of the microgrid functions, seamless islanding for economic, reliability, or resilience reasons, and optimization of generation resources.

The Village's critical loads will remain powered on while the microgrid is islanded. In addition to providing resiliency for critical loads, Willdan's proposed Community microgrid could provide economic and reliability benefits for the Village's electric power customers including critical facilities such as fire and police public safety services, medical services, and water treatment plants, as well as maintaining power for public street lighting and security lighting all across Sleepy Hollow while the microgrid is islanded and during any prolonged period of loss of bulk power.

The existing technologies that support smart grid and microgrid capabilities will be screened for their application to the Community microgrid. This involves appropriating the benefits to the specific wants and needs of the stakeholders as well as thinning the list to the reasonable and applicable technologies for the region. The remaining technologies, applications, and revenue streams are then evaluated based on financial and technical feasibility in their application to the Community microgrid. This primarily consists of detailed research into the existing infrastructure available and compatibility of the proposed technology with this infrastructure and with the other resources available in the microgrid. Finally, the passing technologies are studied in detail, with tools such as the Distributed Energy Resources Customer Adoption Model (DER-CAM), to determine the range of acceptable capacity as well as the rough costs and cost savings.

## Community Microgrid

Willdan proposes a community microgrid for the Village of Sleepy Hollow, which will enhance the overall operational reliability of the electrical distribution system. By providing a master controller, the Community Microgrid would be capable of seamless islanding and resynchronization for economic, reliability, or resilience purposes. Seamless islanding and resynchronization is defined as automatic separation from the grid on loss of utility power and automatic restoration of grid power after an outage on the grid side is cleared.

Normal operating conditions would see reliability improvements, through infrastructure reconfiguration, such as a High Reliability Distribution System (HRDS) which senses and clears faults with virtually no impact on building loads, to a self-healing and more fault tolerant grid, by reducing the number of single points of failure by adding redundancy to the electrical and communications networks, and by adding alternate sources of generation to serve critical and non-critical loads. In addition to increased reliability, or a reduction in the frequency and/or duration of outages, the Community Microgrid would reap economic benefits in the form of added revenue streams from demand response, alternate generation sources, and energy efficiency measures to reduce overall energy costs. as Additional revenue streams could be realized by participating in ancillary service markets such as fast regulation and operating reserve markets. Based on the price of electricity and availability of Distributed Energy Resources (DERs), the master controller will optimally dispatch the units to provide the cheapest, cleanest, and most reliable energy possible to the critical and non-critical microgrid facilities.

During emergency operating conditions, the Community Microgrid master controller would optimize generation and load to provide uninterrupted power to critical loads, through the use of DERs and load shedding schemes that ensure safe and reliable operation of the buildings that matter most in emergency situations. Long term outages will be mitigated by large natural gas fed combined heat and power (CHP) plant, which will maintain a black-start capability in the event the outage occurs when the CHP facility is not active. These plant or plants will rely on robust natural gas pipelines and produce enough power to serve all of the critical facilities, public street and security lighting, and some residential load. This added resiliency will keep emergency responders and residents safe and provide the Community Microgrid with heat and power when it needs it most.

# Load

## Sleepy Hollow Existing Resources

The total population of Sleepy Hollow Electric's service territory is approximately 10,000. During the winter season, Sleepy Hollow depends on natural gas for heating. Figure 14[1] shows the monthly average demand for the load in Sleepy Hollow and Tarrytown .The locations of the nine critical facilities are shown in figure 1.

As Willdan is working closely with the community members and ConEd to acquire all of the necessary information to successfully perform the feasibility study, Task 2 will see more detailed load information for the critical facilities, and for the identified clusters, as well as specific analyses. To avoid additional delays in Task 1, this information was temporarily left out and added into Task 2 and the final reports.

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[1] This is shown in Figure 14 as it was included in Task 2 when more data was available at the recommendation of the NYSERDA project manager.

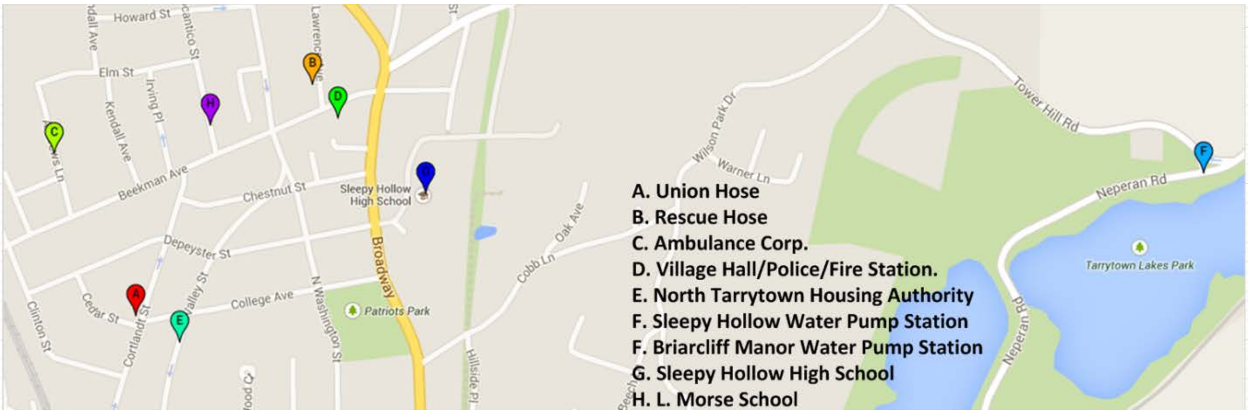



*Figure 1. Critical Facilities for the Sleepy Hollow Community Microgrid*

The Village Sleepy Hollow's loads can be separated into the broad load categories, critical and non-critical. The Sleepy Hollow critical facilities include the Union House, the Rescue House, the Ambulance Corp. the Village Hall/Police/Fire Station, the North Tarrytown Housing Authority, the Sleepy Hollow High School, and the W.L. Morse School, and the non-critical facilities include the many other businesses and residential customers. The electric critical load demand in year 2014 is over 540 kW for Sleepy Hollow and the total electricity usage of critical facilities is 1,860,400 kWh. The load demand in each facility can be further separated into the following load categories as shown in table 2 to describe the unique nature of, and opportunities available for, the different load types. The detailed load information for all the critical loads are shown in table 3. The facilities depend on natural gas for heating in winter seasons.

Sleepy Hollow has already implemented several energy efficiency projects which include: hybrid geothermal domestic hot water system in the Municipal Housing Authority facilities, solar array for the Village Hall, oil to natural gas conversion for public schools of the Tarrytowns, and backup diesel generators for all municipal facilities.  These measures have reduced the Village's carbon footprint, improved energy resiliency, and helped the facilities make incremental steps towards load curtailment.

*Table 2. Electrical Load Type*

| Type | Description | Opportunities |
|---|---|---|
| Lighting | General, task, exits, and stairwells, decorative, parking lot, security, normal, and emergency. | Load curtailment |
| Transportation | Elevators, dumbwaiters, conveyors, escalators, and moving walkways. | Critical Load |
| Appliances | Business and copying machines, receptacles for vending machines, and general use | Load curtailment |
| Data processing | Desktop computers, central processing and peripheral equipment, and uninterruptible power supply (UPS) systems, including related cooling | Critical Load |
| Space conditioning | Heating, cooling, cleaning, pumping, and air-handling units | Short term Load curtailment and shifting |
| Food preparation | Cooling, cooking, special exhausts, dishwashing, disposing, and so forth | Load curtailment |
| Plumbing and sanitation | Water pumps, hot water heaters, sump and sewage pumps, incinerators, and waste handling | Short term load curtailment |
| Special loads | For equipment and facilities in mercantile buildings, restaurants, theaters, recreation and sports complexes, religious buildings, health care facilities, laboratories, broad casting stations, and so forth | Critical load |
| Fire protection | Fire detection, alarms, and pumps | Critical Load |
| Miscellaneous loads | Security, central control systems, communications; audio-visual, snow-melting, recreational, or fitness equipment | Critical load |

*Table 3. Sleepy Hollow Critical Loads (Year 2014)*

| **Critical Facilities** | Max kW | Total kWh |
|---|---|---|
| Sleepy Hollow High School | N/A | N/A |
| W.L. Morse School | N/A | N/A |
| Briarcliff Manor Water Pump Station | 168 | 716,000 |
| Union Hose | 10.6 | 23,652 |
| Rescue Hose | 20.1 | 66,216 |
| Ambulance Corp | 22 | 65,256 |
| Village Hall/Police/Fire Station | 68.8 | 321,920 |
| Sleepy Hollow Water Pump Station | 132.8 | 372,800 |
| North Tarrytown Housing Authority | 118.4 | 467,440 |
| **Total** | **540.7** | **2,033,284** |

### Consequences

Sleepy Hollow has been increasingly affected by severe weather condition with disruptions to basic services resulting from outages caused by major storms such as Lee, Sandy, and the October 2011 Winter Storm, and more localized severe weather related problems such as the 2006 Westchester County tornado which cut power to 10,000 people in the county. The system is also entirely reliant on the points of connection with the bulk grid, which represents the primary resiliency issues.

### Opportunities

Sleepy Hollow will explore placing the microgrid's CHP and distributed generation resources near the worst of the residential load pockets to reduce amperage on the substation feeders/transformers. Sleepy Hollow is planning to implement a number of additional Energy Conservation Measure (ECM) upgrades including lighting, steam trap replacement, solar array, and building envelope. The intent is to parlay the energy efficiency and curtailment measures already in place or planned to develop the community grid at the lowest possible cost. By implementing an Advanced Metering Infrastructure (AMI), customers would be provided real-time monitoring of their electricity usage. Through real-time pricing, energy consumers would be encouraged to shift their use from high demand periods to low demand periods. By decreasing peak demand surges the entire energy infrastructure could be run more efficiently.

## Proposed/Suggested Improvements

A community microgrid would be helpful for solving any existing constraints by providing additional capacity and resiliency. Willdan proposes to replace all the existing diesel generators with natural gas fired CHP. Willdan will evaluate supporting critical facilities with distributed generation resources including CHP generators, locating at minimum 1,000 kW of generation resources near critical facilities, which will operate in synchronous and islanded modes to automatically supply facilities in the event of an outage. Additional generation capacity will be considered in steps of 100kW to eliminate excess consumption for the residential and commercial load pockets near the critical facilities. Innovative technologies and new generation sources including solar, wind, tidal, combined heat and power (CHP), power and battery storage, and off-grid hybrid wind and solar LED lighting will also be studied for its environmental and economic benefits.  New CHP plants and demand response would help in mitigating the reliance on power from utility grid. Willdan proposes to replace all the existing lighting with high efficient LED (Light Emitting Diode) fixtures.  By applying the latest building control technology in each building, Sleepy Hollow would be able to have the direct control capability on the curtailable and shift-able loads through a microgrid master controller. Willdan recommends educating the residential customers to participate in peak-load demand response program.

#### *Benefits*

With a community microgrid, the Village would be able to provide more reliable electricity to its electric customers.  The critical facilities would remain powered on in emergency situations and when the power supply from the utility grid is lost. The community microgrid would also help the Village to reduce the high cost of purchasing power from the bulk provider. By using the more efficient and safe LEDs for public street lighting and residential lighting, both commercial and residential customers can reduce maintenance cost and electricity bills. With the capability of direct control of the loads, the Village would not only be able to improve the reliability of the community distribution system, but would have the potential to participate in ancillary service markets such as, frequency regulation, demand response, etc. Electric customers would also have better quality of electricity service while reducing their electricity bills.

### *Barriers*

Implementing the community microgrid would require new investment in generation resources and distribution equipment devices. A greater review of the exact equipment installed must be done to determine any necessary reconfiguration of the existing distribution network and communication system. It would also be necessary to educate the electric customers that would be involved in the demand response program.

## DERs

### Existing Resources

The existing DERs located in the proposed Community microgrid are used primarily as backup generators in the event that utility power is interrupted. The Village has already implemented several ECMs which include backup diesel generators for all municipal facilities. Based on the most recent review, many of the DERs located in the Village are Diesel Generators, distributed among the critical facilities, and retain about a week of fuel. The existing DERs related to critical loads are shown in figure 1. The detailed location and capacity information of the existing DERS are listed in table 4.

*Table 4. Sleepy Hollow Existing Backup Generators*

| Location | Capacity (kW) | Fuel Type |
|---|---|---|
| Sleepy Hollow High School | 0 | N/A |
| W.L. Morse School | 0 | N/A |
| Briarcliff Manor Water Pump Station | YES | TBD |
| Union Hose | 35 kW | Diesel |
| Rescue Hose | TBD | TBD |
| Ambulance Corp | TBD | TBD |
| Village Hall/Police/Fire Station | YES | TBD |
| Sleepy Hollow Water Pump Station | YES | TBD |
| North Tarrytown Housing Authority | 0 | N/A |
| **Total** | **Over 35 kW** | |

### Consequences

Based on the last available information, not all the critical facilities have backup generators to supply power in the event of an emergency. Comparing table 3 with table 4, there is a disparity between the generation available and the peak load of critical facilities. It can be seen that backup generation is not available for Sleepy Hollow High School, W.L. Morse School, and the North Tarrytown Housing Authority. This means that a number of vital critical facilities, including those that would be used as emergency shelters, would be out of power in the event of an emergency, putting the entire county of Westchester in a dangerous position. In addition, the community pays to maintain and test the backup generators, or runs the risk of the generators not working when needed, and doesn't see any value added beyond emergency situations. Finally, it is worth noting that all the generation runs off of diesel fuel, which is a relatively dirty fuel source that reduces the quality of the air and increases the carbon footprint of the Village, and must be stored or shipped into the village in the event of an outage.

### Opportunities

Sleepy Hollow is considering the innovative technologies and new generation sources which include solar, wind, tidal, combined heat and power (CHP), battery storage, and off-grid hybrid wind and solar LED lighting. Based on its close proximity to the Hudson River, Willdan intends to vet the use of "Tidal Electric" and advanced hybrid solar wind technologies as well as solar, and wind. Sleepy Hollow is exploring innovative projects and smart grid circuit isolation to meet its demand and consumption needs such as using combined heat and power (CHP) generation. The Village is interested in exploring an expansion of CHP for a number of their critical facilities. This expansion would allow the Village to participate in Demand Response programs and reduce their dependency on utility electric power purchases.

## Proposed/Suggested Improvements

### DER Technology

Table 5 includes the screened technologies and their barriers and opportunities specific to the Village.

*Table 5. Distributed Energy Resources*

| Type | Description | Barriers | Opportunities |
|---|---|---|---|
| Combined Heat and Power (CHP) | Natural Gas fired turbines used to generate electricity and provide heat to nearby buildings | Space, Capital Cost, Cost of NG, Heating Infrastructure | Clean and Reliable, Reduce winter peak load, Resiliency |
| Solar | Renewable energy source powered by the sun | $/kW of solar is greater than electricity price | Clean, Reduce daytime peak load |
| Electric Storage | Converts electrical energy to chemical or mechanical for rapid dispatch when needed | Space, Capital Cost | Fast Regulation, Provides power during NG spool up |
| ICE Distributed Generation (ICE DG) | Backup generation | Cost, Range of use, Maintenance | Black Start for CHP, Provides power during NG spool up |
| Wind | Renewable energy source powered by the wind | Space, Capital Cost, maintenance | Clean Source |
| Hydro | Renewable energy source powered by the flow of water | Location, Cost, maintenance | Clean Source |
| Alternative Fuel Sources | Production of fuel from local processes (garbage dump, WWTP) | Supply | Converts waste into electricity |
| Tidal | Renewable energy source powered by the wave | Location, Cost, maintenance | Clean Source, Reliable, High Efficiency |

A screening of the available DER technology available to the Community microgrid favors CHP, Batteries as Energy Storage, Anaerobic Digestion as an Alternate Fuel Source, ICE DG[1] as black start generators for CHP, and solar. Based on initial analyses, Wind, Tidal and Hydro, are not justified economically or in terms of resiliency, investment cost or locations and do not merit further consideration.

## *Benefits*

The addition of a range of DERs, including long term sources like CHP, small hydro, and short term sources like Batteries, solar and ICE DG, would allow the Village to operate as a microgrid and to take advantage of new revenue streams such as Demand Response and Fast Regulation Markets. The planned generation capacity and distribution automation capabilities are expected to dramatically increase available capacity for demand-response, increase resiliency through on-site generation, and reduce charges associated with high winter heating loads by utilizing generation near residential load pockets. Distribution of these additional resources close to the school system, the fire department, nursery facilities and other critical facilities, will ensure that critical facilities will remain powered on in emergencies, providing the Village with peace of mind.

[1] In Case of Emergency Distributed Generator.

### *Barriers*

Considering the utilization of equipment vendor warranties, plant managers for CHP will have to be hired internally or externally and training will be required for maintenance and operators of the proposed DERs.

# Electrical and Thermal Infrastructure

## Existing Resources

Consolidated Edison (ConEd) owns and operates the distribution system within the village to serve all the electricity and natural gas customers. A number of clusters of critical facilities have been identified as likely candidates for generation resources and their infrastructure can be seen in two groups, Sleepy Hollow clusters and Crossover clusters with critical facilities in both Sleepy Hollow and Tarryotwn.

### *Sleepy Hollow Cluster*

The identified Sleepy Hollow cluster, figure 2, includes the Rescue Hose and the Village Hall, Police, and Fire department all fed off a 500 kVA transformer off of the Sleepy Hollow 13 kV primary feeder and the Union Hose and the North Tarrytown Housing Authority, each fed off their own individual 500 kVA transformer off the 13 kV primary feeder. There is available Natural Gas on Cortland Street and off of Pocantico Street.

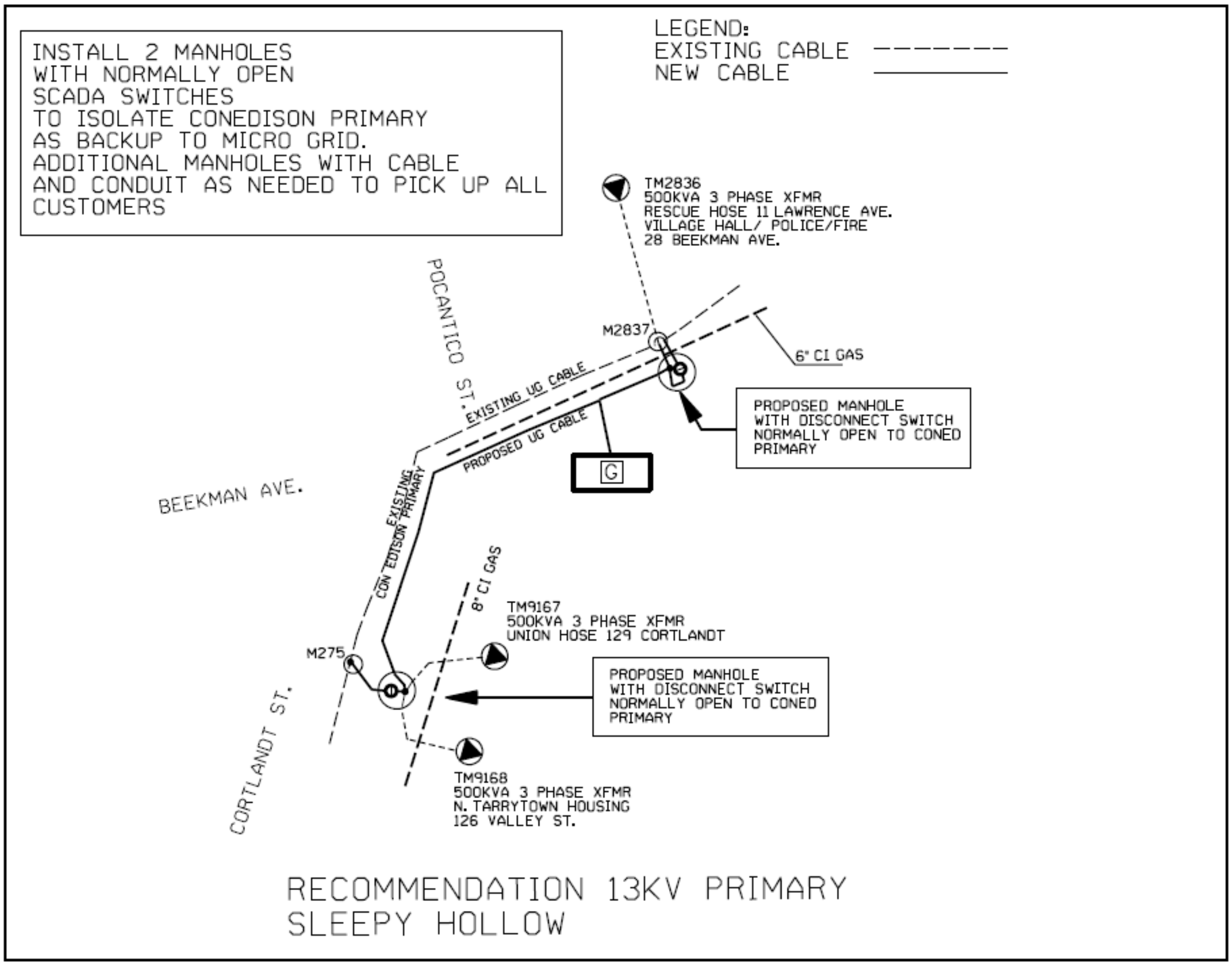



*Figure 2. Sleepy Hollow Cluster*

### *Tarrytown Clusters*

Seen in figure 3 is Tarrytown Cluster 1, which includes the Tarrytown Police and Village Office, the Riverside Hose, and the Tarrytown Municipal Housing Authority (TMHA), connected at the end of a feeder spur. The Tarrytown Police and Village office is fed from a pad mount transformer and Riverside Hose and the TMHA are fed by pole top transformers. There is a 12” medium pressure (MP) natural gas (NG) main running up Franklin Street as well as an 8” MP NG main running down White Street, which is used to heat the critical facilities. There are a number of commercial and residential customers between the critical facilities identified that will be considered as microgrid customers.

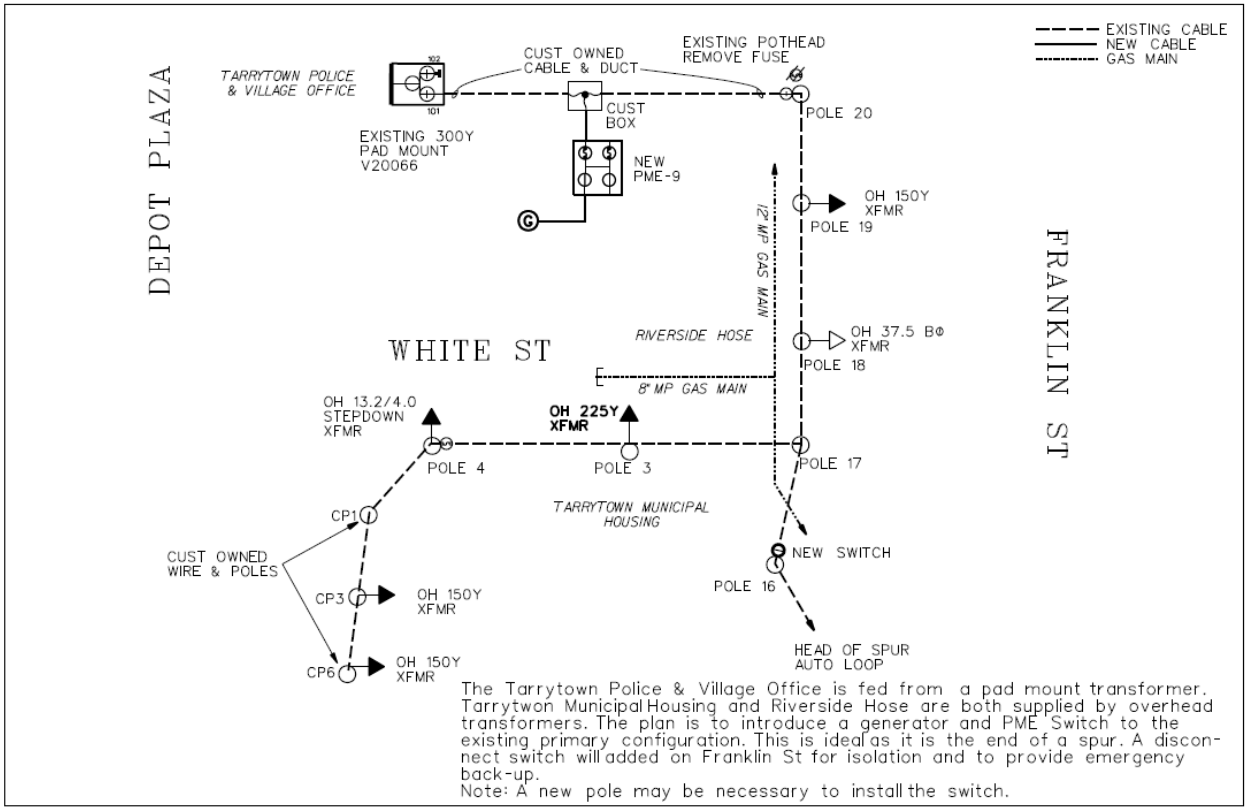



*Figure 3. Tarrytown Cluster 1*

The identified Tarrytown Cluster 2 can be seen in figure 4. All of the shops of the Tarrytown Station Center are fed from the underground secondary network. There are 12" low pressure (LP) NG main running up Cortlandt Street and Wildey Street and 8" High Pressure (HP) NG main running down Central Avenue. 130 Wildey Street through 140 Wildey Street are all fed from this secondary network and can be isolated without affecting other customers.

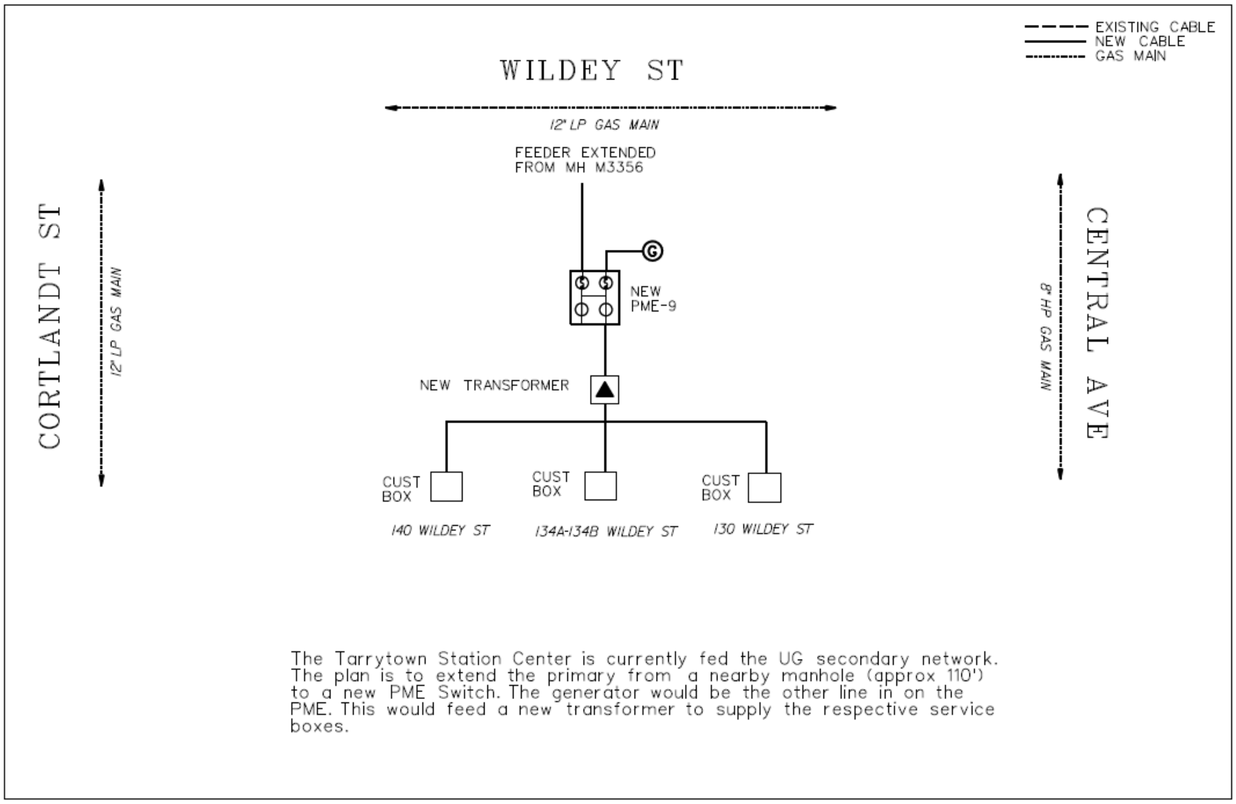



*Figure 4. Tarrytown Cluster 2*

### *Crossover Clusters*

The first of the identified crossover clusters, figure 5, includes both the Sleepy Hollow High and John Paulding Schools which are fed from the underground secondary network. Sleepy Hollow High School has a dedicated pad mount transformer fed from a primary riser. Both schools are directly next to each other and no other customers would have to be recruited to isolate the schools. There is an 8" HP NG main running down Depeyster Street and a 6" LP NG main running up Broadway.

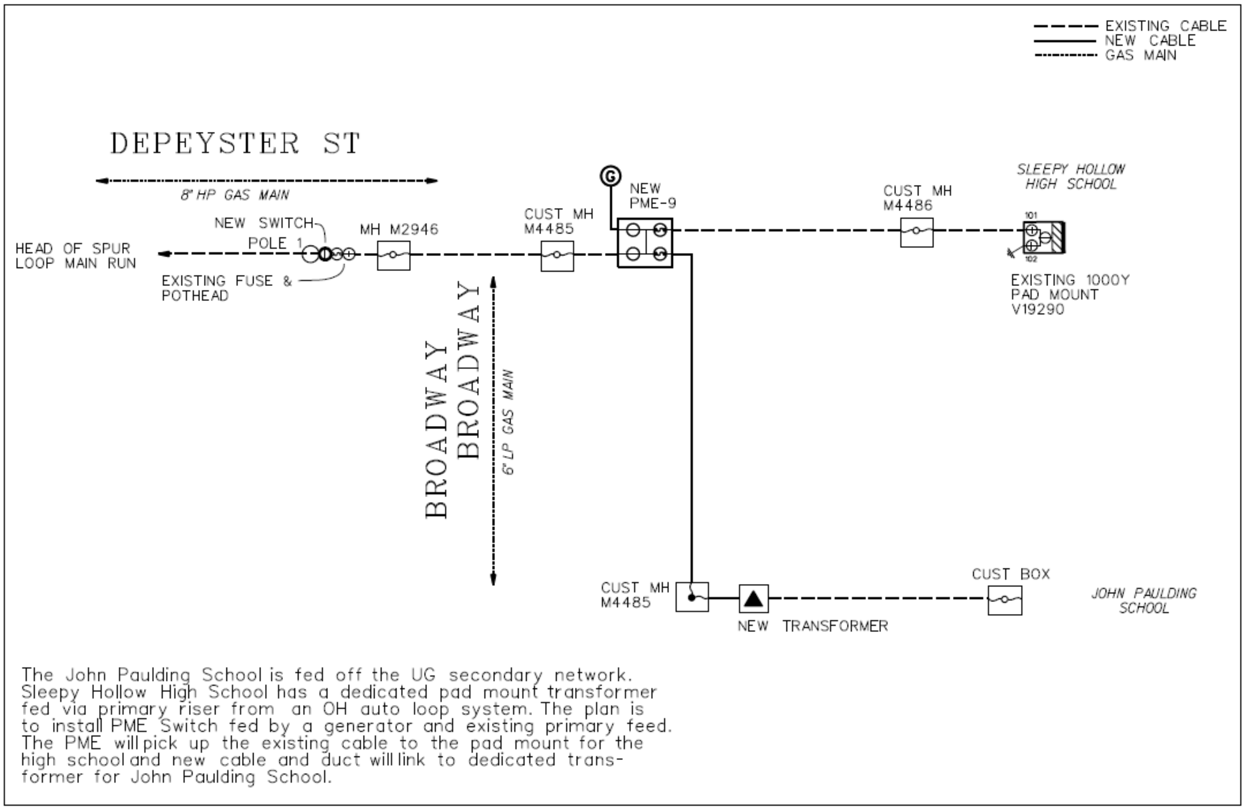



*Figure 5. Crossover Cluster 1*

The second crossover cluster, figure 6, involves three somewhat remote Village pumping stations, Briarcliff, and two for Tarrytown. Each of the three pumping stations is fed from a 500 KVA transformer off of the ConEd open wire primary feeder.

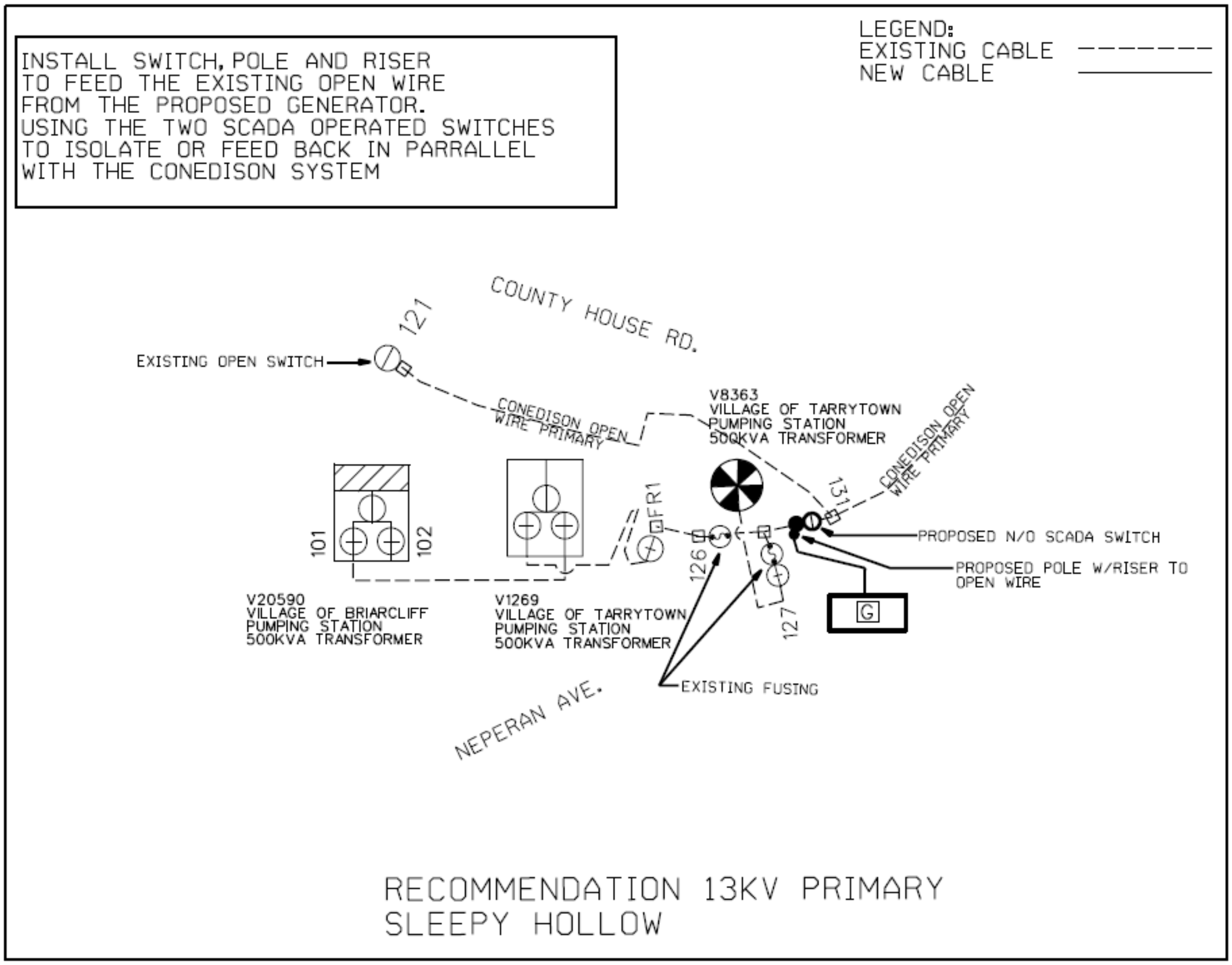



*Figure 6. Crossover Cluster 2*

## Consequences

Sleepy Hollow has been increasingly affected by severe weather with disruptions to basic services resulting from outages from major storms. 2006 Westchester County tornado cuts power to 10,000 people in the county. Any failure at the points of connection would remove electric service to all of the Village's customers, including critical facilities such as fire and police public safety services, and water treatment plants. The communities have long been concerned about the vulnerability to interruption of bulk supply.

## Opportunities

Sleepy Hollow will explore placing the community grid's CHP distributed generation resources near the identified clusters of critical load, while supporting surrounding residential and commercial customers that are interested in resiliency and economic benefits. Investment in a microgrid is a preferred path of the Village to improve the community's safety and resiliency. A community microgrid would solve any constraints by providing additional capacity and resiliency to the electric system. The Village is also looking forward to utilizing the heat produced from planned CHP for heating critical facilities and surrounding buildings.

### Proposed/Suggested

Willdan proposes a Loop-based community microgrid, where possible, for the critical facility clusters. This new distribution network has a meshed structure which can operate as loop or radial, though it is normally operated as radial (i.e., with no loop) so as to make the protection coordination easier (upstream to downstream) and to make the distribution design easier. Also, the Automatic Transfer Switch (ATS) is proposed to be deployed within the community microgrid, which has the capability of network reconfiguration in case of emergency or outage.

#### *Benefits*

The community microgrid can operate in either grid-connected mode or island mode. The distribution network can be easily reconfigured for reliability purpose and minimizing the system loss to 3 to 4 cycles (~40ms). The critical loads can be served by multiple feeders. With the ATS, the community microgrid would be able to automatically isolate those buildings or distribution cables affected by outage, instead of spreading the outage to the whole distribution system.

#### *Barriers*

The existing or future distribution network will need further upgrades which may incur extra investment costs. Also, automatic smart switches are needed for fast automatic switching.

## Master Controller and Building Controls

### Proposed/Suggested Improvements

A major element of the community microgrid is its master controller.  With the master controller, the community microgrid will be capable of fault tolerance, self-healing, emergency demand response, islanding and resynchronization. Various distributed generation and automation technologies for enhancing the power grid economics and resiliency would be enabled. The master controller applies hierarchical control via supervisory control and data acquisition (SCADA) software to ensure reliable and economic operation of the community microgrid. It also coordinates the operation of on-site generation, storage, and individual building controllers. Intelligent switching and advanced coordination technologies of the master controller through communication systems facilitates rapid fault assessments and isolations.

Figure 7 shows the community microgrid elements, functions, and control tasks associated with each criterion. In particular, the tertiary control is the upper level of control system, which ensures the optimal operation of community microgrid by determining the set points of generation and load. In order to achieve the optimal economics, microgrids apply coordination with the utility grid and economic demand response in island mode. The short-term reliability at load points would consider microgrid islanding and resynchronization and apply emergency demand response and self-healing in the case of outages. Functionally, three control levels are applied to the community microgrid:

- Primary control which is based on droop control for sharing the microgrid load among Distributed Energy Resource (DER) units.
- Secondary control which performs corrective action to mitigate steady-state errors introduced by droop control and procures the optimal dispatch of DER units in the microgrid.
- Tertiary control which manages the power flow between the microgrid and the utility grid for optimizing the grid-coordinated operation scheme.

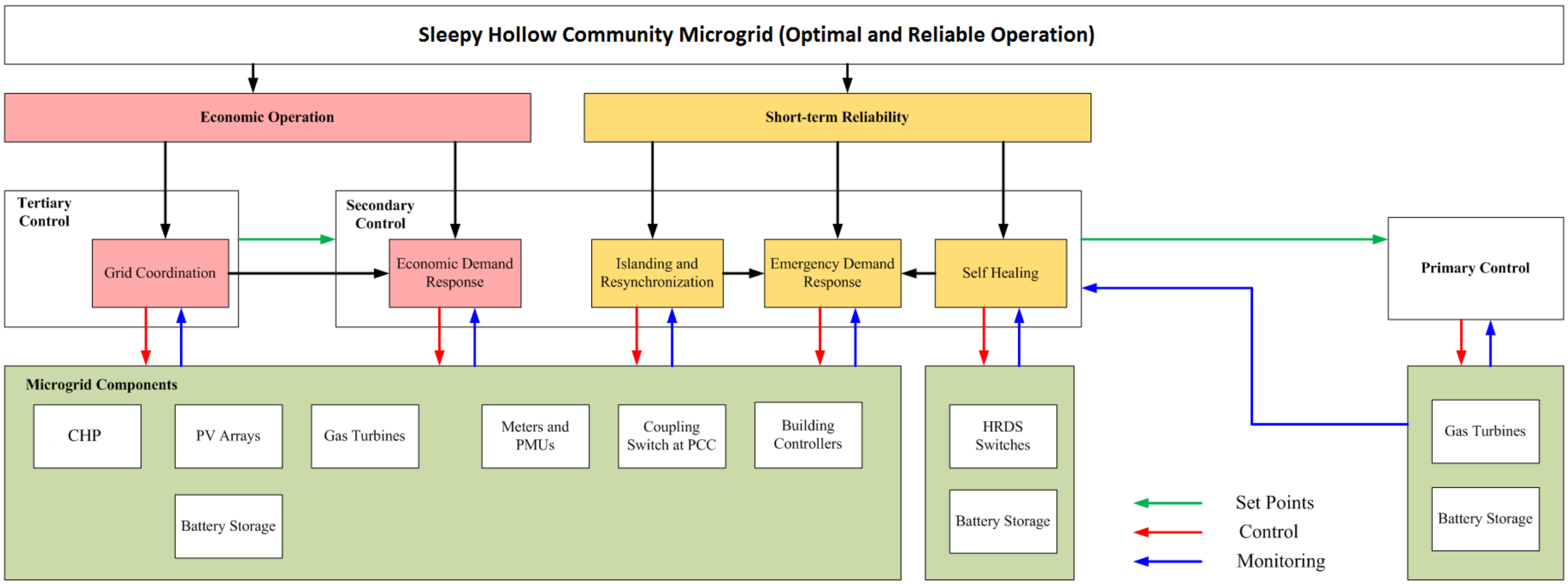
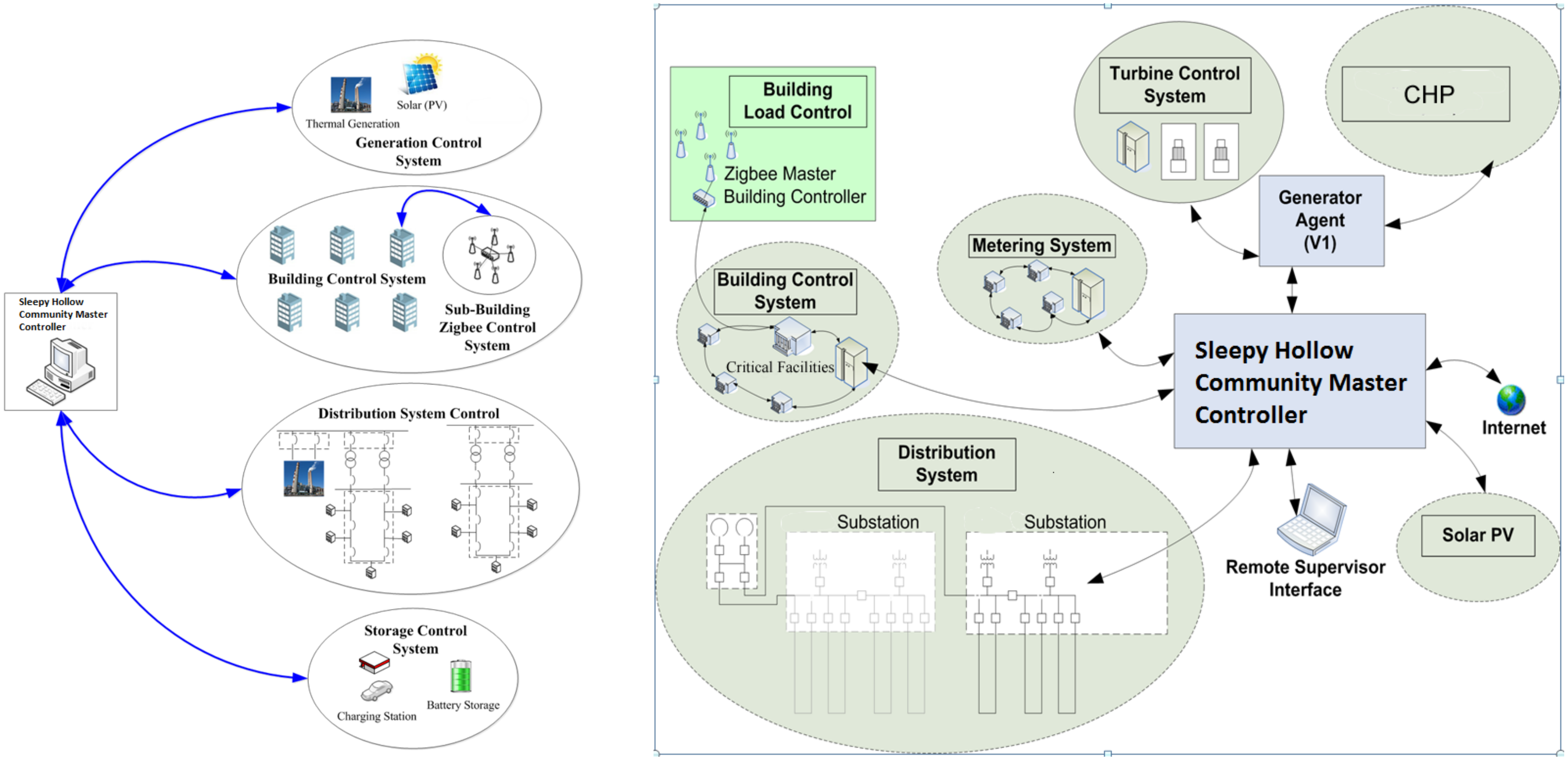



*Figure 7. Objectives and functions for the control and operation of the Sleepy Hollow Community Microgrid*




(a) (b)

*Figure 8. Architecture of master controller for Sleepy Hollow community microgrid.*

The hierarchical secondary control approach would receive the information from loads and power supply entities as well as the information on the status of distribution network and procure the optimal solution via an hourly unit commitment and real-time economic dispatch for serving the load in the normal operation mode and contingencies. Figure 8 shows the hierarchical framework of the Master Controller proposed for the community microgrid projects. In figure 8, the monitoring signals provided to the master controller indicate the status of DER and distribution components, while the master controller signals provide set points for DER units and building controllers. Building controllers will communicate with sub-building controllers and monitoring systems to achieve a device level rapid load management.

The hierarchical protection configuration strategy for community microgrid mainly contains four-level protection: load way, loop way, loop feeder way and microgrid level.

## Clustered Microgrid

Due to the nature of the critical facilities being dispersed among ConEd's electrical distribution system, a fully connected and isolated Microgrid that incorporates all of the critical facilities is not possible. Similar to the way that a master controller communicates with individual buildings and generation resources to optimize the overall microgrid, each cluster would be individually controlled but also connected to the overall clustered microgrid master controller. This level of control would allow the critical facilities' to be optimized at the same time as the benefit to the overall grid and local community is maximized. This interconnection over isolation of the microgrids would have economic, reliability, and environmental merits.

### *Benefits*

The community microgrid master controller offers the opportunity to eliminate costly outages and power disturbances, supply the hourly load profile, reduce daily peak loads, and mitigate greenhouse gas production. The master controller will include the implementation of additional functions for load shedding and coordinating demand response signals with the other controllers for peak demand reduction. With the master controller, the community microgrid would be able to provide ancillary services to the grid including the voltage support and frequency regulation, and the distribution system restoration. In demand response mode, the utility master controller will shutoff loads according to predetermined load priorities. Part of the load shedding will be accomplished by shutting off power to entire building through smart switches and the rest will be accomplished by communicating directly with specific loads distributed across the community via the SCADA network and building controllers.

### *Barriers*

In order to implement the proposed community microgrid, the existing or future distribution network might need a further upgrade which may incur extra investment cost, automatic smart switches are needed for fast automatic switching. The functions of the community microgrid would depend highly on the implementation of a reliable communication system.

## IT/Communication Infrastructure

Any modern utility or system operator relies heavily on their communication infrastructure to monitor and control their grid assets. For a microgrid master controller and microgrid operators, this architecture enables real time control, rapid digestion of critical grid information, and historical data for analysis and reporting. As part of a feasible microgrid, assessment and upgrade of the equipment and protocols used in the microgrid area will be performed.

### Existing Resources

Con Edison owns and operates all the substations and distribution lines serving local customers in Sleepy Hollow. A large majority of those customers are individually metered. Many of the distribution loops and feeders have mechanical switches or automatic switches that are not remotely controlled. The switches that are controllable are connected using fiber optic lines.

#### *Consequences*

A limited communications architecture can lead to increased frequency and duration of outages if problems must occur and be reported rather than having symptoms trigger notifications to grid operators of location and scope of the issue. Limited information and delay in this information leads to man hours wasted and longer duration of customers without power, putting strain on residential customers and potentially costing commercial customers significant amounts of money. Systems could have telltale signs of issues for weeks, but operators may not discover these until they have caused damage and outages to the electric grid or substations, costing the utility money and potentially endangering employees and customers.

#### *Opportunities*

Sleepy Hollow is considering an Advanced Metering Infrastructure (AMI) expansion, which would involve adding wireless communication infrastructure throughout each meter in the Village to allow for automatic and digital meter reads. The key advantage of this expansion would be the network addition, which often utilizes the 900 MHz ISM band and relies on communication between integrated Network Interface Cards (NICs) that form a mesh network, allowing signals to hop between any installed meters to reach their ultimate destination and increases the propagation range of the signal in proportion to the number and dispersion of integrated NIC Smart Meters. The integrated NICs are connected to a local Access Point (AP) that transmits the metering and control signals for the meters over a cellular wireless network back to the utility data center, where it can be fed into a Supervisory Control and Data Acquisition (SCADA) platform for use in billing or monitoring the overall grid.

Village-controlled AMI would also provide opportunity for community demand response aggregation, in which the microgrid owner will be able to remotely control non-critical loads at the customer level to maximize economic benefit and/or reduce strain on the grid.

## Proposed/Suggested Improvements

The Community microgrid would be connected efficiently and productively, through the use of modern communication architecture and equipment, enabling a master controller to optimize the microgrid control and giving operators the tools they need to perform their daily duties. This network would leverage the AMI network and seek to strengthen it through the use of connected LED lights, which require half the power of the existing High Pressure Sodium (HPS) fixtures and shorten the overall payback of a street lighting upgrade through the implementation of smart photocells or integrated NICs that individually meter and control each streetlight, seen in figure 9.

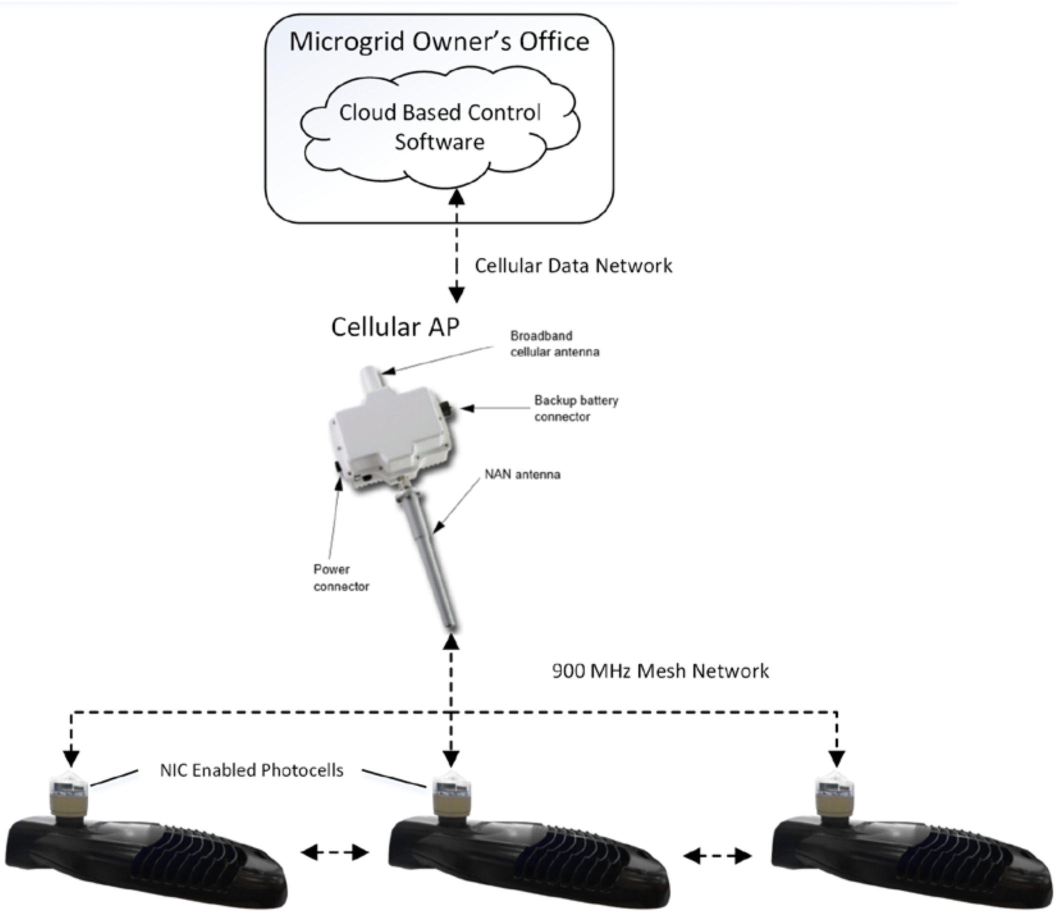



*Figure 9. Sleepy Hollow Proposed LED Lighting Communications and Control Diagram*

In addition to meters and lights, circuit breakers, relays, re-closers and other switchgear are vital to the control of the Community microgrid. While some distributed switchgear can utilize a similar wireless infrastructure, with data being fed through substations instead of through a cloud network, the control equipment is more vital to the safe operation of the microgrid and would ideally use a fiber optic backbone between the data center and the substations. The substation relays may have to be upgraded to communicate using the DNP3 protocol over TCP/IP, the de facto standard for modern utility communications, which will be used to monitor and control the proposed DER as well.

Once in the data center, the data will be fed into an upgraded or added SCADA system to allow operators to access, visualize, and control, all of the microgrid assets.

### *Benefits*

Utilizing a fully connected microgrid, with every vital piece of equipment monitored and controlled remotely, the master controller will be able to optimize load and generation automatically and in real time, the microgrid operators will be able to view the status, create reports, and plan future developments, and maintenance will be able to quickly assess and address any issues.

### *Barriers*

A more extensive review of existing communications and control equipment needs to be performed to determine the exact quantity and specification of the upgrade; RF testing will need to be performed to determine the layout of the wireless network proposed. Training would have to be done on the SCADA system and the newly implemented relays, and personal may need to be hired to maintain the network and communications equipment. A review of costs of the current system, including streetlight usage and maintenance data, current metering system costs and inaccuracies, and outage information will have to be performed to determine exact cost savings of upgrading to the new system.

## Clustered Community Microgrid

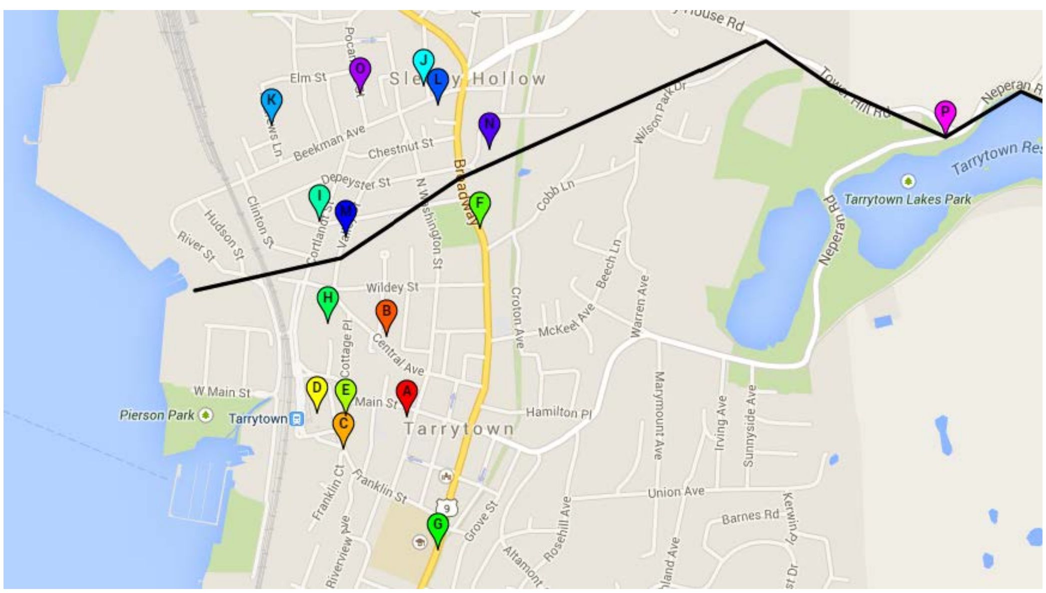



*Figure 10. Village of Sleepy Hollow (Above the line) and Village of Tarrytown (below the line).*

Sleepy Hollow is adjacent to the Village of Tarrytown as shown in figure 10. Willdan proposes a clustered community microgrid for these two communities. These two communities could be operated in connected mode or independently for the purpose of economic and reliability. This would improve the reliability, resiliency, and power quality of both communities, reducing the customer's load interruptions as result.

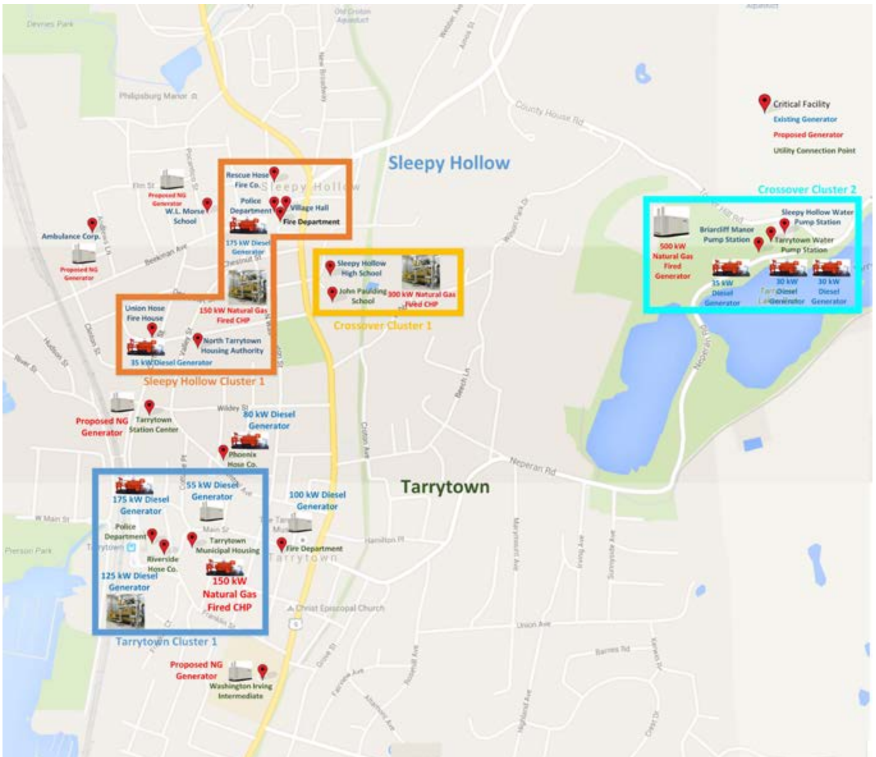



*Figure 11. Critical Facilities Clusters*

Figure 11 shows the critical facilities that are close to each other geographically, which can be configured as energy hubs and operate as different islands in case of emergency. There are colored boxes around the identified clusters that group critical loads by their relevant distribution network and ease of isolation from the surrounding ConEd grid.

# Task 2: Develop Preliminary Technical Design Costs and Configuration

Willdan has conducted a preliminary assessment of the technical design and system configuration for the proposed community microgrid in accordance with the following sub tasks:

## Summary

Willdan was selected by both the Village of Sleepy Hollow and of Tarrytown to perform a feasibility study for a community microgrid in Westchester County, New York. The focus of the study is on relieving the community from high electricity prices as well as providing advanced resiliency capabilities in the event of a bulk power system outage.

Sleepy Hollow and Tarrytown share a border, buildings, public utility resources, such as water and electric service, and the feasibility study performed by Willdan considers this and other neighboring factors, while maintaining a clear priority for the customer in their respective study.

Willdan has worked with ConEd, the electric utility, as well as the community stakeholders to acquire all available electrical, thermal, and other relevant data for the study. This data collection required a review of the electrical distribution system in Westchester County, which has resulted in a shift in the study from a standard community microgrid, with all of the critical facilities connected electrically and surrounding residential and commercial loads also being served by the microgrid, to a concept of independent clustered microgrids including one Sleepy Hollow cluster, one Tarrytown Cluster, and two crossover clusters with a cumulative peak load of 1,268 kW all connected to a single master controller. This is the best option in the communities as ConEd's distribution system covers the village in a mix of primary underground and overhead feeders as well as secondary underground networks that would be extremely expensive to isolate all of the critical facilities.

Working closely with ConEd, Willdan has identified load clusters, figure 13 and table 9, that can be easily electrically isolated for resiliency and economic benefits. These clusters would each have a 'peer', or equally weighted, master controller that would optimize generation and load within the cluster and communicate with a single master controller that supervises and fptimizes the entire system to provide benefits to each other as well as the surrounding community and utility stakeholders.

Using detailed electric and heating load, the microgrid was simulated using the Distributed Energy Resources Customer Adoption Model (DER-CAM) and Combined Heat and Power (CHP) was a favored option based on the availability of natural gas at all critical locations, the price of electricity, and the cost of generating electricity from Natural Gas as well as the benefit of using the heat produced in the clusters. Simulations were run for each cluster to obtain individual capacity recommendations based on existing backup generators and individual cluster loads. It was found that major benefits to the community can also be obtained from implementation of common smart grid technology such as automatic Switches, Advanced Metering, Intelligent LED Streetlights, connected with modern communication practices and monitored by a Supervisory Control and Data Acquisition (SCADA) software.

The results of the quantitative simulations and analysis as well as the qualitative analysis of available Sleepy Hollow community information is presented in the following report based on NYSERDA's sample Scope of work (SOW) and broken down into the following sections; Microgrid operation, Load, Distributed Energy Resources (DERs), Electrical and Thermal Infrastructure, microgrid and building controls, and communications.

## DER-CAM

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 Willdan has used the tool extensively as a key component of the qualitative microgrid analysis.

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 model are the customer's end-use energy loads, energy tariff structures and fuel prices, and user-preferred equipment investment options, with extensive unit cost and operation parameters, see tables 6 and 7 for technology and parameter inputs. The outputs include DER technologies and unit sizing, optimal dispatch or utility purchase of electricity and thermal resources, and high level cost estimation and cost benefit analysis. See figure 12 for more detail. Additional information is available on BNL's DER-CAM website[1]. In addition to DER-CAM simulations, additional modeling was performed using the open GAMS System, the high level modeling system that DER-CAM is built off of. This was done specifically for the resilience scenarios to allow for faster and more customized simulations.

[1] https://building-microgrid.lbl.gov/projects/der-cam

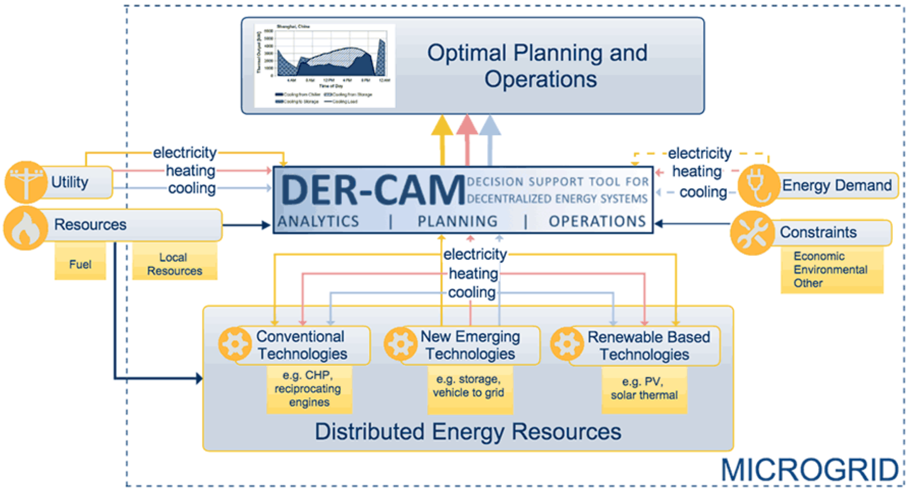



*Figure 12. Schematic of information flow in DER-CAM*[1]

## DER-CAM Input Data

### *Load profile*

Accurate hourly load profiles are critical to DER-CAM simulations. The loads include electricity, space-heating, water-heating, cooling, refrigeration, natural gas only (e.g. for cooking). However, electricity and natural gas for space heating are the most important in terms of impact on the communities. Any ConEd account under 500 kW demand in the Westchester area is manually metered on a monthly basis, and does not have hourly load available. In the absence of Hourly load for the Sleepy Hollow or Tarrytown facilities the hourly load profile of White Plains, NY[2], a city in the same county, was scaled based on the peak load of the facilities to obtain an estimated load profile. For heating load, monthly usage was obtained from utility bills. Then, the average demand was estimated based on this monthly usage for each month. Finally, the demand was applied to an hourly temperature curve in place of an hourly heating demand curve to obtain a rough estimate of hourly heating load.

### *Utility tariff*

NREL lists the average commercial price of electricity in Sleepy Hollow and in Tarrytown as 11.55 $/kWh[3]. This was checked against available demand and energy usage in critical facilities based on ConEd's Service Classification[4] for large customers (over 10 kW demand) and was found to be within 4% of the calculated average energy price for the participating facilities. The NREL electricity price was used as it was likely based on a larger data set than 9 facilities.

The natural gas price is obtained from EIA[5] and the average commercial natural gas price for New York for 2015, based on available months, is used; 0.65 $/Therm.

[1] https://www.bnl.gov/SET/images/DER-CAM/DER-CAM-fig-0.png
[2] http://en.openei.org/datasets/files/961/pub/
[3] http://www.electricitylocal.com/states/new-york/sleepy-hollow/#ref
[4] http://www.coned.com/documents/elecPSC10/SCs.pdf
[5] https://www.eia.gov/dnav/ng/ng_pri_sum_dcu_SNY_m.htm

### *Technologies investment*

In addition to CHP, the impact of Electric Storage and PV was evaluated for the Community microgrid; their investment parameters are shown in table 6. CHP, shown in table 7, was considered in step sizes of 500 kW, 250 kW, and 100 kW, to obtain precise simulation results. Costs were obtained from EIA[1] and from NREL[2,3].

*Table 6. Continuous Investment Parameters*

| Technology | Fixed Cost ($) | Variable Cost ($/kW) | Lifetime (Years) | Fixed Maintenance ($/kW/Month) |
|---|---|---|---|---|
| Electric Storage | 0 | 400 | 15 | 0.069167 |
| PV | 0 | 3250 | 30 | 0.25 |

*Table 7. Discrete Investment Parameters*

| Technology | Max Power (kW) | Lifetime (Years) | Capital Cost ($/kW) | Om variable ($/kWh) | Fuel | Efficiency | Alpha (Heat to Power Ratio) |
|---|---|---|---|---|---|---|---|
| CHP Option 1 | 500 | 20 | 1200 | 0.011 | NG | 0.32 | 1.4 |
| CHP Option 2 | 250 | 20 | 1200 | 0.011 | NG | 0.32 | 1.4 |
| CHP Option 3 | 100 | 20 | 1200 | 0.011 | NG | 0.32 | 1.4 |

### *Weather information*

Hourly solar irradiance (Global Horizontal Irradiation (GHI)), hourly temperature, hourly wind speed were obtained from NREL's Solar Irradiance database[4]

### *Global setting*

For this analysis, a 10 year maximum payback period was input to DER-CAM as a constraint, based on the estimated 15-25 year lifetime of the microgrid. Minimizing energy cost was selected to maximize the economic benefit.

[1] http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf
[2] http://www.nrel.gov/docs/fy11osti/48595.pdf
[3] http://www.nrel.gov/docs/fy13osti/56776.pdf
[4] https://maps.nrel.gov/nsrdb-viewer

## Simulations

For all of the NY Prize feasibility studies, Willdan considered all of the scenarios a typical community microgrid could encounter. All of the analyses necessary to justify the integration of a community microgrid into the Village were simulated as described by the following steps.

Step 1: A base case without any investment was simulated to obtain the reference cost. In this case the annual cost, as well as optimal heat and electricity dispatch, were calculated using DER-CAM, shown in section 2.2. The calculated annual operational cost was used for the following steps as a reference cost.

Step 2: An investment case was simulated to see the economic and CO2 emissions benefits while allowing DER-CAM to choose the best DERs based on their operational cost and amortized capital cost. Results showed that the system should purchase all electricity and fuel for heat from ConEd or the local fuel provider. It should be noted that for the base case with investments, there were no DERs recommended for purely financial benefits. As a result of this, a number of the simulations described below returned the same zero value for suggested DER and were not included in the report, except as evidence for the recommendation that DER is not feasible for purely financial reasons.

Then a series of simulations were run to simulate a microgrid in both Grid Connected and Island mode operations. The goal of this step was to determine the optimal value of DER in both modes of operation.

**Grid Connected mode**

In this mode, the optimal level of DERs was obtained to maximize reliability and economics.

Reliability simulations include:

1. Demand response at the point of common coupling (PCC) with different level (5%, 10%,15%,20%,25% of total load)
2. Direct Load Controlling (DLC) with different load reduction (5%,10%,15%,20%,25% of total load)

Economics simulations include:

1. Sensitivity analysis to electricity price increase, from 0.11 $/kWh to 0.15 $/kWh
2. Sensitivity analysis to natural gas price increase, from $0.69 /Therm to $3.52 /Therm
3. Sensitivity analysis to load increase, from 5% to 25%

All simulations were designed to account for possible changes over the 15-25 year life of the microgrid. The goal is to design a microgrid, which will be as tolerant as possible to electricity, natural gas and load fluctuations. In addition, the analysis informs the potential microgrid owner of risks in relying solely on the utility or any one type of DER.

**Island mode**

In this mode the goal was to maximize load recovery at the time of an outage, planned or unplanned.

Load Recovery simulations include:

1. Outage for a period of hours (Summer and Winter off and on Peak)
2. Outage for a period of days (Summer and Winter off and on Peak)
3. Outage for a period of a week (Summer and Winter off and on Peak)

Simulations designed to account for likely and drastic outage scenarios and to see the effect on the microgrid.

Step 3: Additional scenarios were created to account for all manner of resiliency situations the microgrid might encounter, such as main backup generators being out of commission or not shared by the microgrid, CHP being limited or being out of commission, etc.

These simulations were run for the overall Sleepy Hollow clusters of load as well as for each individual cluster load, to account for differences in installed backup generators as well as existing natural gas usage. This resulted in simulations being run for the combination of Sleepy Hollow cluster one, two crossover clusters, and Tarrytown Cluster one. Which have an overall peak load of 1,531 MW, reflected in figure 16 as a higher average load, and overall recommended generation, in addition to existing backup generation, of 1,100 kW, reflected in the DER-CAM results shown in Sections 2.3 and 2.4. Results from the individual clusters resulted in the recommendations throughout the report of individual generators for each cluster, while the overall results, for both Sleepy Hollow and Tarrytown, were included in the report to give the reader an understanding without having to include 3 repeated figures each time with the individual results. These are marked as Total System.

The results of these simulations along with analysis of parameters outside of DER-CAM's array of options, such as Demand Response capacity credits, as well as qualitative additions to the Community microgrid, to be accepted or denied during the cost benefit analysis stage of the study, were analyzed and compiled in the following report based on technical and preliminary financial feasibility.

## Sub Task 2.1 Proposed Microgrid Infrastructure and Operations

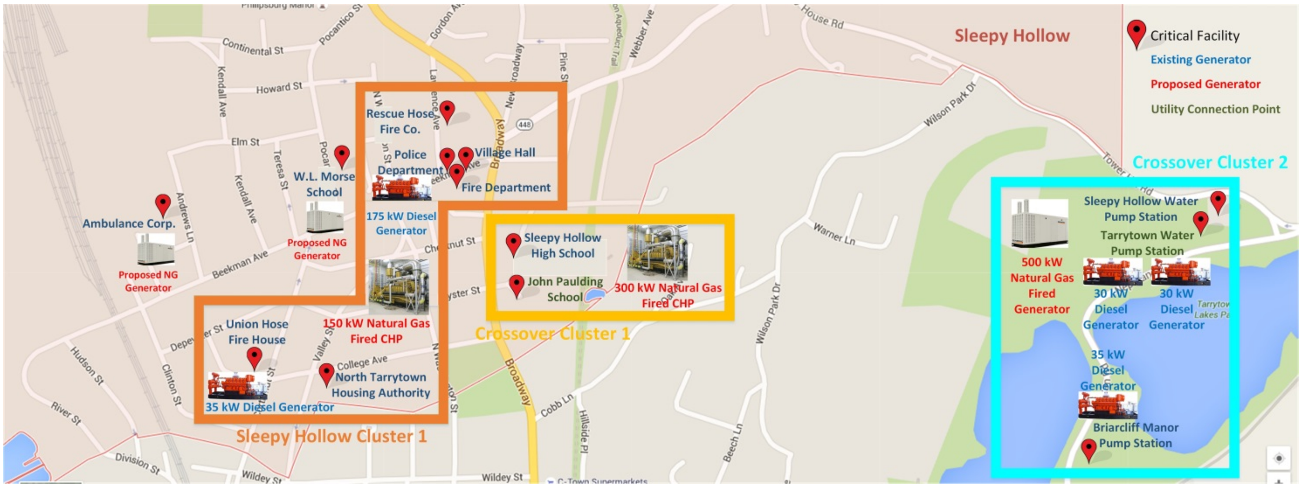



*Figure 13. Sleepy Hollow Generation Simplified Equipment Layout Diagram*[1]

Normal operating conditions would see reliability improvements, through infrastructure reconfiguration, such as a High Reliability Distribution System (HRDS) which senses and clears faults with virtually no impact on building loads, to a self-healing and more fault tolerant grid, by reducing the number of single points of failure by adding redundancy to the electrical and communications networks, and by adding alternate sources of generation to serve critical and non-critical loads. In addition to increased reliability, or a reduction in the frequency and/or duration of outages, the Community microgrid would reap economic benefits in the form of added revenue streams from demand response, alternate generation sources, and energy efficiency measures to reduce overall energy costs, as well as participating in ancillary service markets such as frequency response and operating reserve markets. Based on the price of electricity and availability of Distributed Energy Resources (DERs), the master controller will optimally dispatch the units to provide the most cost-effective, cleanest, and most reliable energy possible to the critical and non-critical microgrid facilities.

During emergency operating conditions, the Community microgrid's master controller would optimize generation and load to provide uninterrupted power to critical loads, through the use of DERs and load shedding schemes that ensure safe and reliable operation of the buildings that matter most in emergency situations. Long term outages will be mitigated by natural gas fed combined heat and power (CHP) plants and natural gas fired generators, which will maintain a black-start capability in the event the outage occurs when the CHP facility is not active. These plant or plants will rely on robust natural gas pipelines and produce adequate power to serve all of the critical facilities, public streets and security lighting, and some residential load. This added resiliency will keep emergency responders and residents safe and provide the Community microgrid with heat and power when it needs it most.

[1] Each Cluster will be utility connected as detailed in Figures 20-26.

## Sub Task 2.2 Load Characterization

*Table 8. Electrical Load Type*

| Type | Description | Opportunities |
|---|---|---|
| Lighting | General, task, exits, and stairwells, decorative, parking lot | Load curtailment |
| | Security and emergency | Critical Load |
| Transportation | Elevators, dumbwaiters, conveyors | None – Critical Load |
| Appliances | Business and copying machines, receptacles for vending machines, and general use | Load curtailment and shifting |
| Data processing | Desktop computers, central processing and peripheral equipment, and uninterruptible power supply (UPS) systems, including related cooling | None – Critical Load |
| Space conditioning | Cooling, cleaning, pumping, and air-handling units | Short term Load curtailment and shifting |
| Food preparation | Cooling, cooking, special exhausts, dishwashing, disposing | Load curtailment |
| Plumbing and sanitation | Water pumps, hot water heaters, sump and sewage pumps, incinerators, and waste handling | Short term load curtailment and shifting |
| Special loads | For equipment and facilities in mercantile buildings, restaurants, theaters, recreation and sports complexes, religious buildings, health care facilities, laboratories, broadcasting stations | None – Critical load |
| Fire protection | Fire detection, alarms, and pumps | None – Critical Load |
| Miscellaneous loads | Security, central control systems, communications; audio-visual, snow-melting, recreational, or fitness equipment | None – Critical load |

### Sleepy Hollow Existing Resources

The total population of Sleepy Hollow is approximately 10,000. During the winter season, Sleepy Hollow splits its building's space heating load between natural gas and No. 2 Fuel Oil.

The locations, peak loads, and load clusters of nine critical facilities within Sleepy Hollow and two Tarrytown critical facilities are shown in figure 14 and detailed in table 9 with electrical and thermal load. Sleepy Hollow Cluster 1 consists of the Sleepy Hollow Police Department, fire Department, and Village Hall, Rescue Hose fire Co., the Union Hose Fire House and the North Tarrytown Municipal Housing Authority. Crossover Cluster 1 is on the border between Sleepy Hollow and includes the John Paulding School from Tarrytown's critical facilities as well as the Sleepy Hollow High School from Sleepy Hollow's critical facilities. Crossover Cluster 2 is located west of Sleepy Hollow proper and includes the Sleepy Hollow Water Pump Station, the Tarrytown Water Pump Station, as well as the Briarcliff Manor Water Pump Station.

Two identified critical facilities that, based on their electric wiring feasibility, are not included in a proposed microgrid cluster are the Ambulance Corp., and the W.L. Morse School., which have been studied instead as nano-grids, or buildings that are able to isolate behind the meter to provide their own electricity through on-site generation resources and building level load control, such as micro-CHP installations, energy efficiency improvements, etc. These improvements and especially the financial feasibility of implementing a nano-grid will be investigated in more detail in the cost benefit analysis phase of the study.

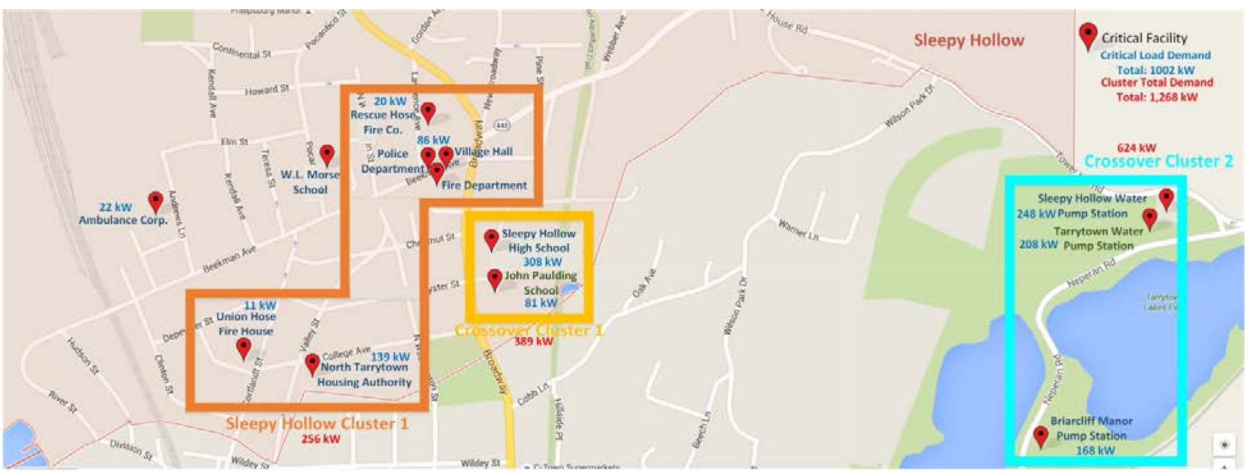



*Figure 14. Load Simplified Layout Diagram for the Sleepy Hollow Community Microgrid*

*Table 9. Sleepy Hollow Originally Considered Critical Facilities (Year 2014)*[1]

| Critical Facilities | Peak kW | Total kWh | Average Heating Demand (Therms/Hr)[2] |
|---|---|---|---|
| Sleepy Hollow High School | 307.9 | N/A | 51.29 |
| W.L. Morse School | N/A | N/A | N/A |
| Briarcliff Manor Water Pump Station | 168 | 716,000 | 0.0 |
| Union Hose | 10.6 | 23,652 | 1.01 |
| Rescue Hose | 20.1 | 66,216 | 1.91 |
| Ambulance Corp | 22 | 65,256 | N/A |
| Village Hall/Police/Fire Station | 68.8 | 321,920 | 4.15 |
| Sleepy Hollow Water Pump Station | 132.8 | 372,800 | 0.0 |
| North Tarrytown Housing Authority | 118.4 | 467,440 | 25.53 |
| **Total** | **848.6** | **2,033,284** | **83.89** |

The Village's loads can be separated into the broad load categories, critical and non-critical, with critical facilities including the Union House, the Rescue House, the Ambulance Corp. the Village Hall/Police/Fire Station, the North Tarrytown Housing Authority, the Sleepy Hollow High School, and the W.L. Morse School, and non-critical facilities including the many other businesses and residential customers. The load demand in each facility can be further separated into the load categories shown in table 8 to describe the unique nature of, and opportunities available for, the different load types. The peak critical facility demand in year 2014 was over 849 kW and the total electricity usage of the critical facilities is 2,033,284 kWh. Detailed load information for all the critical facilities are shown in table 9. The facilities with natural gas demand depend on natural gas for space heating in winter seasons, while the facilities with zero natural gas demand rely on No. 2 Fuel Oil or have no heating demand.

The Village is seeking to increase energy efficiency of a number of facilities within the village including the Village Hall, police HQ and Fire Stations, which are currently supported by backup diesel generators. Willdan has commenced ASHRAE Level 2 Energy Audits at most of these facilities and potential energy conservation measures currently under consideration include upgrades to the building envelope and windows, HVAC system, and lighting system and the integration of solar. These measures are intended to reduce the Village's carbon footprint, improved energy resiliency, and help each facility make incremental steps towards curtailment. The intent is to parlay the planned energy efficiency and curtailment measures to develop the community grid at the lowest possible cost.

[1] Sleepy Hollow Con Edison Billing.xlsx
[2] These values based on ConEd usage Billing data and converted to hourly average values. Ratio of Therms/Hr to kW is 1:29.3.

### *Consequences*

Sleepy Hollow has been increasingly affected by severe weather events with disruptions to basic services resulting from outages from major storms such as Lee, Sandy, the October 2011 Winter Storm, and more localized severe weather related problems such as the 2006 Westchester County tornado which cut power to 10,000 people in the county. The system is also entirely reliant on the points of connection with the bulk grid, which represents the primary resiliency issues.

### *Opportunities*

Willdan, on behalf of the Village, is exploring placing the microgrids CHP and distributed generation resources in the identified clusters to provide an alternative source of electricity to utility purchase as well as meet the heat demand of the facilities. These resources could have the added benefit of reducing load on the ConEd distribution system and substation feeders/transformers, which has the potential to alleviate maintenance and engineering costs for ConEd, the utility stakeholder. The Village is planning to implement a number of additional Energy Conservation Measure (ECM) upgrades including lighting, steam trap replacement, solar array, and building envelope. The intent is to parlay the energy efficiency and curtailment measures already in place, or planned, to develop the community grid at the lowest possible cost, while reducing the required size of any added generation. In addition, the Village aim to utilize any added DER to reduce peaks supplied by the bulk power supply and to participate in ConEd or NYISO demand-response programs.

As the proposed microgrid consists of a relatively small number of facilities, more advanced cost benefit analysis will need to be performed to determine the financial feasibility of an Advanced Metering Infrastructure (AMI) expansion. By implementing an AMI, customers would be provided real-time monitoring of their electricity usage and have the opportunity to participate in real time pricing. Through real-time pricing, energy consumers would be encouraged to shift their use from high demand periods to low demand periods by offering lower prices during these periods. By decreasing peak demand surges the entire energy infrastructure could be run more efficiently and customers that participate benefit from lower overall energy prices.

*Table 10. Microgrid Cluster Breakdown*

| Cluster | Involved Buildings | Demand (kW) | Average Heating Demand (Therms/Hr)[1] | Backup Generation | Proposed Generation |
|---|---|---|---|---|---|
| Sleepy Hollow Cluster 1 | Rescue Hose Fire Co | 20.1 | 1.9 | NO | 150 kW Natural Gas Fired CHP |
| | Police Department/Village Hall/ Fire Department | 85.7 | 4.2 | 175 kW Diesel | |
| | Union Hose Fire Hose | 10.6 | 1.0 | 35 kW Diesel | |
| | North Tarrytown Housing Authority | 139.3 | 25.5 | NO | |
| **Total SH Cluster 1** | | **255.6** | **32.6** | **210 kW** | **150 kW** |
| Tarrytown Cluster 1 | Police Department | 76 | 3.68 | 175 kW Diesel | 150 kW Natural Gas Fired CHP |
| | Riverside Hose | 14.7 | 1.39 | 80 kW Diesel | |
| | Tarrytown Municipal Housing Authority | 172.2 | 31.6 | 200 kW Diesel | |
| **Total TT Cluster 1** | | **262.9** | **36.6** | **455 kW** | **150 kW** |
| Crossover Cluster (CC) 1 | Sleepy Hollow High School | 307.9 | 51.3 | NO | 300 kW Natural Gas Fired CHP |
| | John Paulding School | 80.8 | 18.9 | NO | |
| **Total CC 1** | | **388.7** | 70.2 | **NONE** | **300 kW** |
| Crossover Cluster (CC) 2 | Sleepy Hollow Water Pump Station | 248 | NONE | 30 kW Diesel | 500 kW Natural Gas Fired Generator |
| | Tarrytown Water Pump Station | 208 | NONE | 30 kW Diesel | |
| | Briarcliff Water Pump Station | 168 | NONE | 35 kW Diesel | |
| **Total CC 2** | | **624** | NONE | **95 kW** | **500 kW** |
| **Total** | | **1,531.2** | **139.5** | **655kW[2]** | **1,100 kW** |

[1] These values based on ConEd usage billing data and converted to hourly average values Ratio of Therms/Hr to kW is 1:29.3.

[2] This number was obtained from the available information at the time; a reported 30 kW generator, two 35 kW generators, and 150-200 kW generator (assumed to be 175 kW) and one confirmed generator with unreported size that was estimated based on similar building types with confirmed generators in Tarrytown.

## Proposed/Suggested Improvements

A community microgrid would be helpful for solving the current problem in the Village of limited existing backup generation providing additional capacity and therefore increasing the resiliency of the community. Willdan proposes the addition of natural gas fired CHP in areas with significant heating load and natural gas generators in areas with electric load only. Willdan has evaluated supporting critical facilities with distributed generation resources including CHP generators, locating a total of 1100 kW of generation resources, based on DER-CAM simulation results seen in more detail in Section 2.3, in the microgrid clusters, which will operate in synchronous and islanded modes to automatically supply facilities in the event of an outage. Innovative technologies and new generation sources including solar, wind, tidal, combined heat and power (CHP), power and battery storage, and off-grid hybrid wind and solar LED lighting were also studied for their environmental and economic benefits.

New CHP or NG fired generating plants and demand response would help in mitigating the reliance on power from utility grid. Willdan proposes to upgrade all the existing lighting that has not been upgrade with high efficient LED (Light Emitting Diode) fixtures. By applying the latest building control technology in each building, the Village would be able to have the direct load control capability on the curtailable and shift-able loads through a microgrid master controller, see Section 2.5 for more detail on microgrid control and master controller operation. Willdan recommends educating the residential customers to participate in peak-load demand response program.

### *Benefits*

With a community microgrid, the Village could provide more reliable and resilient electricity to their electric customers. The critical facilities would remain powered on in emergency situations and when the power supply from the utility grid is lost. The community microgrid would also help the Village to reduce the high cost of purchasing power from the bulk provider. By using the more efficient and safe LEDs for public street lighting and residential lighting, both commercial and residential customers can reduce maintenance cost and electricity bills. With the capability of direct control of the loads, the Village would not only be able to improve the reliability of the community distribution system, but would have the potential to participate in ancillary service markets such as, frequency regulation, demand response, etc. Microgrid facilities could also have better quality of electricity service while reducing their electricity bills.

### *Load Visualization*

Figure 15 shows the hourly load profile of the total system load that is served by the Community microgrid. The hourly load is broken down by month to reflect the drastically different usage from month to month. It can be seen that the electric air conditioning load in August causes the daily load profile to be raised to significantly more than the levels of that in January, as is seen in many of the other summer months versus winter months.

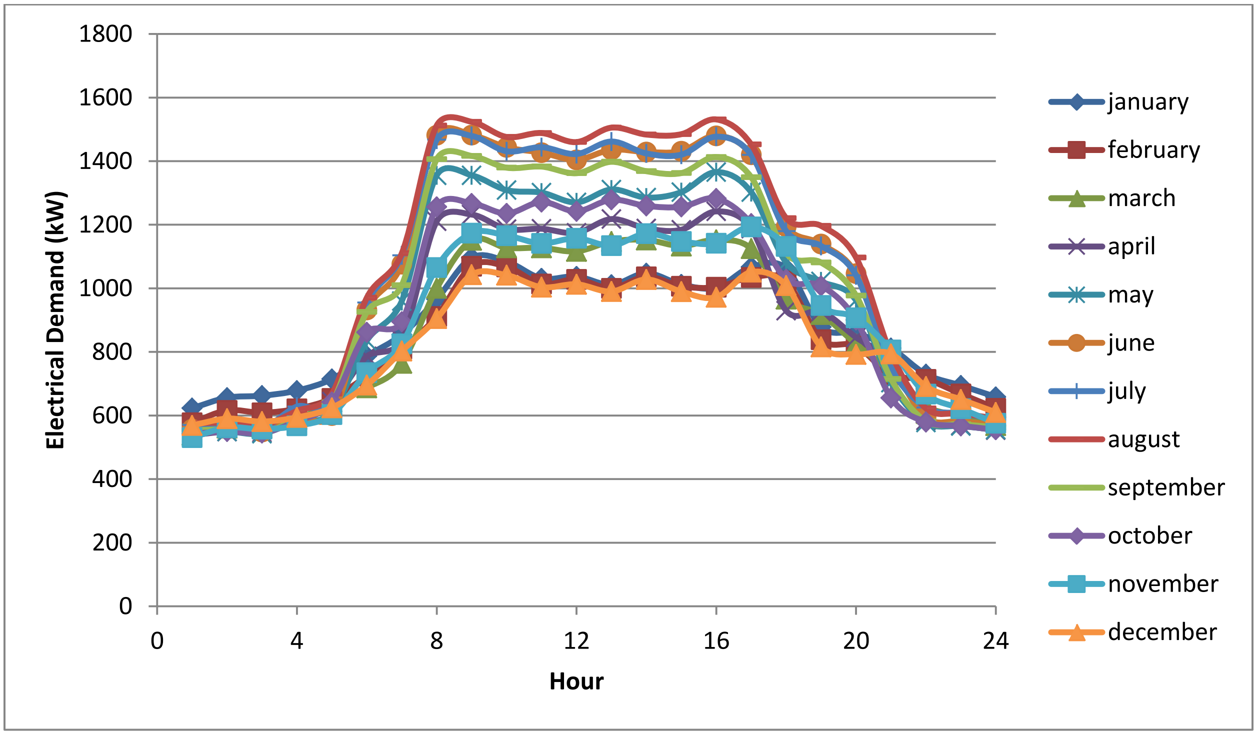



*Figure 15. Total System Average Daily Load by Month*[1]

The proposed Community microgrid focuses on providing electricity and heat for the identified clusters. Total cluster demand of 1,531.2 kW (table 10). The installation of at least 1,100 kW of CHP would be able to adequately serve the critical facilities, depending on the level of load shedding implemented; however, as the Community microgrid would be organized as four individually operated microgrid clusters, the load would be distributed electrically to four groups and need to be served by appropriately sized generators.

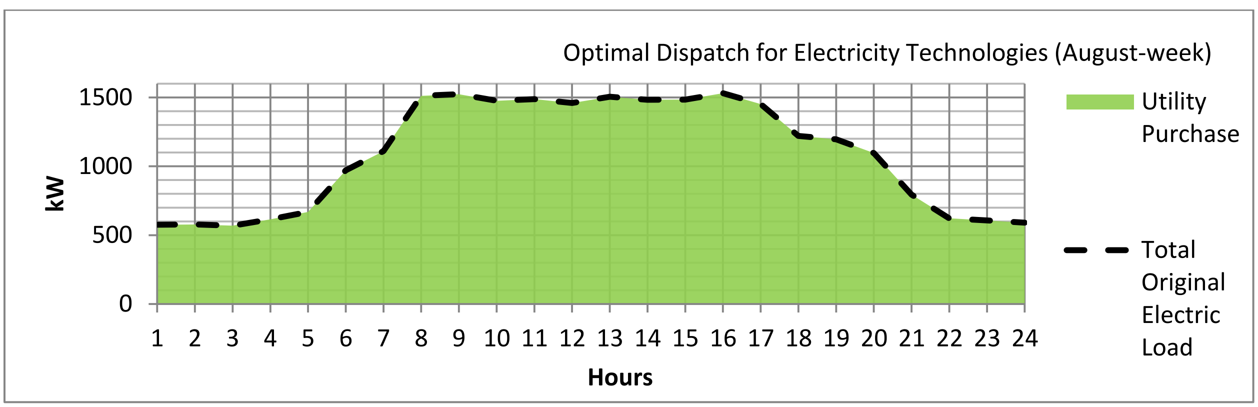



*Figure 16. Pre Investment Average Electricity Dispatch for Total System*

[1] In the absence of Hourly load for the Sleepy Hollow facilities the hourly load profile of White Plains, NY[1], a city in the same county, was scaled based on the peak load of the Sleepy Hollow facilities to obtain this estimated load profile

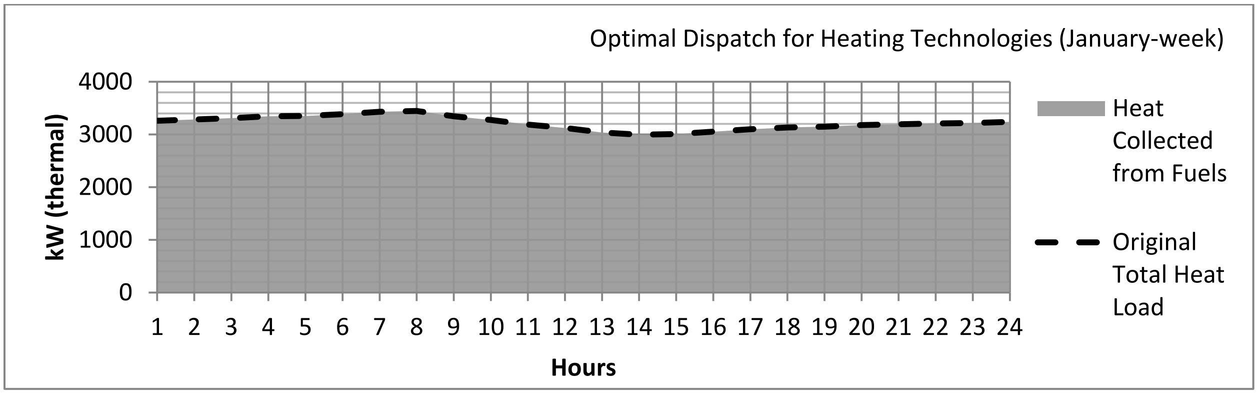



*Figure 17. Pre Investment Average Heating Dispatch for Total System*

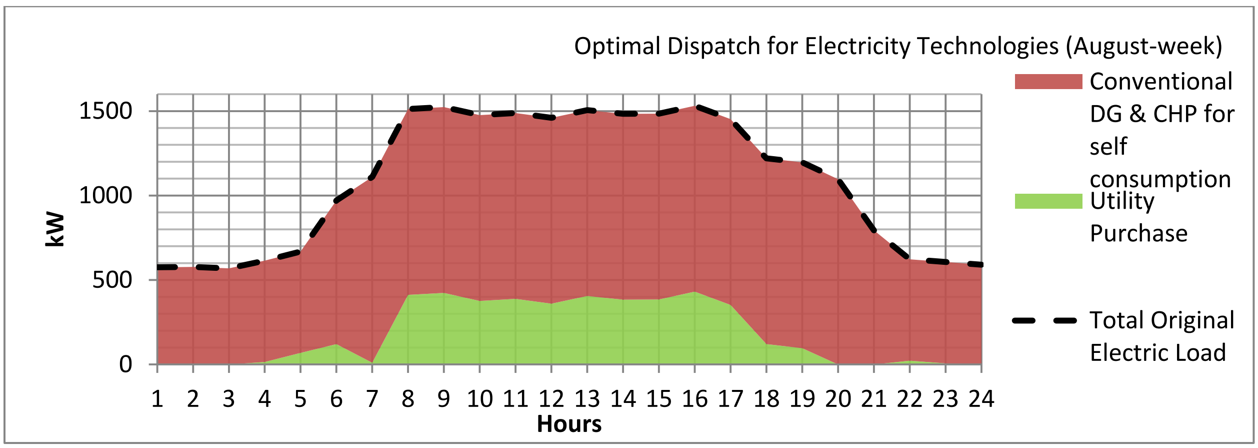



*Figure 18. Post Investment Average Electricity Dispatch for Total System*

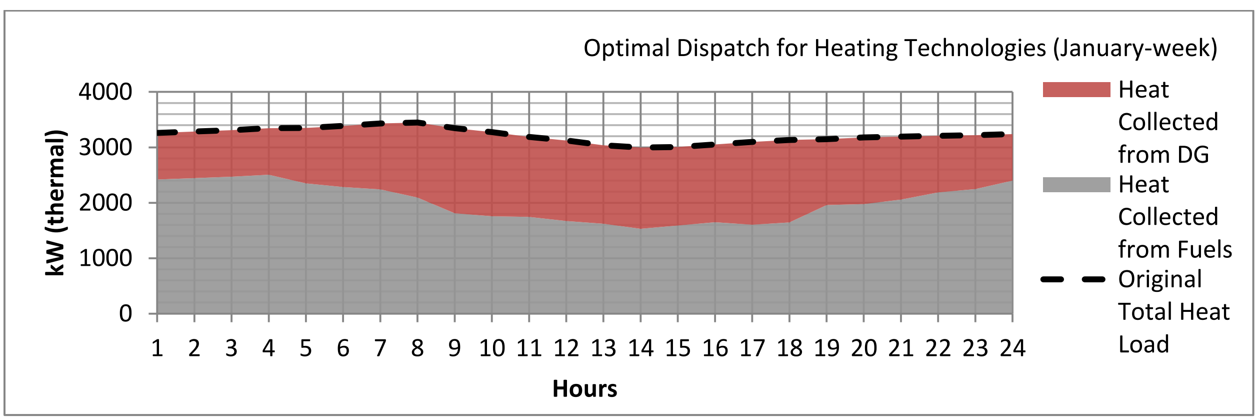



*Figure 19. Post Investment Average Heating Dispatch for Cluster Total*

Figures 16 and 17 show DER-CAM simulation results for the critical buildings in the Community microgrid under normal base (interconnected mode) conditions with no added generation. It can be seen that there are peaks around 9 am and around 7 pm due to industrial and residential customer's high electricity consumption, respectively. The entirely green graph in figure 16 indicates that all of the electricity used before any added investment comes from the utility, while the gray in figure 17 indicates that the entire natural gas space heating load comes directly from fuel. Figures 18 and 19 show the same time period and load being served, but includes the proposed CHP being optimally dispatched throughout the day. It can be seen that a portion of the heating load is served by heat collected from DG (CHP) in figure 19 by noticing the red, or electricity produced by CHP. In addition, a portion of the heating load is covered by heat collected from fuels. It should be noted that the ratio of electric power produced to steam produced for heating purposes, or heat to power ratio, used in the simulations was chosen as an average value based on available CHP units. Willdan recommends selecting CHP units with a heat to power ratio that will not produce excess heat in summer months when heating demand is significantly lower.

### Proposed Energy Efficiency Improvements

Willdan proposes an energy efficiency program for the Community microgrid participants for the purpose of economics and reliability. This program would focus on lighting, building envelope, energy management system, heating, ventilating, and air conditioning (HVAC), and plug load management. Based on energy audits of the proposed microgrid facilities, Willdan recommends steam trap replacement, lighting retrofits, roof replacement, weatherization, and Solar PV for the MHA and other applicable buildings. By applying a time of use (TOU) electricity price mechanism within the community, customers can save both on energy cost and peak-demand charge by curtailing energy usage or shifting their energy usage from peak load hours to off-peak load hours, and then reduce the amount of their energy bill. By shifting the energy usage from peak load hours to off-peak load hours, any overload on the distribution cables and substations would be mitigated and the reliability of the distribution system could be improved.

## Sub Task 2.3 Distributed Energy Resources Characterization

### Existing Resources

There are a number of buildings in the Village which have generators but the detailed information was not available when preparing this report. These generators are assumed as diesel backup generators and the sizes are estimated based on the similar buildings in the Sleepy Hollow area All the DERs located in Sleepy Hollow, distributed among the critical facilities, and retaining about a week of fuel, are shown in figure 13. The detailed location and capacity information of the existing DERs in Sleepy Hollow are listed in table 11.  The characteristics of the existing DERs for DER-CAM simulation are assumed and listed in table 12. The candidate CHP units which DER-CAM simulation could choose from are listed in table 13.

*Table 11. Sleepy Hollow Existing Backup Generators*

| Location | Capacity (kW) | Fuel Type | Demand (kW) |
|---|---|---|---|
| Sleepy Hollow High School | 0 | N/A | N/A |
| W.L. Morse School | 0 | N/A | N/A |
| Briarcliff Manor Water Pump Station | 30[1] | Diesel | 168 |
| Union Hose | 35 | Diesel | 10.6 |
| Rescue Hose | 0 | N/A | 20.1 |
| Ambulance Corp | 0 | N/A | 22 |
| Village Hall/Police/Fire Station | 175* | Diesel | 68.8 |
| Sleepy Hollow Water Pump Station | 30* | Diesel | 132.8 |
| North Tarrytown Housing Authority | 0 | N/A | 118.4 |
| **Total** | **270 kW** | | **540.7** |

*Table 12. Main Parameters of Existing Backup Generators*[2]

| Location | Capacity (kW) | Capital Cost ($/kW) | Variable Operating and Maintenance ($/kWh) | Sprint Capacity (kW) | Efficiency | Backup Only |
|---|---|---|---|---|---|---|
| Briarcliff Manor Water Pump Station | 30 | 865 | 0.015 | 30 | 0.32 | Yes |
| Union Hose | 35 | 865 | 0.015 | 35 | 0.32 | Yes |
| Village Hall/Police/Fire Station | 175 | 865 | 0.015 | 175 | 0.32 | Yes |
| Sleepy Hollow Water Pump Station | 30 | 865 | 0.015 | 30 | 0.32 | Yes |

[1] Estimated based on similar buildings in the Sleepy Hollow and Tarrytown area.
[2] The parameters for each kind of generators are taken from DER-CAM database.

*Table 13. Main Parameters of Candidate CHP units*[1]

| Location | Capacity (kW) | Capital Cost ($/kW) | Variable Operating and Maintenance ($/kWh) | Sprint Capacity (kW) | Efficiency | Alpha[2] | Backup Only |
|---|---|---|---|---|---|---|---|
| CHP Option 1 | 500 | 1200 | 0.011 | 500 | 0.32 | 1.4 | No |
| CHP Option 2 | 250 | 1200 | 0.011 | 250 | 0.32 | 1.4 | No |
| CHP Option 3 | 100 | 1200 | 0.011 | 100 | 0.32 | 1.4 | No |

## Consequences

As shown in tables 11 and 12 and figures 13 and 14, not all the critical facilities have backup generators to supply power in the event of an emergency (loss of power supply from utility due to weather or other events). Comparing the existing DERs with load demands in table 11, there is a disparity between the generation available and the peak load of critical facilities. It can be seen that backup generation is not available for Sleepy Hollow High School, W.L. Morse School, and the North Tarrytown Housing Authority. This means that a number of vital critical facilities, including those that would be used as emergency shelters, would be out of power in the event of loss the power supply from utility grid. In addition, the community pays to maintain and test the backup generators, or runs the risk of the generators not working when needed, and does not see any value added beyond emergency situations. Finally, it is worth noting that all the generation runs off of diesel fuel, which is not considered a clean fuel source that reduces the quality of the air and increases the carbon footprint of the communities, and must be stored or shipped into the Village in the event of an outage. The diesel storage capacity information is not available at this time but generally retain fuel for 48-96 hours, the diesel delivery delay and unavailability may cause another resiliency issue during extreme weather conditions.

### *Opportunities*

Since the average commercial electricity rate in the Village is 11.55Cent/kWh[3,4], it is economical to install CHP and use local DERs to serve the critical facilities. The Village is exploring innovative projects and smart grid circuit isolation to meet its demand and consumption needs such as using combined heat and power (CHP) generation. The additional heat capacity provided will be utilized to improve the year-round efficiency of supplementing local facilities. The Village is interested in exploring an expansion of CHP for a number of their critical facilities as well as adding a generation source to their schools. CHP Plants, proposed to improve the grid resiliency, could cover the electricity needs of the currently vulnerable critical facilities. The heat provided from the CHP plants could feed the high temperature hot

[1] CHP was considered in step sizes of 500 kW, 250 kW, and 100 kW, to obtain precise simulation results and due to the fact that DER-CAM considers a maximum of six of each of the suggested technologies, allowing for a maximum of 5,100 kW of CHP to be suggested.

[2] Alpha: Heat-to-power ratio for CHP, the overall efficiency of CHP can reach 0.768 which will satisfy the fuel conversion efficiency requirement (minimum 60%).

[3] http://www.electricitylocal.com/states/new-york/sleepy-hollow/#ref

[4] http://www.electricitylocal.com/states/new-york/tarrytown/

water (HTHW) loop in the winter and the domestic hot water (DHW) in the summer and potentially alleviate the energy consumption. This expansion would also allow the Village to participate in NYISO Ancillary Service Markets, such as demand response or frequency regulation, and reduce its dependency to bulk electric power provider.

## Proposed/Suggested Improvements

Sleepy Hollow and Tarrytown are neighboring communities and their critical facilities can be grouped into different clusters which can each be treated as an individual microgrid, as shown in figure 20. Willdan recommends and DER-CAM simulations support 1,100kW DERs for the microgrid clusters to power on the critical facilities for seven days during utility grid outage in peak load season for the community microgrid. In order to avoid the extra electrical and thermal infrastructure cost, the suggested capacity of CHP is distributed to different load cluster shown in figure 20.

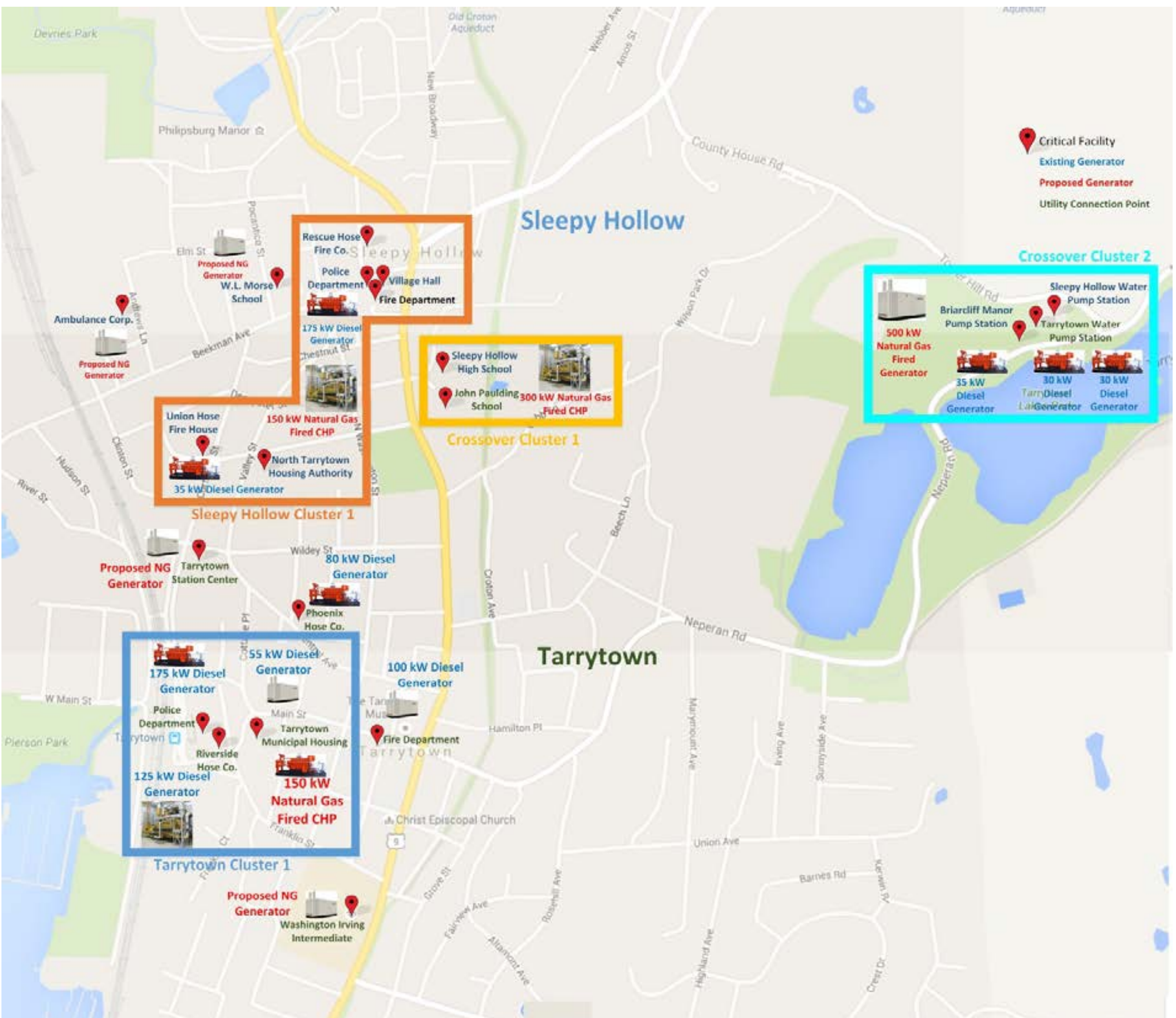



*Figure 20. Proposed Generation for Microgrid Clusters in Sleepy Hollow*

In this report, DERs are proposed for the purpose of resilience since most of the existing backup generators are diesel, which have a limited fuel reserve and their owners don't necessarily want to share their asset with the community microgrid, so Willdan proposed new DERs for the resilience and existing backup generators are suggested to be kept. Based on the analysis of the available data, Sleepy Hollow mainly uses natural gas or oil boilers for heating in winter seasons. The heat produced by the proposed CHP plants could be utilized for serving this heating demand as well as the year-round heating demands of nearby buildings.

### *Benefits*

The proposed installation of CHP would have both reliability and economic merits for the Village. The added CHP would enable the community to have the capability to be isolated from utility grid. In addition, the added CHP would lead to savings on electricity bill for the customer, 22.1% savings based on the simulations, as the customers in the Village pay a relatively high electricity rate (11.5cent/kWh, higher than the generation cost of 8.3cents/kWh from CHP[1]). Addition of a range of DERs, including long term sources like CHP would allow the Village to operate as a microgrid and to take advantage of new revenue streams such as Demand Response and Capacity Markets. Proposed generation capacity and distribution automation capabilities are expected to dramatically increase available capacity for demand-response, increase resiliency through on-site generation, and reduce charges. Distribution of these additional resources close to the school system, water plant, and other critical facilities, will ensure that critical facilities will remain powered on when there is a loss of power from the utility grid.

The CHP can operate in grid-connected mode and island mode. In grid-connected mode, the Master controller adjusts P/Q set points via tertiary control. In island mode, the CHP will receive grid-forming control signals (maintain frequency and voltage). CHP implements frequency and voltage signals through primary and secondary functions. When the microgrid is operating in island mode, the secondary control function will be responsible for maintaining the normal operation of microgrid, i.e., to maintain the operating frequency and voltage magnitude at the rated values. In island mode, tertiary control is applied for microgrid energy management, which is to determine the dispatch of DERs for the economic operation of autonomous microgrid.

Each microgrid is able to initiate communication to its neighbor microgrids and requests generation support through already installed community system or proposed express lines. In this case, this microgrid acts as master and the requested microgrids act as slaves (acting as a generator) at the tertiary level.

### *Barriers*

Since the cost (purchase or leasing rate) of land used for CHP installation varies dramatically from location to location and due to the unavailability of detailed network data (one-line diagram and network model) to locate the exact location of CHP installation site at the time of preparing this report, the land cost has not been taken into consideration in this feasibility study. This report provides a

[1] http://www.enwaveseattle.com/documents/CHP%20as%20part%20of%20CES.pdf

general figure of the proposed community microgrid assuming that the space for the proposed CHP installation is available. The exact size and capacity of the proposed units to ensure feasibility are subject to financial and space constraints. Training will be required for maintenance and operation of the proposed DERs.

As Natural Gas fed CHP is the most feasible option for the proposed Community Microgrid, the microgrid will rely heavily on Natural gas pipelines to power the facilities. Pipelines are highly resilient to inclement weather, but do have the potential to break down or be damaged. This would have to be monitored closely to prevent any small issues from becoming major problems if there is an interruption in natural gas supply. In order to fully utilize the heat produced by the CHP, either new heat infrastructure needs to be added for building or the existing heat infrastructure needs to be upgraded, which would cause extra investment cost.

Based on sensitivity analysis for the electricity rate and natural gas price, the proposed Community Microgrid is not sensitive to the increases of Electricity price since the electricity rate in this area is already higher than the generation cost of CHP, and it would mainly depend on the proposed CHP for serving its critical facilities.  While the proposed community microgrid is highly sensitive to the increase of natural gas price since the increased natural gas price would cause the increase of CHP's generation cost. The increase of natural gas price would have more overall impact on the generation cost of local natural gas fired DER than the overall electricity rate in the electricity market. As natural gas price increases, it would be less expensive to purchase electricity from the grid or install other types of DERs with lower generation cost such as solar instead of dispatching CHP for generating electricity. The levelized cost of energy (LCOE) for solar is around 12.5 Cent/kWh in which the LCOE is calculated as (Total life Cycle Cost/Total Lifetime Energy Production)[1].  The natural gas price in The Village shown in figure 21 is much cheaper than the Solar's LCOE, so the DER-CAM will prefer to install natural gas fired CHP instead of Solar PV. As shown in figure 21, when natural gas price increases, the electricity rate is still cheaper than the Solar's LCOE, so the DER-CAM would still prefer to purchase electricity from grid instead of installing Solar unit in high natural gas price scenarios.

[1] http://solarcellcentral.com/cost_page.html

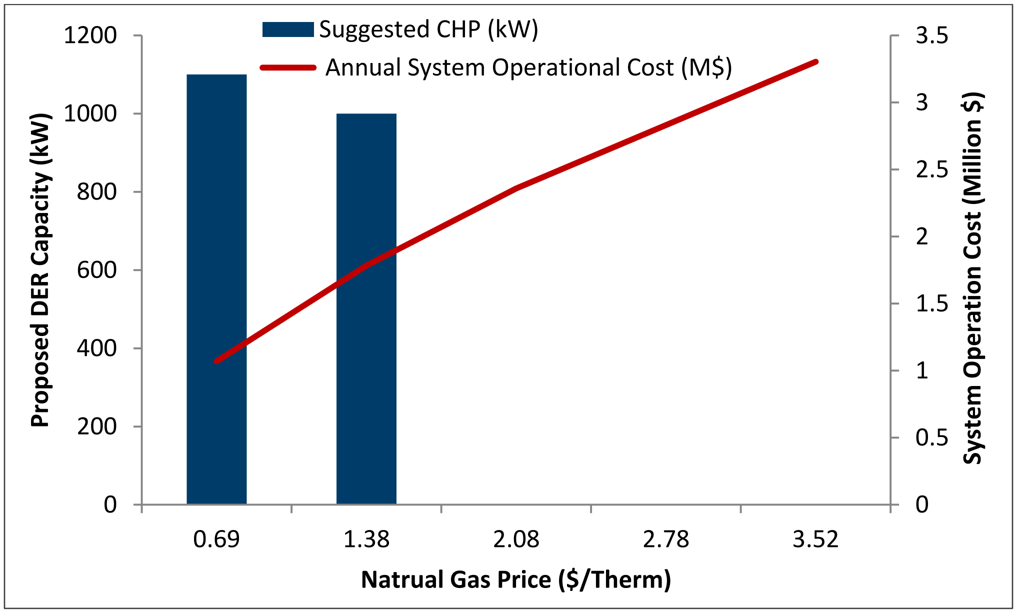



*Figure 21. Total System Sensitivity Analysis Results for Natural Price*[1]

The proposed CHP would have the black-start capability and the black start can be initiated by the master controller based on a pre-defined black start procedure. The proposed Community Microgrid master controller would determine the optimal and reliable operation of the microgrid through optimal generation dispatch and load signals. The generation dispatch signals are sent to dispatchable distributed energy resource (DER) units and the load signals are sent to building controllers. An interactive grid-forming control would be used either in island or grid-connected mode. In island mode, DERs apply this control scheme to share the load while in the grid-connected mode DERs apply this control scheme to regulate the power exchange between the microgrid and the utility grid. In grid-connected mode, the DER unit with grid-following control follows the microgrid voltage and frequency, which is set by the utility grid in grid-connected mode and other DER units in island mode.

## Sub Task 2.4 Electrical and Thermal Infrastructure Characterization

### Electrical and Thermal Infrastructure

Consolidated Edison (ConEd) owns and operates the distribution system within the community to serve all the electricity and natural gas customers. The identified clusters are shown in figure 20. The existing underground distribution cable would be utilized for connecting the different microgrid clusters. Furthermore, new connection cables installation between the microgrid clusters could be taken into account if the existing distribution cables put any constraints on the energy exchange between the clusters.   The overall distribution system configuration and thermal infrastructure of the Village is not available at the time of preparing this report. The detailed design within each cluster, provided by ConEd, is as follows.

[1] DER-CAM simulation results. DER-CAM utilizes kW or kWh for all its input and output data. Ratio of Therms/Hr to kW is 1:29.3.

### *Sleepy Hollow Cluster 1*

Existing: The identified Sleepy Hollow cluster 1 shown in figure 22 includes the Rescue Hose and the Village Hall, Police, and Fire department all fed off a 500 kVA transformer off of the Sleepy Hollow 13 kV primary feeder and the Union Hose and the North Tarrytown Housing Authority, each fed their own individual 500 kVA transformer off the 13 kV primary feeder. There is available Natural Gas on Cortland Street and off of Pocantico Street.

Proposed: To isolate the critical facilities from the existing underground 13 kV Primary, two manholes with normally open SCADA switches will have to be installed, one on Beekman Avenue to isolate the Rescue Hose and Village Hall, Police, and Fire department, and one on Cortland or Valley St to isolate the Union Hose and North Tarrytown Housing Authority. These switches will be connected by new underground cable and any additional customers interested in being served by the microgrid that are along the route can be added with additional manholes and cable. This configuration will allow a new generation resource to be added anywhere along the new underground cable to electrically serve the entire cluster, allowing a large range of options for a location of the new generation resource and allowing flexibility for any thermal infrastructure, seen in figure 22 as the red line, that must be installed to serve the Village Hall, Police, and Fire department. The proposed generator, located anywhere along Cortland street or Pocantico street, would have an available natural gas supply.

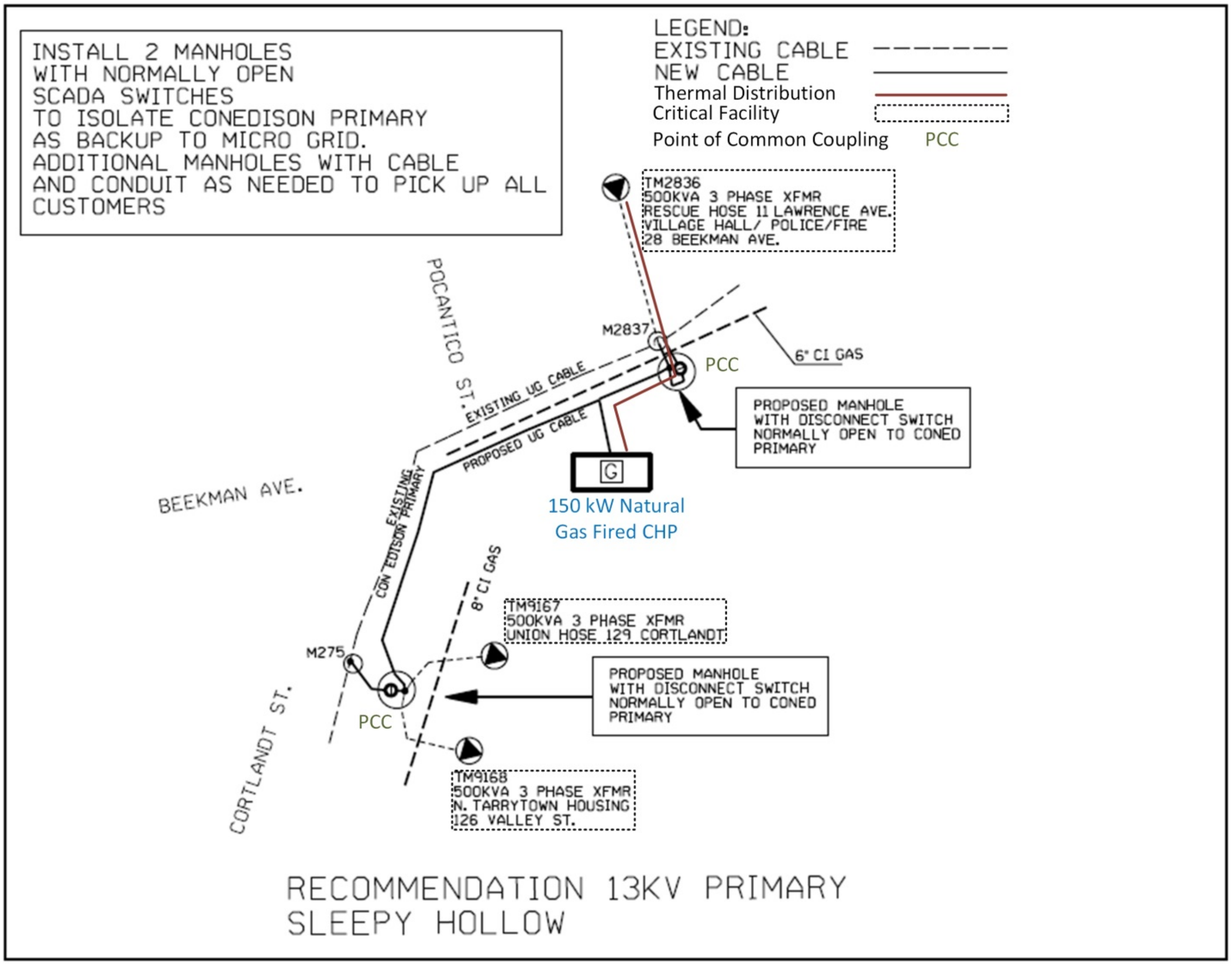



*Figure 22. Sleepy Hollow Cluster 1*

## *Tarrytown Cluster 1*

Existing: The identified Tarrytown Cluster 1 shown in figure 22 includes Tarrytown Police and Village Office, the Riverside Hose, and the Tarrytown Municipal Housing Authority (TMHA), connected at the end of a feeder spur. The Tarrytown Police and Village office is fed from a pad mount transformer and Riverside Hose and the TMHA are fed by pole top transformers. There is a 12" medium pressure (MP) natural gas (NG) main running up Franklin Street as well as an 8" MP NG main running down White Street, which is used to heat the critical facilities. There are a number of commercial and residential customers between the critical facilities identified that will be considered as microgrid customers.

Proposed: In order to isolate the critical facilities in Tarrytown Cluster 1 a new pole top SCADA switch will be installed on Franklin Street to pick up the entire spur, or end section of the feeder, that includes all of the cluster critical facilities. In order to do this, the additional customers on the spur will have to agree to participate in the microgrid or be connected back to ConEd's distribution system. In addition, an S&C PME switch would need to be added to the primary in order to connect a new generation resource, which would likely be located along Depot Plaza. This would allow easy installation of new heat infrastructure, seen in figure 23 as the red line, to serve the heating load of the Tarrytown Police and Village Office and any other chosen heating loads. As the new generation resource would be located along Depot Plaza or Franklin St, it would likely be fed from the 12" MP NG main, which runs along Franklin St.

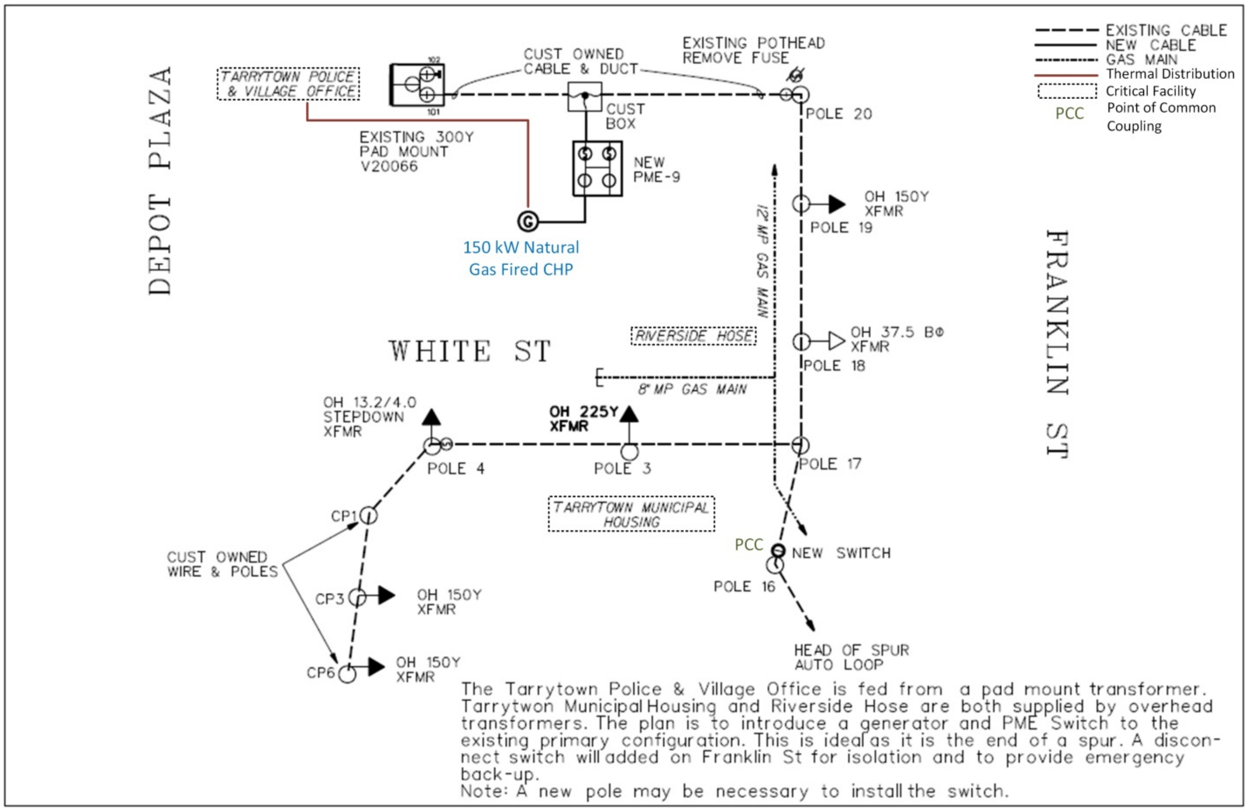



*Figure 23. Tarrytown Cluster 1*

### *Crossover Clusters*

Existing: The first identified crossover clusters, shown in figure 24, includes both the Sleepy Hollow and John Paulding Schools which are fed from the underground secondary network. Sleepy Hollow High School has a dedicated pad mount transformer fed from a primary riser. Both schools are directly next to each other and no other customers between would have to be recruited to isolate the schools. There is an 8" HP NG main running down Depeyster Street and a 6" LP NG main running up Broadway.

Proposed: As the schools are fed via separate sources, with one on the secondary network and one on the primary, it is recommended to install an S&C PME Switch fed by the existing primary feeder. Connected to this would be the existing cable that runs to the Sleepy Hollow High School's existing pad mount transformer, while new cable and duct would need to be installed to connect to a new dedicated transformer for the John Paulding School. This configuration would allow a new generation resource to be connected to the PME switch and serve both of the schools, while any new heating infrastructure could be fed to either of the schools, seen in figure 24 as a red line. This generation resource could be fed by the 8" HP Gas Main that existing along Depeyster Street, where the PME Switch would be installed.

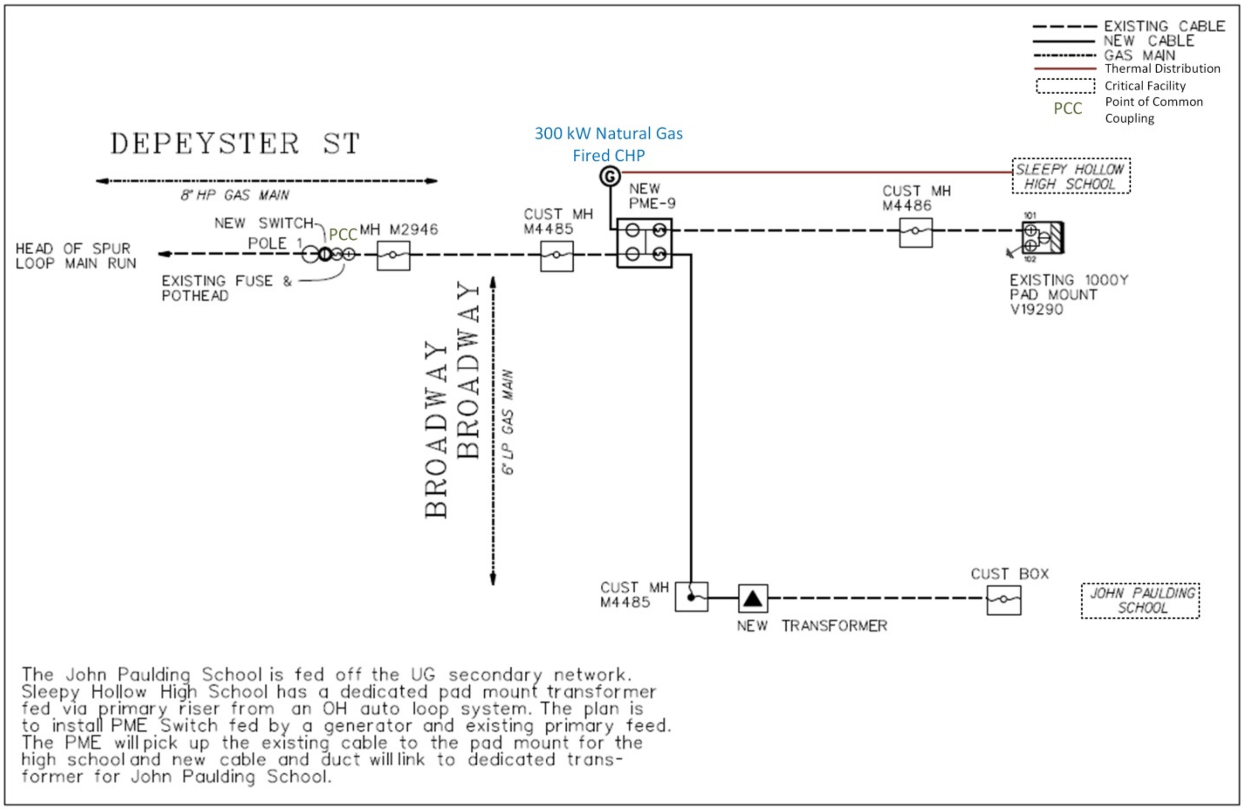



*Figure 24. Crossover Cluster 1*

Existing: The second crossover cluster, figure 25, involves three remote Village pumping stations, Briarcliff, and two for Tarrytown. Each of the three pumping stations is fed from a 500 KVA transformer off of the ConEd open wire 13 kV primary feeder.

Proposed: As the three pumping stations are all fed off the open wire 13 kV primary and have their own individual transformer, two normally open SCADA switches can be installed to pick up the pumping stations. These would require the installation of poles and risers for the switches to allow them to isolate the load or serve the load in parallel to the ConEd system. A new generator can be installed off of the SCADA switch to serve the pumping station load when the cluster is isolated. Nearby gas mains would have to be identified, and possibly extended, to feed the proposed generation resources.

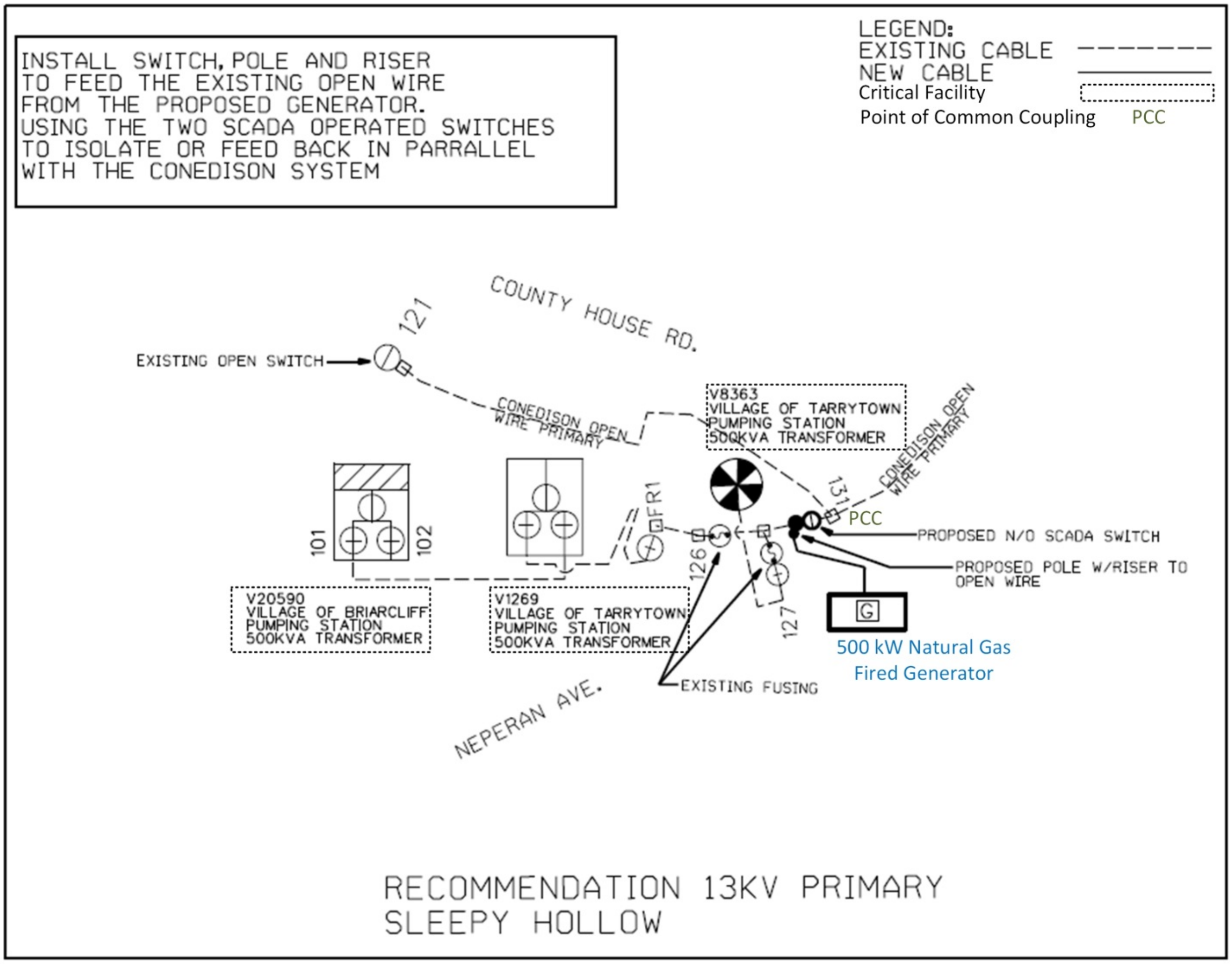



*Figure 25. Crossover Cluster 2*

## *Resilience of the Electrical and thermal Infrastructure*

This failure at the points of connection would remove electric service to all of the Village' customers, including critical facilities such as fire and public safety services, and water treatment plants. The communities have long been concerned about the vulnerability to interruption of bulk supply.

Resilience refers to the ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions, i.e., the ability to recover from a disturbance[1]. The electrical and thermal infrastructure is vulnerable to many phenomena, such as, hurricanes, earthquakes, drought, wildfire, flooding, and extreme temperatures, etc. Some extreme weather events have become frequent and severe in recent years due to climate change.  Snow storms and peak loads in winter season could cause damages or outages on the over-head system in the Village. Also heat waves in summer could affect distribution line conductor sags and any equipment that needs to be cooled off, such as, transformers, etc. A wind gust could cause tower/pole and conductor faults due to

[1] Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure. Available online: http://energy.gov/sites/prod/files/2015/04/f22/QER%20ch2%20final_1.pdf

trees falling. It would be also necessary to upgrade designs and focus more on emergency planning and restoration. For example, hurricane sandy occurred in 2012, which caused a widespread blackout of the power system in the eastern seaboard and left millions of homes in the dark from a couple hours to a few weeks. Natural gas disruptions are less likely than electricity disruptions, however, it is relatively more difficult to recover from the natural gas system failure driven outages than electric systems because of the difficulty to locate and repair the underground leakages. The extreme weather would affect both individual equipment failure and system operations. The damage from such events can impose large costs on distribution system as well as severe impact on the local economies. A community microgrid would solve the constraints by providing additional capacity and resiliency to the Sleepy Hollow Electric system.

In order to optimize the selection and operation of distributed energy resources, DER-CAM is applied here for microgrid simulations. A case in which maintaining the critical facilities' power with a one week disruption of power supply from the utility grid is presented here to show the investment options for addressing the system resilience. Table 14 and figures 26 and 27 present the DER-CAM simulation results. DER-CAM suggested 1,100 kW CHP to supply power to all Sleepy Hollow's critical facilities where even there are seven day's outages in utility grid. Shown in figure 26, the proposed community would mainly depend its own DERS (proposed and existing) to supply the load demand (left pie chart). The middle pie chart in figure 26 shows the DER-CAM suggestions and right pie chart is the existing DERs as the input data for DER-CAM simulations, all these pie charts are produced by DER-CAM automatically. It can be seen from figure 27 that all the critical facilities can be satisfied by the new added DERs along with the existing generation resources. The local DERs can also provide power to critical facilities during grid-connected mode shown in figure 28 which would improve the energy resilience of the critical facilities. It can be seen that the critical facilities would mainly be served by the proposed CHPs even in grid-connected mode.

*Table 14. The annual Costs Savings by the Investment for Supplying the Facilities in Sleepy Hollow and Tarrytown with Islanding in Peak Load Season (July)*

| Case | Base Case (no investment) | Investment Case (investment) | Saving |
|---|---|---|---|
| Total Annual Energy Costs (K$) | 1431.4 | 1,114.8 | 22.1% |

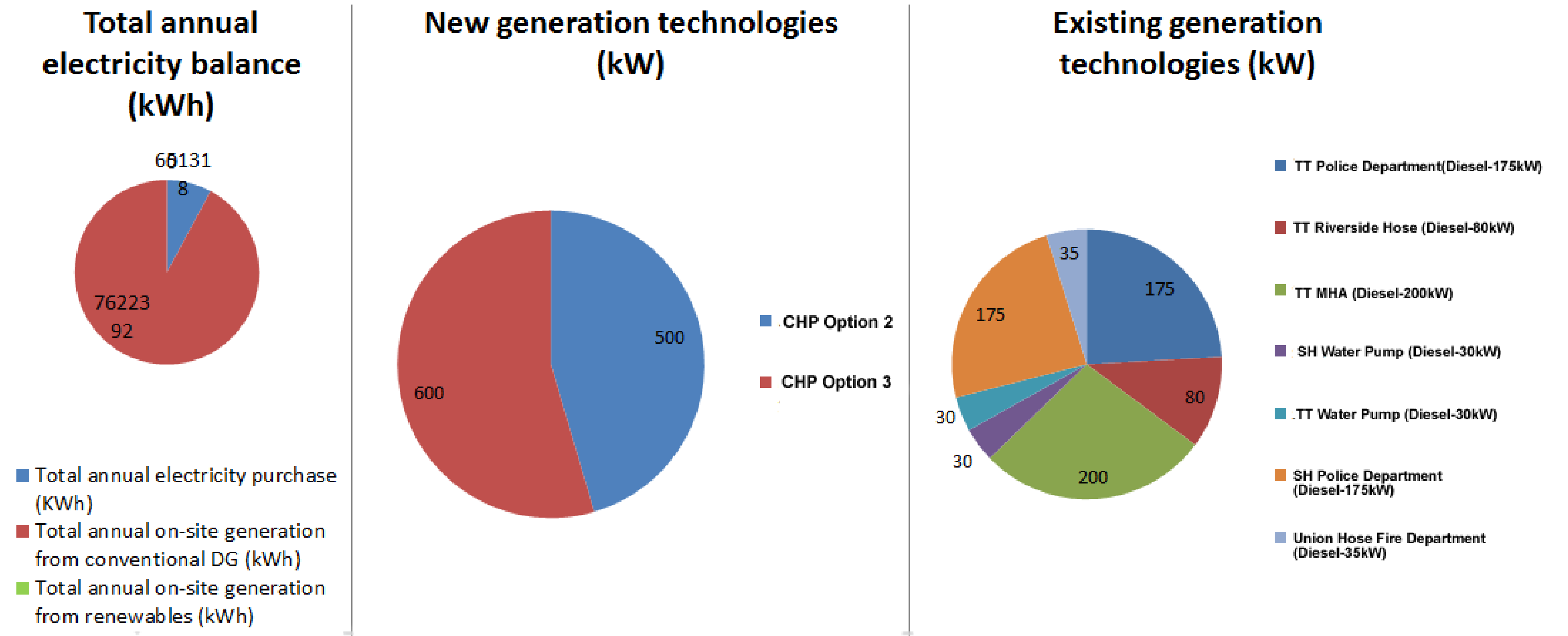



*Figure 26. DER-CAM investment results – Serving Total System Critical Facilities with one week island in July*[1]

[1] DER-CAM simulation results.

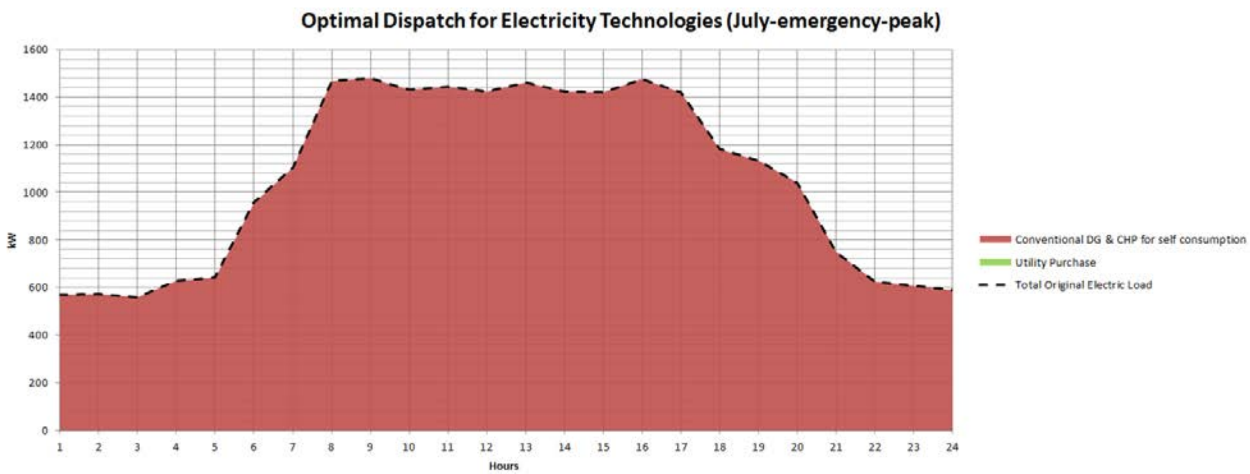



*Figure 27. Total System Optimal Dispatch during islanding mode*

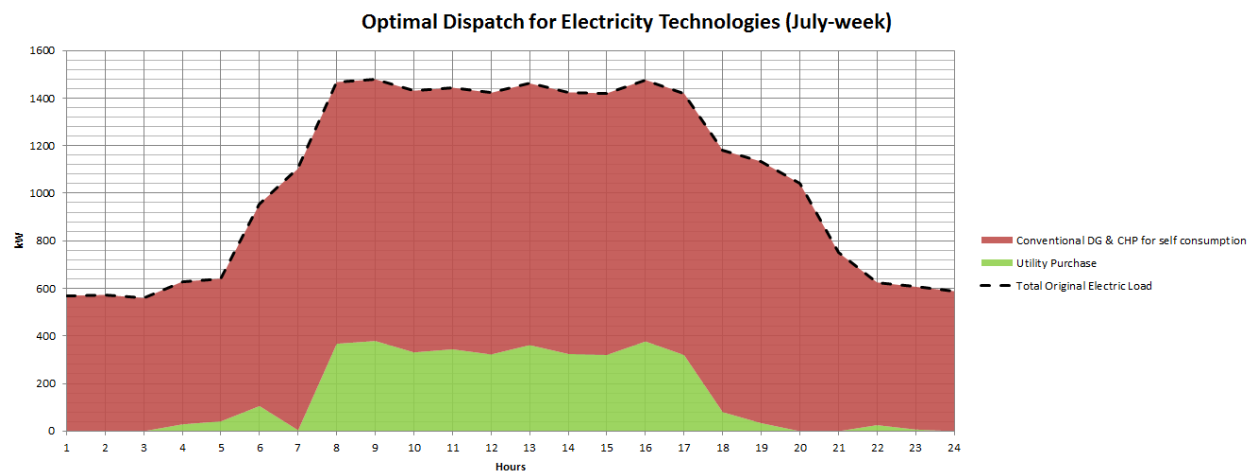



*Figure 28. Total System Optimal Dispatch in Grid-Connected Mode*

Regarding the critical facilities, DER-CAM is applied for the analysis of serving power to critical facilities with different islanding time periods, from one day to one week, and also different load levels are taken into account (load curtailment levels). The proposed DER capacity and operational costs to serve all the critical facilities (100% level/No curtailment) obtained from DER-CAM simulation are shown in figure 29. The proposed new capacity would depend on the peak critical load and doesn't change along with the islanding time period. The operational costs are almost flat with the increase of islanding time period in the 100% load level since most of the loads is served by local DERs and local DER operation cost is only dependent on natural gas price. While DER operation is dependent only on natural gas price, overall operation cost, included as the red line the charts below, includes amortized capital cost as well as the cost of running diesel backup generators, which is more expensive per kWh than the natural gas turbines. These differences explain the only minor fluctuations in operation cost as the level of DER proposed changes to serve the microgrid during islanding.

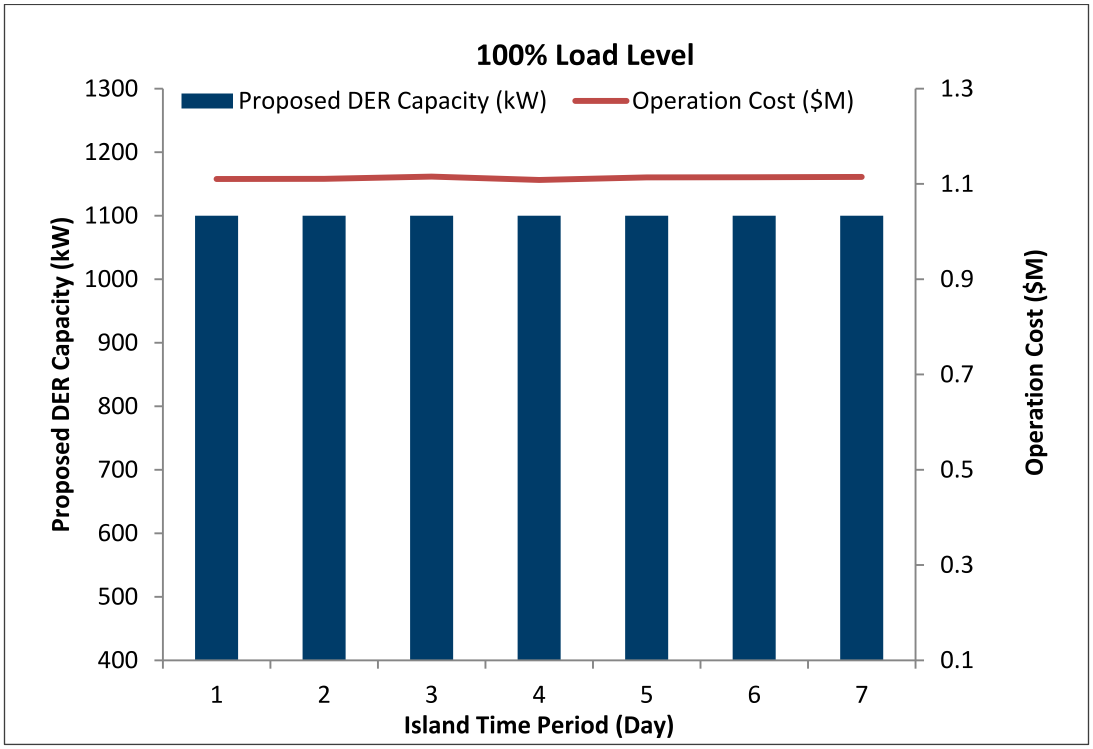



*Figure 29. Proposed DER Capacity and Operation Cost for Serving 100% of Total System Critical Facilities*

Figures 30-33 show the simulation results with 10%-40% load curtailment of critical facilities (for serving 90%-60% of critical facilities' loads), respectively.

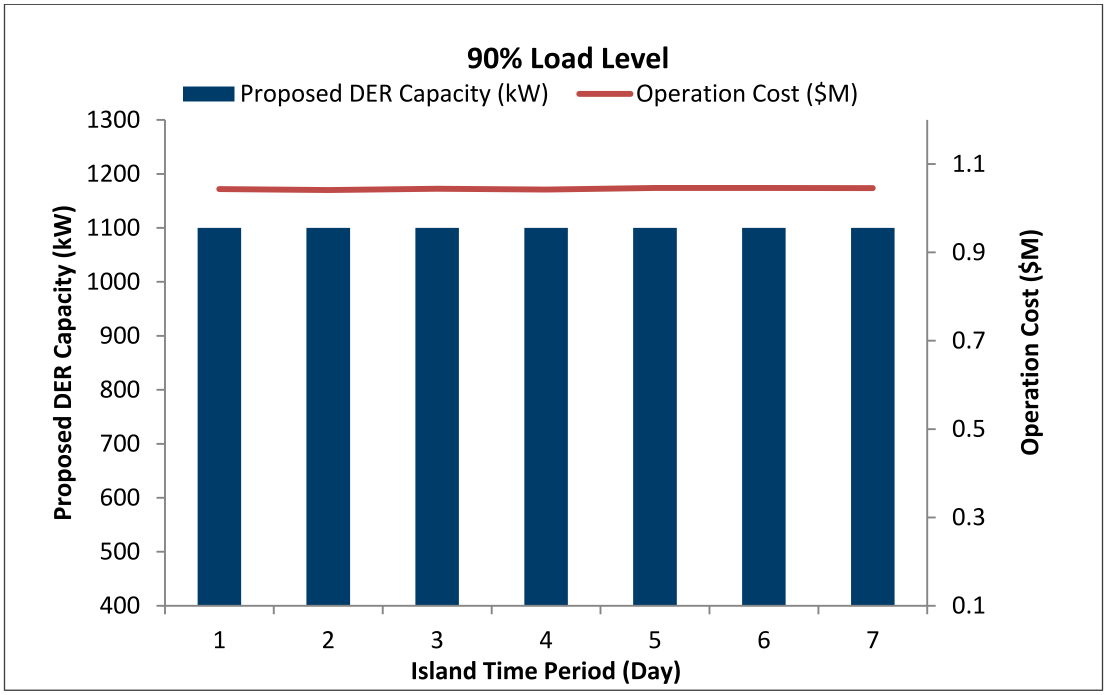



*Figure 30. Proposed DER Capacity and Operation Cost for Serving 90% of Total System Critical Facilities*

In figure 30, as seen in this case the extra 10% reduction in peak load causes the de-commitment of 100kW unit compared with figure 29.

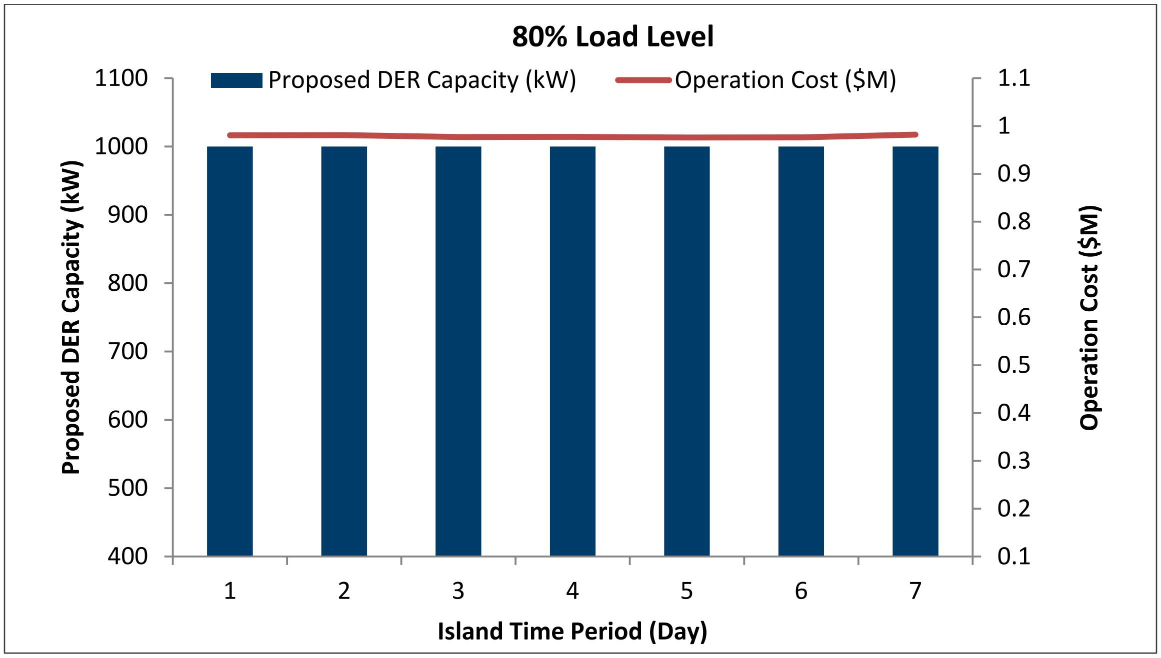



*Figure 31. Proposed DER Capacity and Operation Cost for Serving 80% of Total System Critical Facilities*

In figures 31 and 32, another 10% causes the de-commitment of another 100kW and 150kW unit, respectively. It can be seen that lower investments would be needed as more load is curtailed, just as the operational costs are reduced, which indicate that higher resilience of critical facilities can be achieved through either load management or adding new generation resources. The new added CHP would also help in reducing the operation cost.

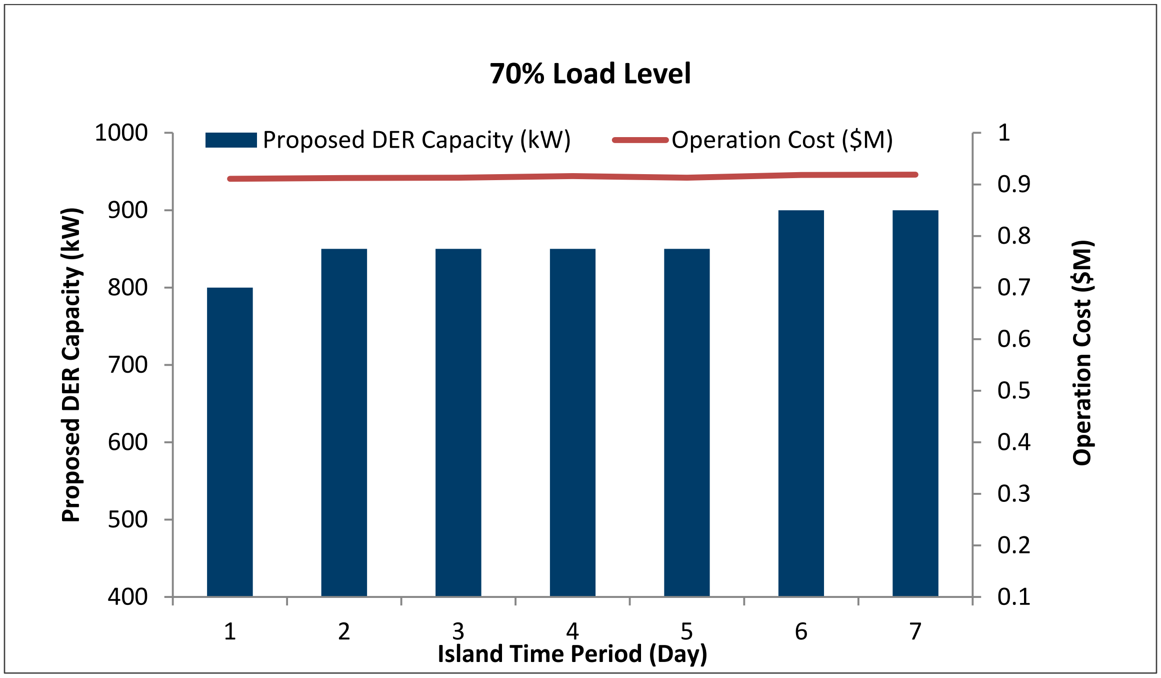



*Figure 32. Proposed DER Capacity and Operation Cost for Serving 70% of Total System Critical Facilities*

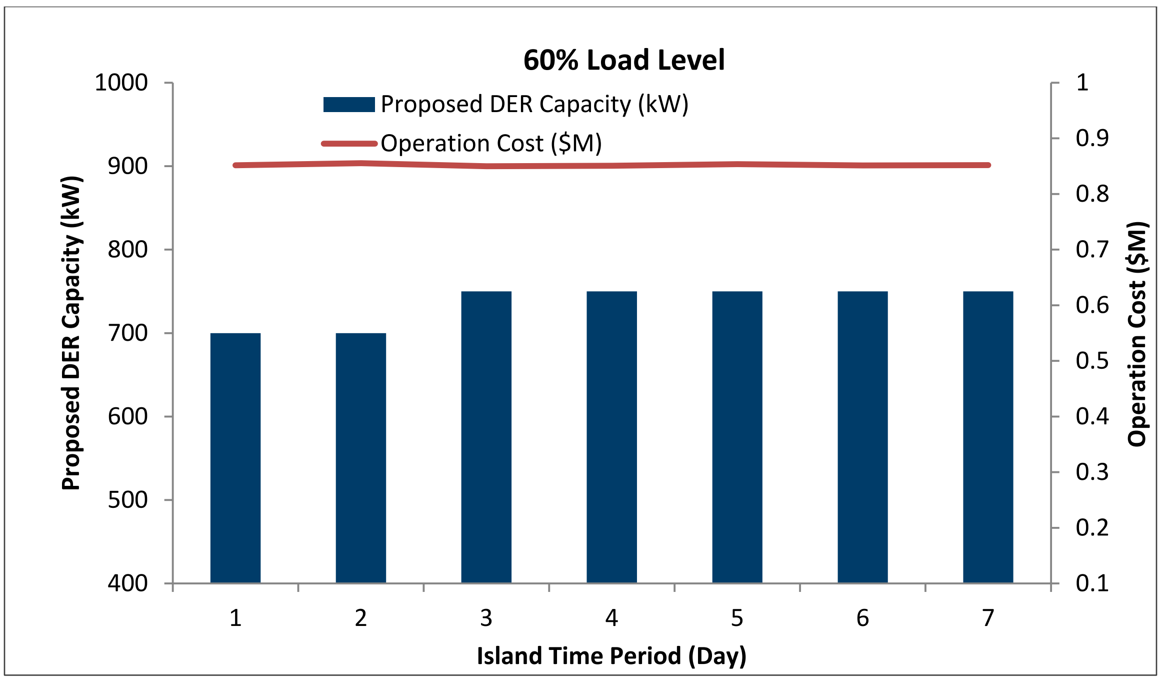



*Figure 33. Proposed DER Capacity and Operation Cost for Serving 60% of Total System Critical Facilities*

The DER-CAM simulation results are also shown in tables 15 and 16, based on the order of resilience in which we define that the capacity serving critical facilities without any disruption for seven days with no critical load curtailment as 100% resiliency and the capacity of serving 60% critical load for one day as 10% resiliency.

*Table 15. The annual costs savings by the investment for supplying power for total system critical facilities with one week islanding in peak load season (July)*

| Islanding Days | Load Curtailment (%) | Resilience (%) | Proposed DER Capacity(kW) | Operation Cost ($) | Investment Cost ($) |
|---|---|---|---|---|---|
| 7 | 0 | 100% | 1,100 | 1,114,785 | 1,321,000 |
| | 10% | 97.35% | 1,100 | 1,045,618 | 1,321,000 |
| | 20% | 94.71% | 1,000 | 981,923 | 1,201,000 |
| | 30% | 92.06% | 900 | 918,824 | 1,081,000 |
| | 40% | 89.41% | 750 | 852,782 | 901,000 |
| 6 | 0 | 86.76% | 1,100 | 1,113,966 | 1,321,000 |
| | 10% | 84.12% | 1,100 | 1,046,059 | 1,321,000 |
| | 20% | 81.47% | 1,000 | 976,254 | 1,201,000 |
| | 30% | 78.82% | 900 | 918,422 | 1,081,000 |
| | 40% | 76.18% | 750 | 852,328 | 901,000 |
| 5 | 0 | 73.53% | 1,100 | 1,113,759 | 1,321,000 |
| | 10% | 70.88% | 1,100 | 1,045,867 | 1,321,000 |
| | 20% | 68.24% | 1,000 | 975,877 | 1,201,000 |
| | 30% | 65.59% | 850 | 913,039 | 1,021,000 |
| | 40% | 62.94% | 750 | 853,717 | 901,000 |
| 4 | 0 | 60.29% | 1,100 | 1,112,457 | 1,321,000 |
| | 10% | 57.65% | 1,100 | 1,042,504 | 1,321,000 |
| | 20% | 55.00% | 1,000 | 977,383 | 1,201,000 |
| | 30% | 52.35% | 850 | 916,120 | 1,021,000 |
| | 40% | 49.71% | 750 | 851,821 | 901,000 |
| 3 | 0 | 47.06% | 1,100 | 1,112,318 | 1,321,000 |
| | 10% | 44.41% | 1,100 | 1,043,993 | 1,321,000 |
| | 20% | 41.76% | 1,000 | 977,077 | 1,201,000 |
| | 30% | 39.12% | 850 | 912,962 | 1,021,000 |
| | 40% | 36.47% | 750 | 851,524 | 901,000 |
| 2 | 0 | 33.82% | 1,100 | 1,110,760 | 1,321,000 |
| | 10% | 31.18% | 1,100 | 1,041,376 | 1,321,000 |
| | 20% | 28.53% | 1,000 | 981,058 | 1,201,000 |
| | 30% | 25.88% | 850 | 912,319 | 1,021,000 |
| | 40% | 23.24% | 700 | 851,247 | 841,000 |
| 1 | 0 | 20.59% | 1,100 | 1,110,259 | 1,321,000 |
| | 10% | 17.94% | 1,100 | 1,043,330 | 1,321,000 |
| | 20% | 15.29% | 1,000 | 980,566 | 1,201,000 |
| | 30% | 12.65% | 800 | 911,017 | 961,000 |
| | 40% | 10.00% | 700 | 851,116 | 841,000 |

*Table 16. Serving Total System Critical Facilities with Islanding in Peak Load Season (July)*

| Islanding Days | Load Curtailment | Resilience Weight (%)[1] | Proposed DER Capacity(kW) | Operation Cost (K$) | Investment Cost (K$) |
|---|---|---|---|---|---|
| 7 | 0-40% | 100% - 89.41% | 1, 100-750 | 1,114.8-852.8 | 1,321 – 901 |
| 6 | 0-40% | 86.76% -76.18% | 1,100-750 | 1,113.9-852.3 | 1,321 – 901 |
| 5 | 0-40% | 73.53% - 62.94% | 1,100-750 | 1,113.7-852.1 | 1,321 – 901 |
| 4 | 0-40% | 49.71% - 73.53% | 1,100-750 | 1,112.5-851.8 | 1,321 – 901 |
| 3 | 0-40% | 47.06% - 36.47% | 1,100-750 | 1,112.3-851.5 | 1,321 – 901 |
| 2 | 0-40% | 33.82% - 23.24% | 1,100-700 | 1,110.8-851.2 | 1,321 – 841 |
| 1 | 0-40% | 20.59% - 10% | 1,100-700 | 1,110.2-851.1 | 1,321 – 841 |

Willdan proposes a loop-based network which has the capability of supplying power to critical facilities from two feeders in order to improve the energy resilience of critical facilities. In cases of extreme weather events, if one feeder fails, the loads can be transferred to another feeder and will still receive power feed. The load transfer procedure is shown in figure 34.

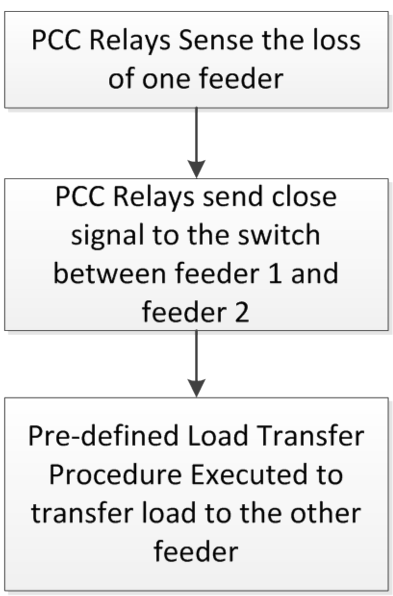



*Figure 34. Load Transfer Procedure*

[1] Resiliency weight is introduced based on the maximum number of days that critical facility capacity is being responded in the grid outage duration and maximum level of critical facility which can be served. We define that the capability of serving critical facilities with no curtailment for seven days (as customer's requirement) is 100% resiliency and the capability of serving 60% critical facilities for one day is 10% resiliency.

## Connecting the Community Microgrid with Grid and Microgrid Protection

The substation to which the 13kV primary feeders are connected in the proposed community could be the point of common coupling (PCC) where the proposed community microgrid could be isolated from the utility grid in order to operate in island mode in case of emergency, and resynchronize with the utility grid in order to operate in grid-connected mode. In the case of the clusters, each one will have an individual PCC with the surrounding primary feeders or secondary network.

Three phase power flow is integrated with the master controller which ensures stability and security of the community microgrid in both grid-connected and islanded mode. A hierarchical protection configuration strategy is proposed to for the protection which mainly contains four-level protection: load way, loop way, loop feeder way and microgrid level. Each level is equipped with protection devices. Also the four levels are coordinated. The protection devices and operational rules in each level are summarized in table 17. The load-shedding and other control schemes could also be implemented on the load-way protection level based on under/over-voltage and under/over-frequency functions of these relays. The hierarchical strategy aims at addressing the challenges in isolating various faults in time from loop based microgrids. The performances of microgrid protection are as summarized as follow.

- Detect and isolate of faults both inside and outside of microgrids,
- Detect and isolate the faults inside the microgrid in both grid-connected and islanded mode
- Detect and immediately isolate the faults of the loads and DGs,
- Prime protection and backup protection for protective device malfunction
- Compromise between selectivity and speed.

*Table 17. The Protection Devices and Operation Rules at Each Protection Level*[1]

| Protection Level | Protection Devices and Operation Rules in Grid-Connected and Island Modes |
|---|---|
| Load-way protection | Directional Overcurrent (DOC) digital relay with adaptive relay setting (responding to lower fault current in island mode):<br>—Operates only in load-way faults (DOC and auto reclosing). |
| Loop protection | DOC digital relay with adaptive relay setting:<br>—Operates in loop faults [primary and backup permissive overreach transfer trip (POTT)<br>Schemes<br>—Backup protection for load-way protection. |
| Loop-feeder protection | Non-direction Overcurrent (OC) relay:<br>—Operates to isolate the faulted loop only when the load-way and loop protections have failed within the loop. |
| Microgrid-level protection | OC relay and PCC switch:<br>*In grid-connected mode:*<br>—Unintentional islanding operation due to external fault or disturbance based on the signal from the MC<br>—OC relay (backup protection for the entire microgrid)<br>—Intentional islanding operation based on the islanding command from the MC.<br>*In island mode:*<br>—Resynchronization initiated by a command from the MC. |

## Sub Task 2.5 Microgrid and Building Controls Characterization

### Community Microgrid Control Architecture

Figure 35 shows the community microgrid elements, functions, and control tasks associated with each criterion. In particular, the tertiary control is the upper level of control system, which ensures the optimal operation of community microgrid by determining the set points of generation and load. In order to achieve the optimal economics, microgrids apply coordination with the utility grid and economic demand response in island mode. The short-term reliability at load points would consider microgrid islanding and resynchronization and apply emergency demand response and self-healing in the case of outages. Functionally, three control levels are applied to the community microgrid:

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

[1] Adaptive Protection System for Microgrids: Protection practices of a functional microgrid system. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6774516

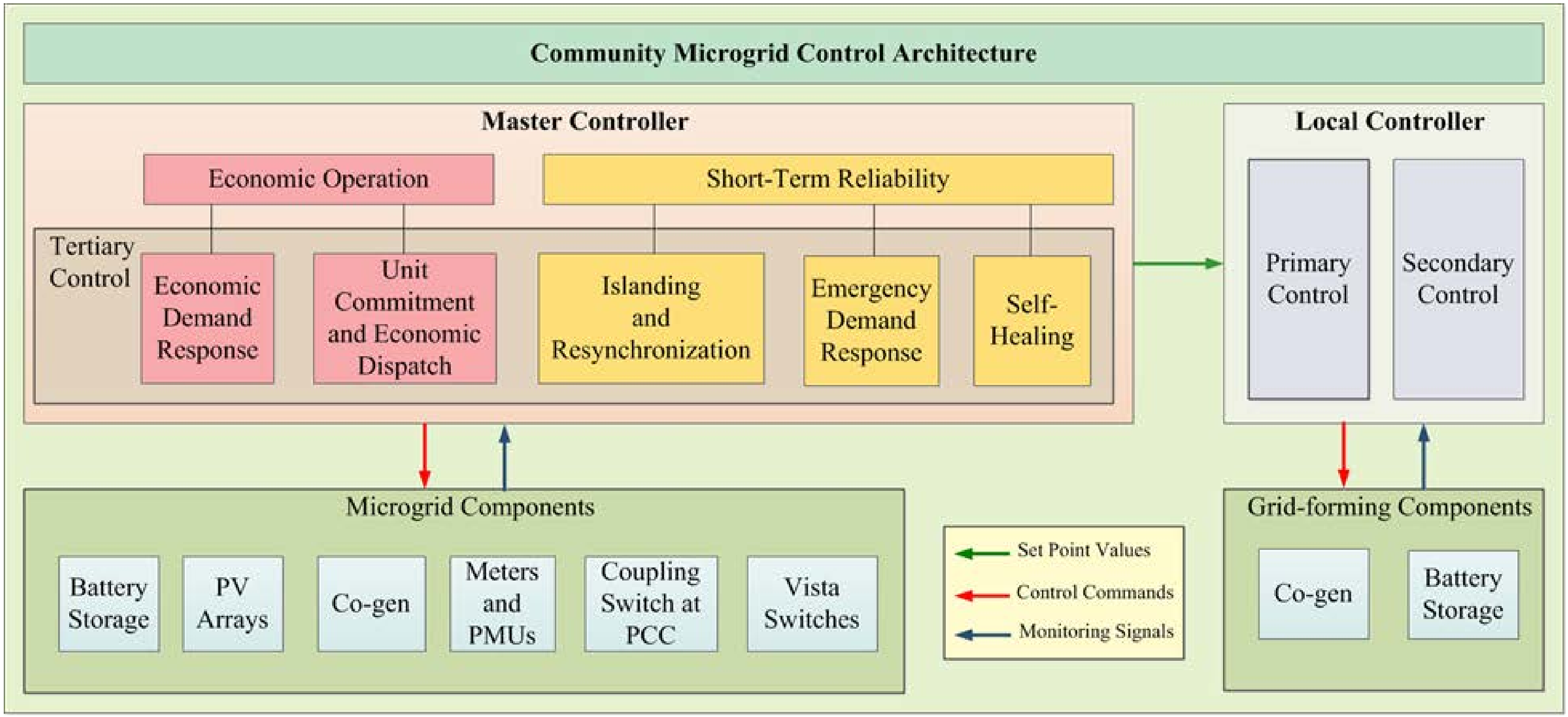
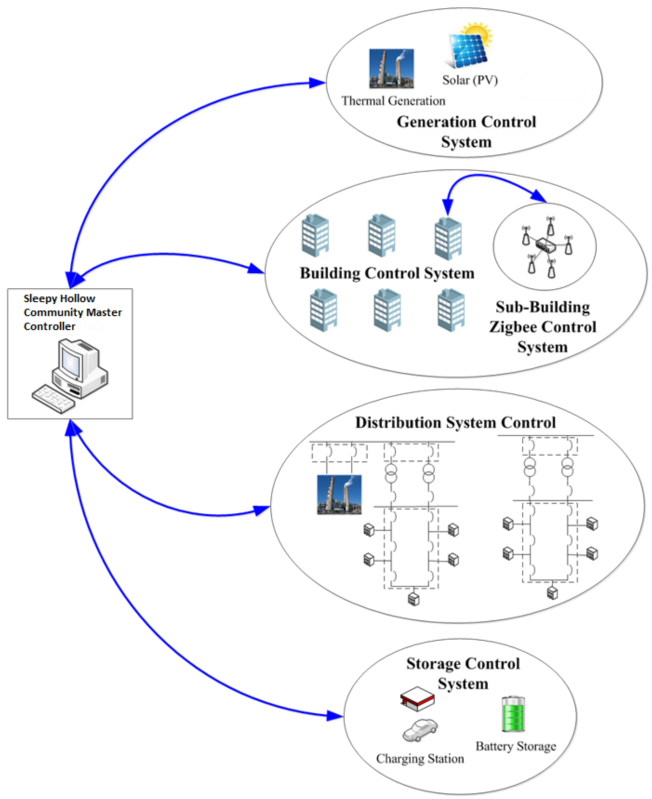
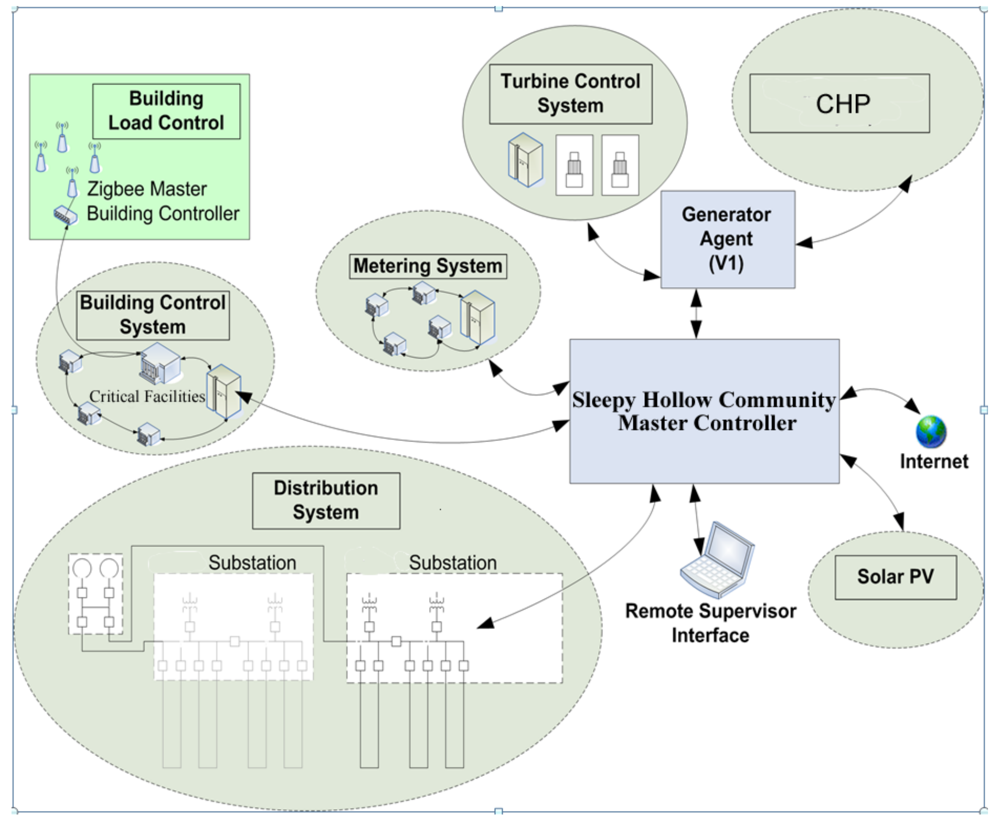



*Figure 35. Objectives and functions for the control and operation of the Community microgrid*




(a)




(b)

*Figure 36. Architecture of master controller for the Community Microgrid*

A major element of the proposed community microgrid is its master controller. The control signals from the master controller (MC) include the setpoints to adjust the CHP or other dispatchable DERs (grid-forming elements for maintaining frequency and voltage if any), and the signals to open/close switches. The master controller applies hierarchical control via supervisory control and data acquisition (SCADA) software to ensure reliable and economic operation of the Community microgrid. It also coordinates the operation of on-site generation, and individual building controllers. Intelligent switching and advanced coordination technologies of master controller through communication systems facilitates rapid fault assessments and isolations. In case of the failure of master controller, the primary control and secondary control would keep maintaining the stability of voltage and frequency.  The main functions of the community microgrid master controller are as follows.

- Communications and errors management – detection and or safe shutdown
- P/Q control for generators
- Point of Common Coupling (PCC) management - Power factor correction
- PCC management - Peak shaving/smoothing
- PCC management - Islanding and reconnection to grid
- Following active power command and voltage management
- Loss of communications safety
- Power limits, both kW and kVAR
- Loss of generation/storage asset management during grid-tied conditions
- Loss of generation/storage asset management during islanded conditions
- Unit commitment/availability
- Load shedding/Shifting
- Event logging

The hierarchical secondary control approach would receive the information from loads and power supply entities as well as the information on the status of distribution network and procure the optimal solution via an hourly unit commitment and real-time economic dispatch for serving the load in the normal operation mode and contingencies. Figure 35 shows the hierarchical framework of the Master Controller proposed for the Village' community microgrid project. In figure 36, the monitoring signals provided to the master controller indicate the status of DER and distribution components, while the master controller signals provide set points for DER units and building controllers. Building controllers will communicate with sub-building controllers and monitoring systems to achieve a device level rapid load management.

Multiple microgrid clusters are proposed for the Villages. Figure 37 shows the structure of the cluster master controller which coordinated all the microgrids by communicating with each of their master controller. All the clusters can either operate together as one microgrid or as individual microgrid simultaneously.

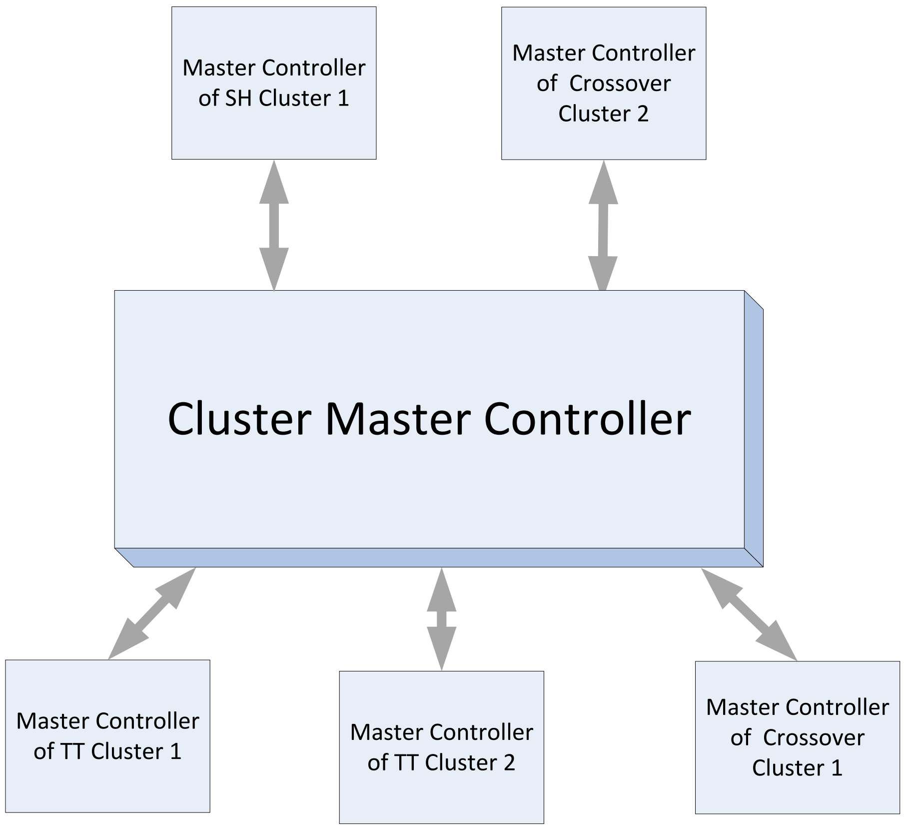



*Figure 37. Master controller for Microgrid Clusters*

With the master controller, the community microgrid would be able to provide ancillary services to the grid including the voltage support and frequency regulation, and the distribution system restoration. The master controller would collect the real-time information and send out set-point information through SCADA. In most of the time, the master controller would operate in autonomy mode based on predefined rules while keeping the reliability and economics of the whole community microgrid. In case of emergency, the controller would utilize the master controller to isolate the community from the utility grid and operate in island mode. Within the community microgrid, the non-critical load could be curtailed or disconnected through smart meter or breaker, local distribution networks are reconfigured so the local DERs can supply power to the critical facilities.

The proximity of power generation to microgrid consumptions could result in improved power quality, lower power losses, better voltage stability, and higher reliability (fewer customer outages) by engaging fewer components, and eliminating additional transmission services. With the added DERs, breaker and other smart devices, the proposed community microgrid could significantly improve the reliability indices which include the system average interruption frequency index (SAIFI), system average interruption duration index (SAIDI), customer average interruption duration index (CAIDI), customer average interruption frequency index (CAIFI), expected energy not supplied (EENS), and loss of load expectation (LOLE). The main services and benefits which the proposed community microgrid could provide are summarized as follows.

1. Increase Reliability and resiliency - The Community microgrid will be able to automatically island the electric system, energize critical facilities, and allow a portion of the system to be energized in the event of a bulk system outage. A CHP-driven microgrid will also introduce additional redundancy into the existing thermal system, allowing the main boilers to be shut down in the summer for regular maintenance, which will improve the reliability and resiliency of the overall system. The Reliability would be improved in normal operating conditions through infrastructure reconfiguration, such as a High Reliability Distribution System (HRDS) which senses and clears faults with virtually no impact on building loads, to a self-healing and more fault tolerant grid, by reducing the number of single points of failure by adding redundancy to the electrical and communications networks, and by adding alternate sources of generation to serve critical and non-critical loads.

   During emergency operating conditions, the Community microgrid would be able to provide uninterrupted power to critical loads, through the use of DERs and load shedding schemes that ensure safe and reliable operation of the buildings that matter most in emergency situations. Long term outages will be mitigated by large natural gas fed combined heat and power (CHP) plant, which will maintain a black-start capability in the event the outage occurs when the CHP facility is not active. These plant or plants will rely on robust natural gas pipelines and produce enough power to serve all of the critical facilities, public street and security lighting, and some residential load. This added resiliency will keep emergency responders and residents safe and provide the Community microgrid with heat and power when it needs it most.

2. Reduce energy cost uncertainties and exposure to market fluctuations - Additional heat generation electricity from a centrally located CHP plant, in each cluster that has heating requirements, would allow the Village to meet their summer/winter heat load without the expense of operating its main boiler or fuel purchase, resulting in a savings of over $1.7 million per year. These savings would then be passed along to the many customers and members in the form of lower energy bills and membership costs.

   Community microgrid would reap economic benefits in the form of added revenue streams from demand response, alternate generation sources, and energy efficiency measures to reduce overall energy costs. In the case of distributed energy resources, the Village will evaluate various ownership models to optimize the economic benefit to the system, including purchase, leasing and third-party ownership.

3. Integrate distributed energy resources (DER) into system operations - The Village will analyze replacing some or all of the non-CHP backup generators with black-start capable interconnected natural gas fired CHP generators strategically distributed at the critical facilities, vacant or unused land. In any case, the heat load from the CHP would be utilized year round, capitalizing on the communities' existing or upgrades piping and distribution infrastructure to deliver thermal loads.

4. Job creation - The operational requirement of a new CHP plant and microgrid system in the Village is expected to require the creation of new professional-level jobs. Current evaluations estimate that eight new jobs may be required to operate the CHP and microgrid systems proposed in this application.

## Sub Task 2.6 Information Technology (IT)/Telecommunications Infrastructure Characterization

Any modern utility or system operator relies heavily on their communication infrastructure to monitor and control their grid assets. For a microgrid master controller and microgrid operators, this architecture enables real time control, rapid digestion of critical grid information, and historical data for analysis and reporting. As part of a feasible microgrid, assessment and upgrade of the equipment and protocols used in the microgrid area will be performed.

### Existing Resources

Con Edison owns and operates all the substations and distribution lines serving local customers in Westchester County. A large majority of those customers are individually metered. Many of the distribution loops and feeders have mechanical switches or automatic switches that are not remotely controlled. The switches that are controllable are connected using fiber optic lines.

#### *Consequences*

A limited communications architecture can lead to increased frequency and duration of outages if problems must occur and be reported rather than having symptoms trigger notifications to grid operators of location and scope of the issue. Limited information and delay in this information leads to man hours wasted and longer duration of customers without power, putting strain on residential customers and potentially costing commercial customers significant amounts of money. Systems could have telltale signs of issues for weeks, but operators may not discover these until they have caused damage and outages to the electric grid or substations, costing the utility money and potentially endangering employees and customers.

#### *Opportunities*

The Village is considering an Advanced Metering Infrastructure (AMI) expansion, which would involve adding wireless communication infrastructure throughout each meter in the community to allow for automatic and digital meter reads. The key advantage of this expansion would be the network addition, which often utilizes the 900 MHz ISM band and relies on communication between integrated Network Interface Cards (NICs) that form a mesh network, allowing signals to hop between any installed meters to reach their ultimate destination and increases the propagation range of the signal in proportion to the number and dispersion of integrated NIC Smart Meters. The integrated NICs are connected to a local Access Point (AP) that transmits the metering and control signals for the lights over a cellular wireless network back to the utility data center, where it can be fed into a Supervisory Control and Data Acquisition (SCADA) platform for use in billing or monitoring the overall grid.

Village-controlled AMI would also provide opportunity for community demand response aggregation, in which Sleepy Hollow will be able to remotely control non-critical loads at the customer level to maximize economic benefit and/or reduce strain on the grid.

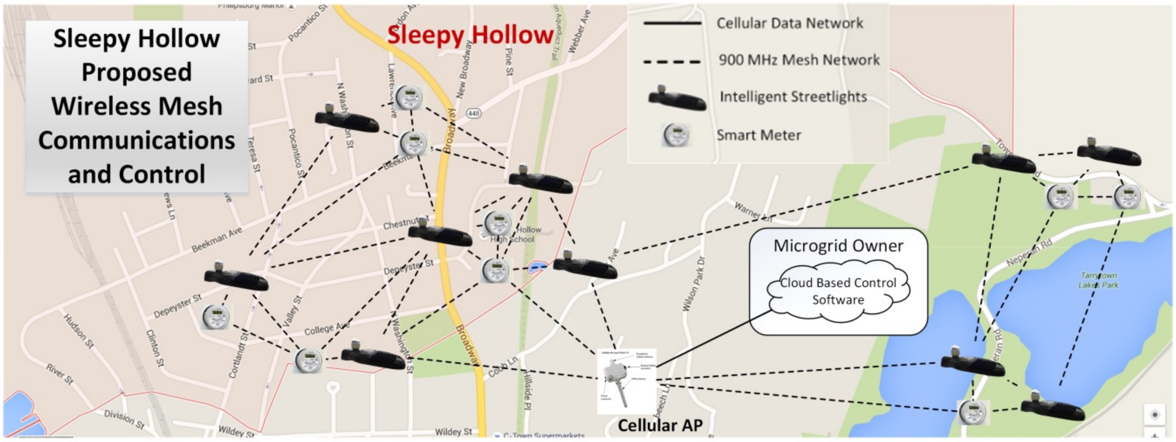



*Figure 38. Sleepy Hollow Proposed Wireless Mesh Network Communications and Control Diagram*

## Proposed/Suggested Improvements

The Community microgrid would be connected efficiently and productively, through the use of modern communication architectures and equipment, enabling a master controller to optimize the microgrid control and giving operators the tools they need to perform their daily duties. Exact upgrades or additions to existing communications infrastructure will need to be determined in a Phase 2 design. This network would leverage the AMI network and seek to strengthen it through the use of connected LED streetlights, which require half the power of the existing High Pressure Sodium (HPS) fixtures and shorten the overall payback of a street lighting upgrade through the implementation of smart photocells or integrated NICs that individually meter and control each streetlight, seen in figure 39.

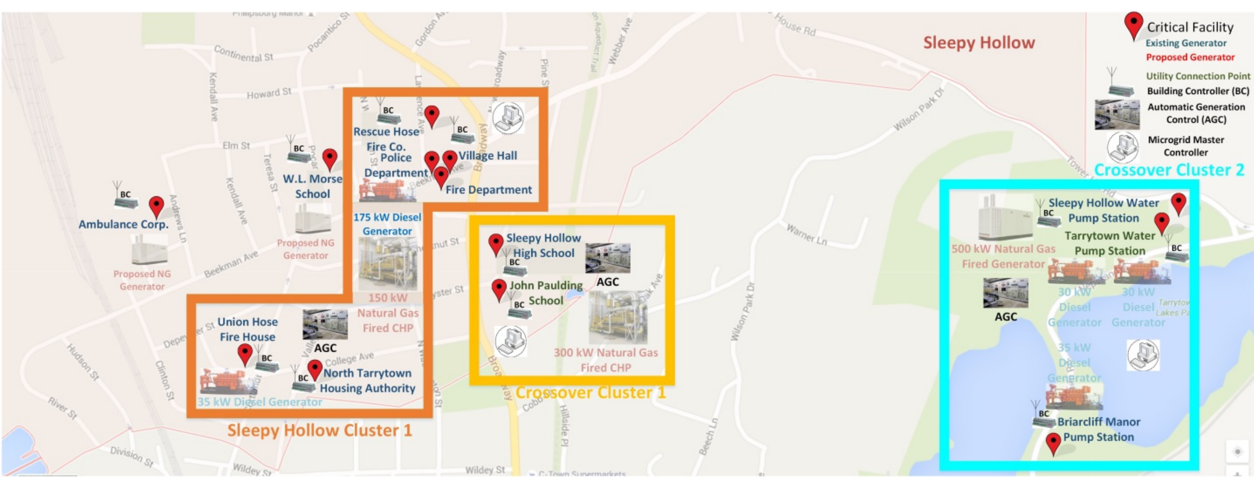



*Figure 39. Network Equipment simplified layout diagram*[1]

[1] Each Cluster will be utility connected as detailed in figures 23-25.

In addition to meters and lights, circuit breakers, relays, reclosers, and other switchgear are vital to the control of the Community microgrid. While some distributed switchgear can utilize a similar wireless infrastructure, with data being fed through substations instead of through a cloud network, the control equipment is more vital to the safe operation of the microgrid and would ideally use a fiber optic backbone between the master controller and the substations. The substation relays may have to be upgraded to communicate using the DNP3 protocol over TCP/IP, the de facto standard for modern utility communications, which will be used to monitor and control the proposed DER as well.

Once collected locally, the data will be fed into an upgraded or added SCADA system to allow operators to access, visualize, and control, all of the microgrid assets.

### *Benefits*

Utilizing a fully connected microgrid, with every vital piece of equipment monitored and controlled remotely, the master controller will be able to optimize load and generation automatically and in real time, the microgrid operators will be able to view the status, create reports, and plan future developments, and maintenance will be able to quickly assess and address any issues.

### *Barriers*

A more extensive review of existing communications and control equipment needs to be performed to determine the exact quantity and specification of the upgrade, RF testing will need to be performed to determine the layout of the wireless network proposed. Training would have to be done on the SCADA system and the newly implemented relays, and personal may need to be hired to maintain the network and communications equipment. A review of costs of the current system, including streetlight usage and maintenance data, current metering system costs and inaccuracies, and outage information will have to be performed to determine exact cost savings of upgrading to the new system.

As an owner/operator for the Community microgrid is chosen later in the study, the Master controller location will need to be determined. The master controller would communicate with the field devices such as the building controllers (BCs) and automatic generation controllers (AGCs) to connect to an automatically operate the electric system. This means that any loss in communications that disrupts the microgrid would need to be between building controllers and the master controller/utility data center and that this loss would only prevent communication with one building, while the rest of the microgrid would maintain normal operation.

Willdan’s proposed Community microgrid would rely heavily on the robust fiber optic backbone and the 900 MHz mesh network for monitoring and control. This system remains extremely resilient in the face of inclement weather due to the fiber optic being underground and the mesh networked being formed by above ground, but heavily redundant, mesh radios. Similar to the building controllers above, if one smart meter or streetlight is unable to communicate, the rest of the lights and meters would remain on the network and leverage each other to maintain a strong network connection.

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

## Sub Task 3.1 Commercial Viability – Customers

The critical services that would be supported by the microgrid clusters serve between 20,000 and 34,000 customers in the Westchester area; these include a fire station, ambulance corp., housing authority, and public schools, and water plants. There is a countywide backup support system in place with the nearby emergency services, including those of nearby Briarcliff Manor which is considering partnering with Sleepy Hollow and Tarrytown on microgrid implementation.

### Direct Services

In addition to increased reliability, or a reduction in the frequency and/or duration of outages, the community microgrid would reap economic benefits in the form of: (i) potential revenue streams from participating in demand response programs; ancillary service markets such as regulation and operating reserve markets as well as retail and wholesale generation sales; (ii) reduced consumption through energy efficiency measures; and (iii) deferring system upgrades. Based on the price of electricity and availability of Distributed Energy Resources (DERs), each individual cluster master controller will optimally dispatch the generation assets to provide the cheapest, cleanest, and most reliable energy possible to the critical and non-critical microgrid facilities. While no power can be directly shared between clusters, the master controllers can communicate to aggregate load for demand response or to coordinate the start-up of generators based on power quality or outage information in other clusters.

### Indirect Services

Utilizing a fully connected microgrid, with every vital piece of equipment able to be remotely monitored and controlled, the master controller will optimize load and generation automatically and in real time, the microgrid owner/operators will be able to view the status, create reports, and plan future developments, and maintenance personnel will be able to quickly assess and address any issues.

The community microgrid will be able to automatically island the electric system, energize and heat critical facilities, and allow a portion of the system to be energized in the event of a bulk system outage.

System reliability would be improved in normal operating conditions through infrastructure reconfiguration, such as a High Reliability Distribution System (HRDS) which autonomously senses and clears faults with virtually no impact on building loads, creating a self-healing and more fault tolerant grid by reducing the number of single points of failure by adding redundancy to the electrical and communications networks, and by adding alternate sources of generation to serve critical and non-critical loads.

During emergency operating conditions the community microgrid would be able to provide uninterrupted power to a portion of critical loads through the use of DERs and load shedding schemes that ensure safe and reliable operation of the buildings that matter most in emergency situations. Long term outages will be mitigated by 1100 kW of natural gas fed combined heat and power (CHP) plants, which will maintain a black-start capability in the event the outage occurs when the CHP facility is not active. These plants will rely on robust natural gas pipelines and produce enough power to serve all of the critical facilities. This added resiliency can keep emergency responders and residents safe and provide the community microgrid with heat and power when it needs it most.

Currently, it is expected that the community microgrid would likely be structured and operated as a regional public project similar to the Tri-Party Agreement established in 2006 between the Village of Tarrytown, Sleepy Hollow, and Briarcliff Manor for connecting to the Delaware Aqueduct. This regional joint authority project will be structured to ensure that any financial obligations are met through public guarantees of the three Villages.

The community microgrid would be the purchaser of power, as ConEd would remain the utility electricity supplier during normal operating conditions. During islanding, the critical facilities would be prioritized for power and payments would be worked out amongst the joint authority.

Each current account within the community microgrid is expected to continue purchasing power from the microgrid in blue sky conditions. While in island mode, only critical facilities including the fire hall, Police Station, and government facilities are guaranteed to be provided service, with additional capacity to provide additional services where needed in order of importance. These lists are different because the total amount of generation proposed under the microgrid is less than the total peak demand of the community microgrid service area. The generation is sized to provide enough capacity to provide power for all critical services in the event of a major outage event, or all facilities while implementing load shedding of non-critical loads.

The joint authority will be responsible for registering additional customers to be served by the microgrid; however, this must occur during the design phase to ensure proper sizing of the generation sources. This is due to the fact that if additional priority customers are to be added then the authority must take this into account and consider larger sized generation along with distribution upgrade requirements.

## Sub Task 3.2 Commercial Viability - Value Proposition

### Utility Costs

Coned would not be faced with the initial investment costs of upgrading their electrical infrastructure to a High Reliability Distribution System (HRDS) including Automatic Transfer Switches (ATS), Upgraded Circuit Breakers and Relays, improved communication infrastructure including, fiber optic and wireless RF, as well as the cost to train CHP plant operators or maintenance supervisors and network and controls engineers to configure and manage the newly upgraded system. Overall the utility cost would be lowered by moving all of these potential costs to upgrade and improve the system to the microgrid owner. This could help the utility avoid upgrade and capacity improvement costs, as well as some maintenance costs for the specific area, based on conversations with ConEd about one or more proposed clusters.

Microgrid development will be funded through feasibility by NYSERDA grants. Development and construction will be funded through available grants, private equity (where possible) and bond issuance. An Engineering, Procurement, and Construction (EPC) contract will be used as a vehicle for performance through the commercial operation date (COD). An operating contract will be executed to cover operations and maintenance upon commercial in-service. Appropriate warranties will be obtained from technology providers and cover each key component of the microgrid. Currently, it is expected that the community microgrid would likely be structured and operated as a regional public project similar to the Tri-Party Agreement established in 2006 between the Village of Tarrytown, Sleepy Hollow, and Briarcliff Manor for connecting to the Delaware Aqueduct. This regional joint authority project will be structured to ensure that any financial obligations are met through public guarantees of the three Villages. Potential Project team members may include bond counsel, private equity advisors, DOE LGO, NYMPA, EPC Contractor, Consulting Engineer, Operator, Permitting Consultant, Environmental Consultant, ConEd, ratepayers, Village Council, stakeholders, and technology providers. Table 18 presents the SWOT analysis.

*Table 18. SWOT Analysis*

| Parameter | Strengths | Weaknesses | Threats | Opportunities |
|---|---|---|---|---|
| Technology | State of the Art | Unproven-- Lack of performance history, in particular in emergency conditions | Disruptive next generation versions or replacements (rapid obsolescence) | Maximize operational efficiency |
| | Resilient | Expensive | Failure (potentially catastrophic) | Reduce environmental impacts |
| | Smart | Complicated | Potentially steep price reductions over near-term (6 months) | Leverage revenue and mitigate cost exposure to power purchases |
| | Efficient | Difficult to obtain private financing absent performance guarantee | Deployment challenges and supporting infrastructure requirements (e.g., AMI IT) | Enhance security and resiliency |
| | New | Limited vendors, lack of standardization (married to technology choice) | Vendor attrition | Economic benefits (enhanced sales, business continuity, rapid recovery, security, load shaping, etc.) |

*Table 18. SWOT Analysis (Continued)*

| Parameter | Strengths | Weaknesses | Threats | Opportunities |
|---|---|---|---|---|
| Regulatory | Complies with REV | Violates strict cost-of-service principles | Ratebase recovery disallowance | Advance next-generation energy resources |
| | Environmental benefits | May not comply with market restructuring rules | Movement toward vertical integration | Increase efficiency, optimize loads, enhance resilience |
| | Enhances grid/energy security | May not comply with franchise arrangements | Stakeholder rejection | Establish rate/recovery precedents |
| | Enhances ability to provide emergency services | May not comply with permitting requirements | Permitting hurdles, obstacles, and timing | Enhanced compliance with civic obligations for safety and emergency services |
| | Supports new technology development | Must go through ConEd to reach NYISO markets | Market rules/access to markets | Tariff and market reforms (ConEd, NYISO) |
| Financial | Facilitates load management | Requires subsidy/guarantee from host/DOE/NYSERDA | Non-performance of vendor/ technology | Cost reduction/peak shaving load shaping |
| | Creates new revenue streams | Revenue streams generally neither guaranteed nor predictable | Increased deployment may limit market opportunities and/or revenue stream values | Establishing new client base and service offerings |
| | Fuel supply price (natural gas) | Fuel supply availability during winter peak can be constrained | Fuel supply price and availability subject to supply/demand competition | Enhancing alternative fuel penetration/markets |
| | Municipal utility ownership and potential bonding/ ratebase recovery | Low cost of power supply | Cost competition from low-cost Niagara hydro allocations | Replacement of obsolete/ aging infrastructure |
| | Current credit ratings | Length of timing for development/deploy ment | Municipal financing may jeopardize ratings and solvency | Revising rate structures and cost of service study to account for microgrid |

*Table 18. SWOT Analysis (Continued)*

| Parameter | Strengths | Weaknesses | Threats | Opportunities |
|---|---|---|---|---|
| Financial (continued) | Enhanced metering accuracy for revenue recovery | Load management can reduce revenue | Data loss or hacking/privacy concerns | New customer service offering and market products |
| Construction/ Operation | EPC turnkey with performance guarantees | Unproven technology/ lack of operating history | Performance shortfalls or failures | Dynamic system optimization |
| | Independent construction monitor/ engineer | Reliance on third parties | Delays in completion and COD | Enhancing/upgrading distribution infrastructure |
| | Municipal ownership | Location (cheap power, grid dynamics) | Fuel supply interruption | Improved billing accuracy |
| | Existing utility and associated infrastructure for metering and billing and distribution | Legacy systems may be old and obsolete | Technology training and additional infrastructure | Improved cost recovery |
| | Enhanced services especially during emergencies | Stakeholder outreach and education | Compatibility with billing and existing systems | Enhanced customer service and interface |

Working closely with ConEd, Willdan has identified load clusters, which can be easily electrically isolated for resiliency and economic benefits. These clusters would each have a ‘peer’, or equally weighted, master controller that would optimize generation and load within the cluster and communicate with a single master controller that supervises and optimizes the entire system to provide benefits to each other as well as the surrounding community and utility stakeholders. This approach provides the best value to the customer in an area with a complex utility distribution network that does not necessarily follow city, county, or municipal boundaries. In addition, this configuration provides benefits to the surrounding area by acting as a demand response aggregator and by providing heat and power to emergency services, such as the fire department and police stations equipped with CHP, when it would not otherwise be available.

The community microgrid will be applicable to many communities. Willdan’s engineering team is leading multiple microgrid feasibility studies for western and southern New York communities and will ensure application of good ideas and best practices of microgrids playing a central role in transforming energy services will propagate throughout the participating municipal and investor owned utilities. Willdan is working closely with ConEd in the hopes that their support will open the option for communities around New York to consider the microgrid option.

The price of electricity in the Village is high enough that the installation and operation of natural gas fired CHP and generators will reduce the overall cost for the community microgrid’s customers when considered alongside the avoided fuel costs for the provided heat.

Many of the existing facilities in the Village rely on No 2 Fuel Oil for space heating. These existing heat sources would be phased out with the addition of the cleaner, more efficient, Natural Gas fired CHP and thermal infrastructure to utilize the waste heat.

Willdan proposes a Loop-based community microgrid. This new distribution network has a meshed structure which can operate as loop or radial, though it is normally operated as radial (i.e., with no loop) so as to make the protection coordination easier (upstream to downstream) and to make the distribution design easier. Also, the Automatic Transfer Switch (ATS) is proposed to be deployed within the community microgrid, which has the capability of network reconfiguration in case of emergency or outage.

Currently, there are no permanent generation resources anywhere in the community microgrid’s system. Only just over 500 kW of backup generators are the only available as distributed energy resources and do not provide sufficient capacity to support critical electric loads. As part of the feasibility study, the community microgrid can replace some or all of the non-CHP backup generators with black-start capable interconnected natural gas fired generators strategically distributed at the critical facilities and load pockets. This will ensure that the communities will be more prepared to weather power outages in emergency situations.

Each community microgrid Cluster would be served by generation sources, centralized within each cluster, supplied by robust natural gas pipelines. The two clusters that have heating load would be provided for by newly installed heating infrastructure from the CHP Plant to ensure heat and power when it’s needed most.

Steam produced by the CHP plants installed throughout the microgrid will be transported and sold to critical facilities and potentially to surrounding commercial or residential customers by way of newly installed thermal transport infrastructure.

Based on the owner/operators chosen business model, the power purchasers, commercial, residential, and Industrial customers, will have the unique opportunity to participate in a potential real-time pricing program, encouraging electricity use off of peak hours and savings for willing participants.

NY REV seeks to transform the state's energy distribution system toward cleaner and more local power, and will change its utilities' business model and regulatory framework. Although the target is investor owned utilities, for now, this project helps ConEd to consider how microgrids, distributed generation and increasing amounts of renewables might all fit together and help NY state to reach to its goals.

*Table 19. Stakeholder Value Proposition*

| Stakeholder | Value Proposition |
|---|---|
| Electricity Purchaser | The community microgrid will ensure a constant reliable source of heat and electricity to the communities critical facilities, ensuring that emergency shelters and police and fire stations remain fully operational in the event of an emergency while, at the same time, lowering the overall cost of electricity purchases by passing along savings from new sources of revenue and cost savings gained by the electric utility |
| Critical Facilities | In the event of an emergency the critical facilities would see uninterrupted flow of heat and electricity and maintenance of the full extent of the facility's operation. During normal operation, the financial benefits to the critical facilities would increase the money available for other community improvements while lowering costs for the critical facilities |
| Utility | The Utility would have deferred upgrades due to the installation of the microgrid assets by the microgrid owner as well as additional capacity due to the microgrid load being served by DER. In addition, there would be some maintenance cost reduction due the microgrid owner being responsible for a small portion of their service area |
| Suppliers and Partners | The microgrid owner would purchase more Natural Gas from their NG Supplier that they would use for CHP for Heat and Power, provide safety and reliability to the residents of Westchester County, and build a stronger and more resilient community in New York |
| NY State | NYISO would benefit from having another Demand Response participant that it could call on in times of need with grid balancing, and finally the state of New York would prosper as a technically advanced and resilient community grows and develops under its guidance |

Financially feasible, commercially viable, and more established or mature technology services or components were primarily considered to allow more financing opportunities for the overall project investments and to mitigate risk of emerging or early stage technologies being incorporated into the community microgrid. With the exception of natural gas-fired CHP technology, each major component proposed is a new (i.e., emerging or young) technology.

## Sub Task 3.3 Commercial Viability - Project Team

Local community groups and the municipal government are existing stakeholders to the microgrid project. The other aspects of the community microgrid have been brought to the community stakeholders to refine the ideas and maintain their support. Most of the facilities are village owned, facilitating their addition to the microgrid and the reconfiguration of their backup resources.

Currently, it is expected that the microgrid would likely be structured and operated as a regional public project similar to the Tri-Party Agreement established in 2006 between the Village of Sleepy Hollow, Tarrytown, and Briarcliff Manor for connecting to the Delaware Aqueduct. This regional joint authority project will be structured to ensure that any financial obligations are met through public guarantees of the three Villages. Potential Project team members may include bond counsel, private equity advisors, DOE LGO, NYMPA, EPC Contractor, Consulting Engineer, Operator, Permitting Consultant, Environmental Consultant, ConEd, ratepayers, Village Council, stakeholders, and technology providers. Willdan is serving and the energy and engineering expertise, with additional team members added as needed to support the construction and financing of the project

Consolidated Edison (ConEd) has been committed to the project and a key stakeholder whose input has guided the scope in a way that provides real value to the customers as well as benefits to any utility interested in integrating a microgrid or clustered microgrid in their service territory.

The Village of Sleepy Hollow has a good financial record and low debt burden. The most recent rating information for Sleepy Hollow is a rating of AA from Standard and Poor's in May of 2014 with a Stable Outlook.[1]

Briarcliff Manor's is AA+ from Standard and Poor's as of April 14, 2015 with $7.9M issuance of Public Improvement Refunding Serial Bonds.

Willdan is a 51-year-old company that provides energy and engineering expertise and professional services to thousands of municipalities across the country. Willdan has recently been awarded 8 NY Prize awards and is a growing force in the microgrid market.

Microgrid development will be funded through feasibility by NYSERDA grants. Development and construction will be funded through available grants, private equity (where possible) and bond issuance. An Engineering, Procurement, and Construction (EPC) contract will be used as a vehicle for performance through the commercial operation date (COD). An operating contract will be executed to cover operations and maintenance upon commercial in-service. Appropriate warranties will be obtained from technology providers and cover each key component of the microgrid.

As of now, the legal and regulatory support is being provided by subject experts within Willdan. Moving forward additional support is being sought from NYSERDA, as well as other industry professionals to support the development of this project. Willdan's existing relationship with Brookhaven National Laboratories has provided assistance in this area as well. Appropriate SMEs will be incorporated into the team as appropriate in the next rounds.

[1] The Village of Sleepy Hollow's issuance of $3.325M of Serial Bonds was rated -AA by Standard and Poor's according to the 2014 Official Statement.

## Sub Task 3.4 Commercial Viability - Creating and Delivering Value

### Selection Process

The existing technologies that may be considered to support smart grid and microgrid capabilities have been screened for their application to the community microgrid. This involved appropriating the benefits to the specific wants and needs of the stakeholders as well as refining the list to the reasonable and applicable technologies for the region. The remaining technologies, applications, and revenue streams were then evaluated based on financial and technical feasibility in their application to the community microgrid. This primarily consisted of detailed research into the existing infrastructure available and compatibility of the proposed technology with this infrastructure and with the other resources which will be available in the microgrid. Finally, the passing technologies were studied in detail to determine the range of acceptable capacity as well as the fit for the Microgrid owner/operator's requirements.

### Benefits

The addition of a range of DERs, including long term sources like CHP and short term sources like ICE DG, would allow the community microgrid to operate as a microgrid, take advantage of new revenue streams generated by microgrid assets such as Demand Response and Fast Response Regulation Markets, increase resiliency through on-site generation, and reduce charges associated with high winter heating loads by utilizing generation in the microgrid clusters. Distribution of these additional resources will ensure that critical facilities will remain powered on in emergencies, providing the Village with greater resiliency to natural and macro-grid events.

### Challenges

Additional modeling will be performed to determine the exact size, cost, benefits, and capacity of the proposed units, to ensure that they are financially feasible and that the space and personnel requirements are met. Plant managers for CHP will have to be hired internally or externally and training will be required for maintenance personnel and operators of the proposed DERs.

As Natural Gas fed generators and CHP are the most feasible option for the community microgrid, the microgrids will heavily rely on Natural gas pipelines to power the facilities. Pipelines are highly resilient to inclement weather, but do have the potential to break down or be damaged. This would have to be monitored closely by the partnership to prevent any small issues from leading to major problems if there is an interruption in natural gas supply. However, since ConEd currently owns and operates the gas distribution system with a high grade of reliability, there is not expected to be any additional burden with regard to gas system maintenance.

### Existing Resources

The total population of Sleepy Hollow's Electric service territory is 10,000. During the winter season, the Village splits its building's space heating load between natural gas and No. 2 Fuel Oil.

The locations, peak loads, and load clusters of nine critical facilities within Sleepy Hollow is shown in figure 40 and figure 41 and detailed in table 20 with electrical and thermal load, along with existing backup generation. Sleepy Hollow Cluster 1 includes the Riverside Hose, Police, Village, and Fire Department building, Union Hose, and the North Tarrytown Housing Authority. Tarrytown Cluster 1 consists of the Tarrytown Police Department, Riverside Hose Co. and Tarrytown Municipal Housing. Crossover Cluster 1 is on the border between Tarrytown and Sleepy Hollow and includes the John Paulding School from Tarrytown's critical facilities as well as the Sleepy Hollow High School from Sleepy Hollow's critical facilities. Crossover Cluster 2 is located northwest of Tarrytown proper and includes the Tarrytown Water Pump Station, the Sleepy Hollow Water Pump Station, as well as the Briarcliff Manor Water Pump Station.

The current distribution infrastructure and especially the building management systems between the buildings do not require a shared network infrastructure. This would have to be installed along with the microgrid assets to allow for the connections necessary to efficiently operate the microgrid.

The community microgrid master controller would determine the optimal and reliable operation of microgrid through optimal generation dispatch and load schedule signals. The generation dispatch signals are sent to dispatchable distributed energy resource (DER) units and the load schedule signals are sent to building controllers. An interactive grid-forming control would be used either in island or grid-connected mode. In island mode, DERs apply this control scheme to share the load, while in the grid-connected mode. DERs apply this control scheme to regulate the power exchange between the microgrid and the utility grid. In the grid-connected mode, the DER unit, with grid-following control, follows the microgrid voltage and frequency, which is set by the utility grid in grid-connected mode and other DER units in island mode. The proposed generation will be located at Village owned buildings, on the proposed network upgrades, with the master controller at a secure village owned location ensuring smooth operation of the microgrid.

Permits and permission may be required for the installation of additional DG though these are likely to be similar for any project. Additional air or discharge permits may also be required, thought this will be studied in greater detail in the next phase.

Willdan is leading the project development for the community stakeholders. The general process will proceed from feasibility assessment to design and construction in phases beginning with the CHP upgrade, followed by electrical infrastructure, and concluding with the master controller installation and commissioning.

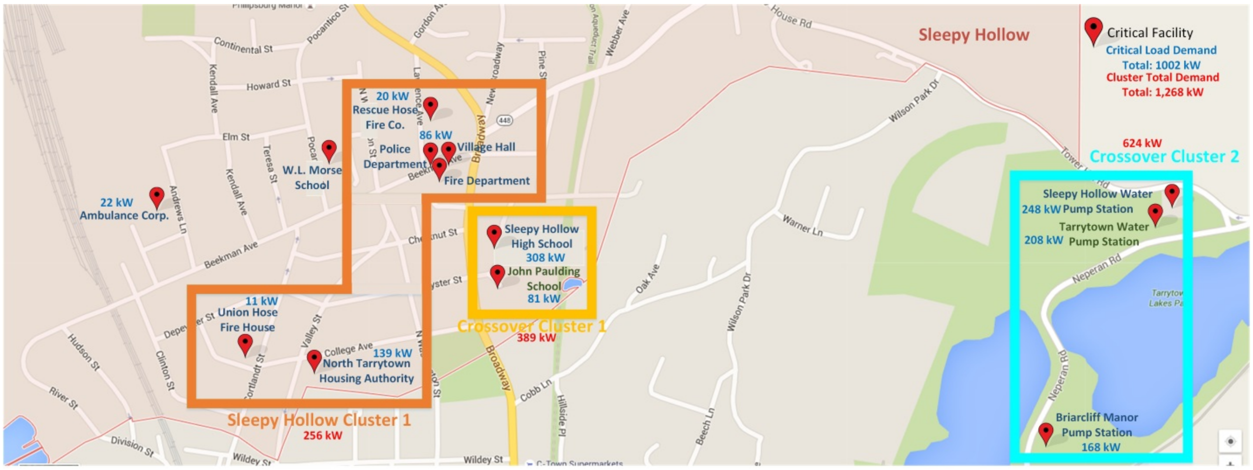



*Figure 40. Sleepy Hollow Load Simplified Layout Diagram*

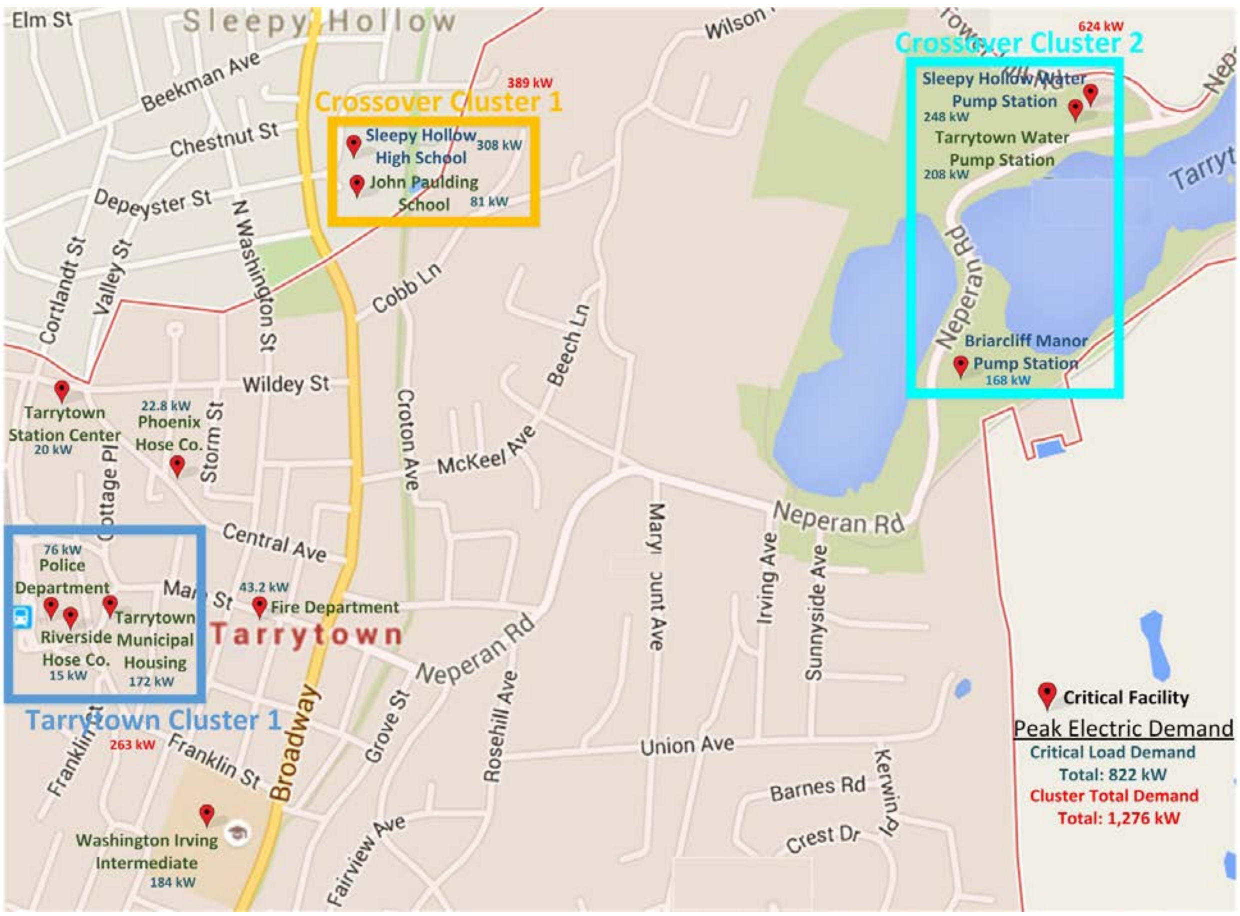



*Figure 41. Tarrytown Load Simplified Layout Diagram*

*Table 20. Microgrid Cluster Breakdown*

| Cluster | Involved Buildings | Demand (kW) | Average Heating Demand (Therms/Hr) [1] | Backup Generation | Proposed Generation |
|---|---|---|---|---|---|
| Sleepy Hollow Cluster 1 | Rescue Hose Fire Co | 20.1 | 1.9 | NO | 150 kW Natural Gas Fired CHP |
| | Police Department/Village Hall/ Fire Department | 85.7 | 4.2 | 175 kW Diesel | |
| | Union Hose Fire Hose | 10.6 | 1.0 | 35 kW Diesel | |
| | North Tarrytown Housing Authority | 139.3 | 25.5 | NO | |
| **Total SH Cluster 1** | | **255.6** | **32.6** | **210 kW** | **150 kW** |
| Tarrytown Cluster 1 | Police Department | 76 | 3.68 | 175 kW Diesel | 150 kW Natural Gas Fired CHP |
| | Riverside Hose | 14.7 | 1.39 | 80 kW Diesel | |
| | Tarrytown Municipal Housing Authority | 172.2 | 31.6 | 200 kW Diesel | |
| **Total TT Cluster 1** | | **262.9** | **36.6** | **455 kW** | **150 kW** |
| Crossover Cluster (CC) 1 | Sleepy Hollow High School | 307.9 | 51.3 | NO | 300 kW Natural Gas Fired CHP |
| | John Paulding School | 80.8 | 18.9 | NO | |
| **Total CC 1** | | **388.7** | 70.2 | **NONE** | **300 kW** |
| Crossover Cluster (CC) 2 | Sleepy Hollow Water Pump Station | 248 | NONE | 30 kW Diesel | 500 kW Natural Gas Fired Generator |
| | Tarrytown Water Pump Station | 208 | NONE | 30 kW Diesel | |
| | Briarcliff Water Pump Station | 168 | NONE | 35 kW Diesel | |
| **Total CC 2** | | **624** | NONE | **95 kW** | **500 kW** |
| **Total** | | **1,531.2** | **139.5** | **515[2] kW** | **1,100 kW** |

[1] These values based on ConEd usage billing data and converted to hourly average values Ratio of Therms/Hr to kW is 1:29.3

[2] This number was obtained from the available information at the time; a reported 30 kW generator, two 35 kW generators, and 150-200 kW generator (assumed to be 175 kW) and one confirmed generator with unreported size that was estimated based on similar building types with confirmed generators in Tarrytown.

The community microgrid will ensure a constant reliable source of heat and electricity to the community's critical facilities, ensuring that emergency shelters and police and fire stations remain fully operational in the event of an emergency, which may otherwise be disastrous with the absence of power, while, at the same time, lowering the overall cost of electricity purchases by passing along savings from new sources of revenue and cost savings gained by the electric utility. These include economic dispatch to reduce the overall price of electricity, and DR aggregation for the clusters.

While customers could see short term increases in rates to realize some of the additional smart grid benefits, over time, energy efficiency and intelligent management programs should enhance and optimize consumption patterns to control costs while increasing resiliency and efficiency. These rate increases are also unlikely, as the aggregated cluster load for each cluster will be considered one customer to ConEd, because there will be a single electrical point of connection with the utility and each cluster will have its own utility owned electric meter, and therefore, will qualify for a lower electricity price as a higher class of service than individually metered buildings. The microgrid owner can decide to pass this cost along to customers directly or consider the difference as a revenue stream.

All of the pieces of the microgrid generation, hardware and software are expected to come from on the-market, proven solutions. In terms of the master controller, Willdan is evaluating potential options, with preference being given to those solutions that have been previously installed and financed in existing microgrids.

All final decisions and responsibilities lie with the owner/operator/developer of the project, the joint community agreement. Willdan shall support the project development and performance guaranteed, backstops, and warranties will be sought out where necessary. Project development will proceed with the microgrid owner selecting a Design firm followed by pursuing construction and financing support. Willdan will support the decision making process with technical expertise and the project team will work to ensure all processes proceed as expected.

As currently structured, the project would be a customer of ConEd and all financial transactions, including electricity purchases, would flow through ConEd. As clusters of buildings would be aggregated, new ConEd meters would have to be placed at the point of common coupling to individually meter each cluster.

The project is municipal in nature, and while the project may be replicable across the State in other municipalities, there are no additional commercialization plans for any piece of this project.

The community microgrid project is located in a congested area of NYISO and therefore offers benefits to the grid as reflected in the potential revenue streams presented herein. The municipal model presents the best option to overcome potential regulatory barriers and existing loan guarantee programs to overcome financing barriers.

# Sub Task 3.5 Financial Viability

## Potential Revenue Streams

Potential revenue streams and/or savings will be highly dependent upon the final configuration of the community microgrid, the ownership structure, factors affecting power prices in the New York Independent System Operator's (NYISO's) markets, and natural gas markets, among other items. Assuming the microgrid includes natural gas-fired CHP, potential revenue sources may include energy sales to Consolidated Edison of New York, Inc., Demand Response related revenues and Ancillary Services payments from NYISO, and potential revenues from other public authorities. Generation technology would also potentially displace energy purchases during NYISO peak summer months. General estimates of these costs follow. Should the community microgrid proceed to the next round, detailed information on actual technology and detailed production cost modeling would be necessary to quantify expected revenue streams.

### *Demand Response Revenues*

Any generation associated with the community microgrid could potentially participate in demand response programs offered by Consolidated Edison, Inc. (ConEd), the regional service provider and a NYISO Market Participant. ConEd's PSC No. 10, Schedule for Electricity Service—General Rules, Regulations, Terms and Conditions under which Electric Service will be Supplied—currently applies to the County of Westchester where the Village is located. Currently, ConEd offers demand response rates under Rider U—Distribution Load Relief Program, Rider V—Emergency Demand Response Program, and Rider W—Day Ahead Demand Reduction Program. ConEd designates eligible SCs for each type of service. The community microgrid would most likely receive service under SC-11—Electric Buy-back. SC-11 service requires a customer to be eligible for service under one of the following SCs: SC-5 (electric traction systems), SC-8 (multiple dwellings-redistribution), SC-9 (general-large >10 kW), SC-12 (multiple dwellings space heating), or SC-13 (bulk power high tension – housing developments). The applicable payments and terms for each of these Riders follow.

Rider U is available between May 1 and September 30 to various SCs including SC-11. Under this Rider, community microgrid would be required to provide at least 50 kW of Load Relief under either a voluntary or reservation payment option as either an Aggregator of loads (in which case a minimum of 100 kW of Load Relief is required) or single account holder. Participants may be called upon to participate in up to two testing events of up to one hour each.

Under the Voluntary option, for each event, ConEd pays $3.00/kWh for the average hourly kWh of Load Relief times the number of event hours.

For Reservation participants, ConEd pays $6.00/kW-month for designated Tier 1 Networks and $15.00/kW-month for designated Tier 2 Networks. In both cases payments are adjusted by a Performance Factor based on historic performance (initially set at 1.0). A Bonus Payment of $5.00/kW-month is paid at the end of the three year incentive period following initial participation. Additional bonus payments are available for Load Relief provided during designated Bonus Hours or Bonus Periods.

Bonus periods apply for each participant event after the sixth Load Relief occurrence during the period from May 1 to September 30. Payments consist of $2.00/kW-month up to the ninth occurrence and $3.00/kW-month per event thereafter, in each case as adjusted by the Performance Factor. Additionally, commencing on the fifth hour of a Load Relief event, a Bonus Hour payment of $3.00/kWh is made. Finally, a Performance Payment of $1.00/kWh applies for each non-Bonus Hour and for each testing event hour.

Rider V—Emergency Demand Response Program—payments are available to various SCs, including SC-8, SC-9, SC-12, and SC-13. Participants can provide 100 kW or more of either Load Reduction or Load Delivery during certain NYISO-declared emergencies. Payments under this Rider consist of 90% of the greater of the real-time zonal Locational Based Marginal Price (LBMP) or $0.50/kWh, for a minimum of four hours.

Rider W—Day Ahead Demand Reduction Program—payments are available to various SCs, including SC-8, SC-9, SC-12, and SC-13. Program participants bid at least 100 kW of Load Curtailment in 100 kW increments starting at $0.05/kWh.

### *SC-11 Revenues*

SC-11—Electric Buy-back applies to the purchase of capacity and energy from certain classes of customers including non-residential CHP DERs. This schedule provides capacity and energy payments to certain designated generators like community microgrid.

Monthly capacity payments under SC-11 are based on the NYISO applicable capacity payments.

*Under this schedule, energy payments to generators are based on the NYISO zonal LBMP. For Generators delivering at secondary distribution, the price is increased by an adjustment of 1.066. Total annual payments are estimated to be around $52,000.Installed Capacity Revenues*

The community microgrid may qualify for sales of Installed Capacity (ICAP) under ConEd’s PSC-10 Rider P—Purchases of Installed Capacity. To be eligible, community microgrid must be a Full Service customer of Con Ed under various rate schedules including those which would likely apply to the community microgrid. ICAP sales are available to a customer who contracts to provide at least 100 kW (in multiples of 100 kW) of curtailment through either Load Reduction or Load Delivery. Purchases of ICAP apply to winter (November through April) and summer (May through October) capability periods.

Table 21 illustrates potential ICAP payments to the community microgrid. Customers can enroll based on Summer (May-Oct) or Winter (Nov-Apr) participation. Based on these estimates, revenues of approximately $52,000 would result from capacity payments for 12-months of participation.

*Table 21. Illustrative Example of ConEd ICAP Revenues*

| | May | Jun | Jul | Aug | Sep | Oct |
|---|---|---|---|---|---|---|
| Price ($/kW-Month)[1] | $10.50 | $9.87 | $9.08 | $8.44 | $8.40 | $8.35 |
| Capacity (MW) | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| ConEd ICAP Payment ($) | $9,975.00 | $9,376.50 | $8,626.00 | $8,018.00 | $7,980.00 | $7,932.50 |
| | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** |
| Price ($/kW-Month)[2] | $3.78 | $3.75 | $3.80 | $3.75 | $3.74 | $3.70 |
| Capacity (MW) | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| ConEd ICAP Payment ($) | $3,591.00 | $3,562.50 | $3,610.00 | $3,562.50 | $3,553.00 | $3,515.00 |
| **TOTAL** | | | | | | **$51,908.00** |

Microgrid generation may potentially participate in other NYISO Ancillary Services Markets, however the extent to which resources can take advantage of these potential revenue streams are dependent upon ConEd tariffs. ConEd's ancillary services charges provide a general estimate of potential revenues available. Table 22 illustrates the ancillary service charges for the Westchester Zone (NYISO load zones H and I) for 2015.

*Table 22. Con Ed Ancillary Service Charges*

| Effective Date | Westchester Zone ¢/kWh |
|---|---|
| 1/13/2015 | 0.1507 |
| 2/12/2015 | 0.1570 |
| 3/16/2015 | 0.1376 |
| 4/14/2015 | 0.1379 |
| 5/13/2015 | 0.1786 |
| 6/12/2015 | 0.2481 |
| 7/14/2015 | 0.2401 |
| 8/12/2015 | 0.1748 |
| 9/11/2015 | 0.1894 |
| 10/13/2015 | 0.1528 |
| 11/10/2015 | 0.1930 |
| 12/14/2015 | 0.2413 |
| 1/13/2016 | 0.2038 |

[1] NYISO, Summer 2015 Monthly Auction Results for UCAP, Auction Starting 05/2015, Posted Date: 04/14/2015 12:01 PM, G-J Locality. http://icap.nyiso.com/ucap/public.
[2] NYISO, Winter 2015-2016 Monthly Auction Results for UCAP, Auction Starting 10/2015, Posted Date: 10/14/2015 12:03 PM, G-J Locality. http://icap.nyiso.com/ucap/public.

The CHP units may be able to participate in the NYISO Demand-Side Ancillary Services Program (DSASP) for which NYISO provides a minimum of $75/MWh. However, FERC is ruling on the eligibility of behind-the-meter generation (Docket #EL13-74-000) and, according to NYISO's recent semi-annual update, there has been no activity for the past several years.[1] At this time revenue streams from this market seem marginal.

## Savings

The community microgrid may be eligible for ConEd's Rider H—Non-Residential DG Gas Rate—for purchased of natural gas. However, such purchases are predicated upon maintaining a 50% annual load factor. Additional information is required to quantify potential savings under this Rider.

*What other incentives will be required or preferred for this project to proceed? How does the timing of those incentives affect the development and deployment of this project?*

### *Additional Infrastructure*

Certain components of the microgrid will require upgrades to existing and installation of new infrastructure (e.g., distribution system, natural gas pipelines, etc). The timing of these resources will impact the microgrid, in particular potential permitting requirements. For example, the microgrid requires deployment of Advanced Metering Infrastructure (AMI). Natural gas infrastructure would likely require upgrades and installation of new assets.

### *Funding*

Microgrid development will depend on access to financing and cost of capital. As with any capital investment, the cost and availability of funding will reflect the risk profile of the venture. In the case of microgrids, the Willdan Team expects first tier risks—that may drive financing terms, where available, or under certain circumstances prevent access to capital markets—to include technology risk, regulatory risk, lack of a proven track record, and market risk. The regulatory regime will affect microgrid projects in three ways: rate recovery methodology/treatment, potential revenue streams (e.g., power pool market rules, limitations on generation ownership, emissions limits, operating restrictions, technology constraints), and project structure/ownership (for example prohibitions on distribution utilities owning generation assets).

### *Project Guarantees/Financing Backstops*

The microgrid may require additional guarantees to secure financing and rate recovery. The availability, cost and timing of such guarantees may impact development. Microgrid technology is emerging and unproven. It offers great possibility and, under the correct circumstances, should be highly attractive to private equity. However, given the risks discussed above, any project's access to private capital will ultimately depend on the guarantor and or backstop underpinning the project. Put another way, with unproven technology in an emerging market, private equity will seek to insulate investors from risk

1 New York Independent System Operator, Semi-Annual Reports on New Generation Projects and Demand Response Programs (Docket Nos. ER03-647-000 and ER01-3001-000) dated June 1, 2015, Attachment II, page 1.

assuming a worst-case scenario to offer capital at a reasonable price. Pension funds and other desirable funding sources will require adequate de-risking of the venture.

Classifying microgrid assets as Critical Infrastructure Protection assets under NERC or security assets under Homeland Security may open avenues to external funding from state and federal sources and/or facilitate use of these entities as backstops or ultimate guarantors. Additionally, on August 24, 2015, President Obama announced that the Department of Energy's Loan Programs Office issued guidance for Distributed Energy Projects, making microgrids potentially eligible for DOE's Loan Guarantees Program. Due to the fees and costs associated with such guarantees, this program is typically cost effective for projects of $25 M or more. The DOE would consider packaging projects together to create a cost-effective critical mass. It is currently unclear the feasibility of such an approach, however the New York Municipal Power Agency may be a potential vehicle for such consolidation. Additional research is warranted in the next phase.

*What are the categories and relative magnitudes of the capital and operating costs that will be incurred by the microgrid owner? Will they be fixed or variable?*

The community microgrid will be subject to various charges depending on the class of service the community microgrid qualifies for under ConEd's PSC-10 Tariff.

### *ConEd SC-11 Charges*

Such potential charges include Customer and Delivery Service Contract Demand Charges under SC-11. Table 23 illustrated those charges based on SC group.

*Table 23. ConEd SC-11 Contract Demand Charges*

| Contract Demand | Service Classification | Customer Charge ($/Month) | Delivery Service Contract Demand Charge ($/kW-month) | |
|---|---|---|---|---|
| | | | High Tension Service <138KV | Low Tension Service |
| Less Than or Equal to 1500kW | SC-5 | 267.87 | 1.91 | 3.08 |
| | SC-8 | 323.61 | 6.72 | 7.17 |
| | SC-9 | 101.99 | 5.14 | 6.88 |
| | SC-12 | 147.74 | 5.15 | 5.56 |
| Greater Than 1500kW | SC-5 | 730.67 | 3.85 | 6.71 |
| | SC-8 | 1,255.85 | 6.41 | 6.80 |
| | SC-9 | 1,969.18 | 6.78 | 7.16 |
| | SC-12 | 821.68 | 5.48 | 5.59 |
| | SC-13 | 2,712.50 | 5.93 | N/A |
| Greater Than 138 KV Service | SC-5 | 639.52 | 1.43 | N/A |
| | SC-8 | 345.74 | 2.50 | N/A |
| | SC-9 | 606.31 | 2.71 | N/A |
| | SC-12 | 321.93 | 1.73 | N/A |
| | SC-13 | 2,241.79 | 2.29 | N/A |

In addition, interconnection related costs would apply for ConEd as described in ConEd's SC-11 tariff.

### *Standby Service Charges*

Depending on the final configuration of the community microgrid, it may or may not be subject to Standby Service charges from ConEd. Customers who install DG and take Standby Service are subject to ConEd's Standby Service rates. Exceptions are made for DG installations that are eligible for Net Metering, for generators that are used solely for emergency use or during Demand Response events, for any residential or non-demand billed customers, for customers whose DG system supplies less than 15% of the facility's peak demand, or for customers that install DG technologies that meet the Designated Technologies criteria: (i) a DG system that exclusively uses a renewable fuel, (ii) fuel cell systems, or (iii) small, efficient types of combined heat and power (CHP) that do not exceed 1 MW of capacity. It therefore appears that the community microgrid may fall within the latter category and may not be subject to these charges. As stated in the Standby Service Tariff:

"Customer With Designated Technologies" for purpose of this General Rule means a Customer with a Contract Demand of 50 kW or greater whose on-site generation has a total nameplate rating equal to more than 15 percent of the maximum potential demand from all sources and:

a) exclusively uses fuel cells, wind, solar thermal, photovoltaics, sustainably-managed biomass, tidal, geothermal, and/or methane waste, and commences operation of its on-site generation facility between July 29, 2003 and May 31, 2019; or
b) uses Efficient CHP that does not exceed 1 MW of capacity in aggregate, and commences operation of its CHP generation facility between July 29, 2003 and May 31, 2019; or
c) uses Efficient CHP with an aggregated capacity greater than 1 MW, but no more than 15 MW, and commences operation of its CHP generation facility between May 31, 2015 and May 31, 2019; …

"Efficient CHP" for purposes of this General Rule means combined heat and power ("CHP") generation that meets eligibility criteria that were approved in the order of the New York State Public Service Commission, dated January 23, 2004, in Case 02-E-0781."[1]

### *Additional Charges*

Depending on the ultimate configuration of the microgrid, additional capital and operating costs may exist; primary components are outlined below.

- Infrastructure upgrades to accommodate the microgrid;
- O&M associated with infrastructure upgrades made to accommodate the microgrid;
- AMI;
- Master controller and communications infrastructure;
- Natural gas system upgrades;

[1] Consolidated Edison Company of New York, Inc., PSC NO: 10 – Electricity, GENERAL RULES, §20 Standby Service, §20.3 Customers Exempt from Standby Service Rates, §20.3.2 Customers With Designated Technologies.

- Natural Gas Cost
- Permitting costs—need to consult experts regarding air permitting of new resources.

### *Profitability*

Currently, it is expected that the community microgrid would likely be structured and operated as a regional public project similar to the Tri-Party Agreement established in 2006 between the Village of Tarrytown, Sleepy Hollow, and Briarcliff Manor for connecting to the Delaware Aqueduct. This regional joint authority project will be structured to ensure that any financial obligations are met through public guarantees of the three Villages. The special purpose entity created through this process would be the customer receiving Full Service from ConEd.

### *Financing Structure*

Microgrid development will be funded through feasibility by NYSERDA grants. Development and construction will be funded through available grants, private equity (where possible) and bond issuance. An Engineering, Procurement, and Construction (EPC) contract will be used as a vehicle for performance through the commercial operation date (COD). An operating contract will be executed to cover operations and maintenance upon commercial in-service. Appropriate warranties will be obtained from technology providers and cover each key component of the microgrid.

## Sub Task 3.6 Legal Viability

### Ownership Structure

Currently, it is expected that the community microgrid would likely be structured and operated as a regional public project similar to the Tri-Party Agreement established in 2006 between the Village of Tarrytown, Sleepy Hollow, and Briarcliff Manor for connecting to the Delaware Aqueduct. This regional joint authority project will be structured to ensure that any financial obligations are met through public guarantees of the three Villages. Potential Project team members may include bond counsel, private equity advisors, DOE LGO, NYMPA, EPC Contractor, Consulting Engineer, Operator, Permitting Consultant, Environmental Consultant, CNG, ConEd, ratepayers, Village Council, stakeholders, and technology providers.

Currently, it is expected that the community microgrid would likely be structured and operated as a regional public project similar to the Tri-Party Agreement established in 2006 between the Village of Tarrytown, Sleepy Hollow, and Briarcliff Manor for connecting to the Delaware Aqueduct. This regional joint authority project will be structured to ensure that any financial obligations are met through public guarantees of the three Villages.

Certain potential sites are currently controlled by the Village. However additional rights-of-way and sites may be required to fully accommodate the final microgrid configuration. Additional design information that will be developed as part of the next phase is required to further identify these sites.

As currently structured, the project would be a customer of ConEd and all financial transactions, including electricity purchases, would flow through ConEd. As clusters of buildings would be aggregated, new ConEd meters would have to be placed at the point of common coupling to individually meter each cluster.

The project is municipal in nature, and while the project may be replicable across the State in other municipalities, there are no additional commercialization plans for any piece of this project.

The community microgrid project is located in a congested area of NYISO and therefore offers benefits to the grid as reflected in the potential revenue streams presented herein. The municipal model presents the best option to overcome potential regulatory barriers and existing loan guarantee programs to overcome financing barriers.

### *Privacy*

AMI infrastructure has the ability to protect customer privacy.  Outcomes will be entirely dependent on the technology chosen as well as the implementation and operation.  It will be incumbent upon The Village to ensure compliance with such requirements, though since The Village is the existing power provider with an existing privacy protocol, continuing the protocol is expected to be straightforward.

### *Financial Strength*

The Village of Sleepy Hollow has a good financial record and low debt burden.  The most recent rating information for Sleepy Hollow is a rating of AA from Standard and Poor's in May of 2014 with a Stable Outlook.[1]

The Village of Tarrytown has a good financial record and low debt burden.  The most recent rating information for Tarrytown is a rating of AA2 from Moody's in July of 2015 with a Stable Outlook.[2]

Briarcliff Manor's is AA+ from Standard and Poor's as of April 14, 2015 with $7.9M issuance of Public Improvement Refunding Serial Bonds.

[1] The Village of Sleepy Hollow's issuance of $3.325M of Serial Bonds was rated -AA by Standard and Poor's according to the 2014 Official Statement.

[2] The Village of Tarrytown's issuance of $7.1M of Serial Bonds was rated AA2 by Moody's according to the 2015 Official Statement.

# Task 4: Cost Benefit Analysis

## Benefit-Cost Analysis Summary Report - Site 26 – Village of Sleepy Hollow

### Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the Village of Sleepy Hollow has proposed development of a microgrid that would enhance the resiliency of electric service for the following seven facilities:

- Sleepy Hollow High School;
- Briarcliff Manor Water Pump Station;
- Sleepy Hollow Water Pump Station;
- The Sleepy Hollow Village Hall, which includes administrative offices as well as police and fire stations;
- Two additional fire stations, Rescue Hose and Union Hose; and
- A large apartment building managed by the North Tarrytown Housing Authority.

The microgrid would be powered by two new natural gas-fired combined heat and power (CHP) generators (combined capacity: 450 kW), a new 500 kW natural gas generator, and four existing diesel backup generators. The new CHP and natural gas generators would produce electricity for the grid during periods of normal operation, while the existing backup generators would be used in islanded mode during power outages only. The system as designed would have sufficient generating capacity to meet average demand for electricity from all included facilities during a major outage. Project consultants also indicate that the system would have the capability of providing frequency regulation and reactive power support to the grid.

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

### Methodology and Assumptions

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

- *Costs* represent the value of resources consumed (or benefits forgone) in the production of a good or service.
- *Benefits* are impacts that have value to a firm, a household, or society in general.
- *Net benefits* are the difference between a project's benefits and costs.

- Both costs and benefits must be measured relative to a common *baseline* - for a microgrid, the "without project" scenario - that describes the conditions that would prevail absent a project's development. The BCA considers only those costs and benefits that are *incremental* to the baseline.

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

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[1] 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.[2]

[1] 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 CO2 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 SO2, NOx, and PM2.5, 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.]

[2] 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;

## Results

Table 24 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that even if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's benefits would exceed its costs by approximately 20 percent. As a result, the analysis does not evaluate Scenario 2. Consideration of Scenario 2 would further increase the project's already positive benefit-cost ratio.

*Table 24. BCA Results (Assuming 7 Percent Discount Rate)*

| Economic Measure | Assumed Average Duration of Major Power Outages | |
|---|---|---|
| | Scenario 1: 0 Days/Year | Scenario 2 |
| Net Benefits - Present Value | $2,420,000 | Not Evaluated |
| Benefit-Cost Ratio | 1.2 | Not Evaluated |
| Internal Rate of Return | 13.0% | Not Evaluated |

The discussion that follows provides additional detail on these findings.

## Scenario 1

Figure 42 and table 25 present the detailed results of the Scenario 1 analysis.

overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. In estimating the reliability benefits of a microgrid, the BCA employs metrics that exclude outages caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

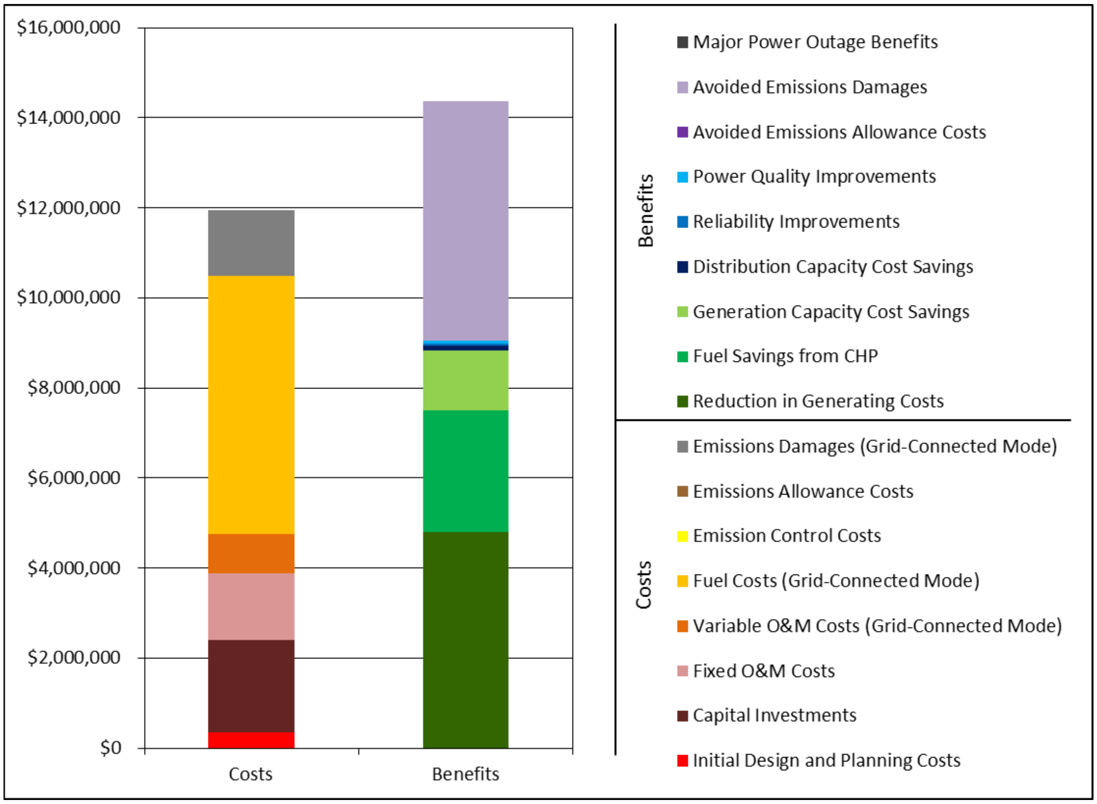



*Figure 42. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)*

*Table 25. 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 | $361,000 | $31,900 |
| Capital Investments | $2,040,000 | $172,000 |
| Fixed O&M | $1,490,000 | $131,000 |
| Variable O&M (Grid-Connected Mode) | $866,000 | $76,400 |
| Fuel (Grid-Connected Mode) | $5,740,000 | $506,000 |
| Emission Control | $0 | $0 |
| Emissions Allowances | $0 | $0 |
| Emissions Damages (Grid-Connected Mode) | $1,450,000 | $94,400 |
| **Total Costs** | **$11,900,000** | |
| **Benefits** | | |
| Reduction in Generating Costs | $4,790,000 | $422,000 |
| Fuel Savings from CHP | $2,720,000 | $240,000 |
| Generation Capacity Cost Savings | $1,320,000 | $117,000 |
| Distribution Capacity Cost Savings | $104,000 | $9,130 |
| Reliability Improvements | $48,500 | $4,280 |
| Power Quality Improvements | $60,800 | $5,360 |
| Avoided Emissions Allowance Costs | $2,360 | $208 |
| Avoided Emissions Damages | $5,310,000 | $347,000 |
| Major Power Outage Benefits | $0 | $0 |
| **Total Benefits** | **$14,400,000** | |
| **Net Benefits** | **$2,420,000** | |
| **Benefit/Cost Ratio** | **1.2** | |
| **Internal Rate of Return** | **13.0%** | |

### *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 $361,000. The present value of the project's capital costs is estimated at approximately $2.04 million, including costs associated with the new CHP systems and natural gas generator; underground cables and conduits; smart meters; and other system controls. The present value of the microgrid's fixed operations and maintenance (O&M) costs (i.e., O&M costs that do not vary with the amount of energy produced) is estimated at approximately $1.49 million, or $131,000 annually.

### *Variable Costs*

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's new CHP and natural gas generators. 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.[1] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $5.74 million.

The BCA also considers the project team's best estimate of the microgrid's variable O&M costs (i.e., O&M costs that vary with the amount of energy produced). The present value of these costs is estimated at approximately $866,000, or $11.00 per MWh.

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 assumption 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 natural gas generators are estimated at approximately $94,400 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 $1.45 million.[2]

### *Avoided Costs*

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. These include generating cost savings resulting from a reduction in demand for electricity from bulk energy suppliers. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $4.79 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. Additional benefits would result from fuel savings due to the new CHP system; the BCA estimates the present value of fuel savings over the 20-year operating period to be approximately $2.72 million. The reduction in demand for electricity from bulk energy suppliers and for heating fuel would also avoid emissions of $CO_2$, $SO_2$, $NO_x$, and particulate matter, yielding emissions allowance cost savings with a present value of approximately $2,360 and avoided emissions damages with a present value of approximately $5.31 million.[3]

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

[1] 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.

[2] Because the project team is uncertain whether the microgrid would be subject to emissions allowance requirements, the BCA also considers the case in which allowances must be purchased. In this case, the present value of emissions allowance costs is estimated at less than $100 over the 20-year operating period, and the present value of emissions damages is estimated at approximately $1.43 million. The effect of this assumption is therefore minimal.

[3] 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.

capacity.[1] The project team estimates the capacity available for the provision of peak load support to be approximately 950 kW per year, based on estimates of the new generators' output during system peak. Furthermore, the project team expects development of the microgrid to reduce the conventional grid's demand for generating capacity by an additional 207 kW each month (approximately 25 percent of the microgrid's peak demand) as a result of new demand response capabilities. Based on these figures, the BCA estimates the present value of the project's generating capacity benefits to be approximately $1.32 million over a 20-year operating period. The present value of the project's potential distribution capacity benefits – stemming from investments in underground distribution infrastructure and smart grid controls – is estimated to be approximately $104,000.

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

### *Reliability Benefits*

An additional benefit of the proposed microgrid would be to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $4,280 per year, with a present value of $48,500 over a 20-year operating period. This estimate is developed using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[2]

- System Average Interruption Frequency Index (SAIFI) – 0.11 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 181.2 minutes.[3]

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

[1] Impacts to transmission capacity are implicitly incorporated into the model's estimates of avoided generation costs and generation capacity cost savings. As estimated by NYISO, generation costs and generating capacity costs vary by location to reflect costs imposed by location-specific transmission constraints.
[2] www.icecalculator.com.
[3] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for ConEdison.

analysis assumes a 15 percent failure rate for backup generators.[1] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

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

### *Power Quality Benefits*

The power quality benefits of a microgrid may include reductions in the frequency of voltage sags and swells or reductions in the frequency of momentary outages (i.e., outages of less than five minutes, which are not captured in the reliability indices described above). The analysis of power quality benefits relies on the project team's best estimate of the number of power quality events that development of the microgrid would avoid each year. Specifically, the project team foresees approximately one power quality event each year at each facility. The model estimates the present value of avoiding these events to be approximately $60,800 over a 20-year operating period.[2] In reality, some customers for whom power quality is important (e.g., the water pump stations) may already have systems in place to protect against voltage sags, swells, and momentary outages. If this is the case, the BCA may overstate the power quality benefits the project would provide.

### *Summary*

The analysis of Scenario 1 yields a benefit/cost ratio of 1.2; i.e., the estimate of project benefits is approximately 20 percent greater than that of project costs. Accordingly, the analysis does not consider the potential of the microgrid to mitigate the impact of major power outages in Scenario 2. Consideration of such benefits would further increase the net benefits of the project's development.

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

[2] Importantly, the model relies on average costs per power quality event for customers across the United States, based on meta-analysis of data collected through 28 studies of electric utility customers between 1989 and 2005. These costs therefore incorporate assumptions about the distribution of customers across economic sectors and other key characteristics, such as the prevalence of backup generation and power conditioning, that may not reflect the characteristics of the proposed microgrid. This is likely to be the case for the Village of Sleepy Hollow. Based on information provided by the site team, the proposed microgrid will not serve any customers in the construction, manufacturing, and financial/insurance/real estate sectors, which typically have the highest costs per power quality event. Instead, the proposed microgrid's customers are more likely to fall into the public administration or services sectors, which typically have substantially lower costs of power quality events. [See: Sullivan, Michael J. *et al*. Estimated Value of Service Reliability for Electric Utility Customers in the United States. LBNL-2132E: June 2009.]

# Disclaimer

The intent of this analysis report is to assess the technical, legal, and financial feasibility of community microgrid and estimate energy savings and additional revenue generation associated with the recommended upgrades to your facilities. Appropriate detail is included to help you make decisions about building community microgrid. However, this report is not intended to serve as a detailed engineering design document, as the improvement descriptions are diagrammatic in nature only, in order to document the basis of cost estimates and savings and to demonstrate the feasibility of constructing the improvements. Detailed design efforts may be required to fully understand the benefits and challenges you may encounter and to implement several of the improvements evaluated as part of this analysis.

While the recommendations in this report have been reviewed for technical accuracy, and we believe they are reasonable and accurate, the findings are estimates and actual results may differ. As a result, Willdan Energy Solutions is not liable if projected, estimated savings or economies are not actually achieved. All savings and cost estimates in the report are for informational purposes and are not to be construed as design documents or guarantees.

In no event will Willdan Energy Solutions be liable for the failure of the customer to achieve a specified amount of savings, for the operation of customer's facilities, or for any incidental or consequential damages of any kind in connection with this report or the installation of the recommended measures.

# Acknowledgement

This project is financially supported by the New York State Energy Research and Development Authority. On behalf of the members of this project, Willdan would like to thank Jim Hastings, NYSERDA Project Manager, for making this work possible. Willdan would also like to thank the Village of Sleepy Hollow project sponsors and staff as well as the Consolidated Edison staff that supported this project. The cost benefit analysis portion of the project was completed by Industrial Economics Inc. The many tasks of this work could not have been completed without the dedicated effort of Katie Zilka, Project Manager, Patrick Burgess, Technical Project Manager, Dr. Wei Tian, Lead Engineer, Lisa Vedder, Financial and Regulatory Lead, and Jim Quinn, Community Support.

# Appendix

## Sleepy Hollow
## NY Prize Benefit-Cost Analysis: Microgrid Questionnaire

This questionnaire solicits information on the community microgrid you are proposing for the NY Prize competition. The information in this questionnaire will be used to develop a preliminary benefit-cost analysis of the proposed microgrid. Please provide as much detail as possible. The questionnaire is organized into the following sections:



If you have any questions regarding the information requested, please contact Industrial Economics, Incorporated, either by email (NYPrize@indecon.com) or phone (929-445-7641).

Microgrid site: 26. Village of Sleepy Hollow

Point of contact for this questionnaire:

Name: Kathryn Zilka

Address: 88 Pine Street, 18th Floor, New York, NY 10005

Telephone: 646-640-6571

Email: kzilka@willdan.com

***A. Project Overview, Energy Production, and Fuel Use***

1. The table below is designed to gather background information on the facilities your microgrid would serve. It includes two examples: one for Main Street Apartments, a residential facility with multiple utility customers; and another for Main Street

Grocery, a commercial facility. Please follow these examples in providing the information specified for each facility. Additional guidance is provided below.

- **Facility name:** Please enter the name of each facility the microgrid would serve. Note that a single **facility** may include multiple **customers** (e.g., individually-metered apartments within a multi-family apartment building). When this is the case, you do not need to list each customer individually; simply identify the facility as a whole (see table 1, "Main Street Apartments," for an example).
- **Rate class:** Select the appropriate rate class for the facility from the dropdown list. Rate class options are residential, small commercial/industrial (defined as a facility using less than 50 MWh of electricity per year), or large commercial/industrial (defined as a facility using 50 or more MWh of electricity per year).
- **Facility/customer description:** Provide a brief description of the facility, including the number of individual customers at the facility if it includes more than one (e.g., individually-metered apartments within a multi-family apartment building). For commercial and industrial facilities, please describe the type of commercial/industrial activity conducted at the facility.
- **Economic sector:** Select the appropriate economic sector for the facility from the dropdown list.
- **Average annual usage:** Specify the average annual electricity usage (in MWh) **per customer**. Note that in the case of facilities with multiple, similar customers, such as multi-family apartment buildings, this value will be different from average annual usage for the facility as a whole.
- **Peak demand:** Specify the peak electricity demand (in MW) **per customer**. Note that in the case of facilities with multiple, similar customers, such as multi-family apartment buildings, this value will be different from peak demand for the facility as a whole.
- **Percent of average usage the microgrid could support in the event of a major power outage:** Specify the percent of each facility's typical usage that the microgrid would be designed to support in the event of a major power outage (i.e., an outage lasting at least 24 hours that necessitates that the microgrid operate in islanded mode). In many cases, this will be 100%. In some cases, however, the microgrid may be designed to provide only enough energy to support critical services (e.g., elevators but not lighting). In these cases, the value you report should be less than 100%.
- **Hours of electricity supply required per day in the event of a major power outage:** Please indicate the number of hours per day that service to each facility would be maintained by the microgrid in the event of a major outage. Note that this value may be less than 24 hours for some facilities; for example, some commercial facilities may only require electricity during business hours.

| Facility Name | Rate Class | Facility/Customer Description (Specify Number of Customers if More Than One) | Economic Sector Code | Average Annual Electricity Usage Per Customer (MWh) | Peak Electricity Demand Per Customer (MW) | Percent of Average Usage Microgrid Could Support During Major Power Outage | Hours of Electricity Supply Required Per Day During Major Power Outage |
|---|---|---|---|---|---|---|---|
| Sleepy Hollow High School | *Large Commercial/Industrial (>50 annual MWh)* | *School* | *All other industries* | 737.7 | 0.31 | *100%* | *24* |
| Briarcliff Manor Water Pump Station | Large Commercial/Industrial (>50 annual MWh) | Water Pump Station, single electric meter | *All other industries* | 716.0 | 0.17 | *100%* | *24* |
| Union Hose | Small Commercial/Industrial (<50 annual MWh) | Fire Station, single meter | *All other industries* | 23.7 | 0.01 | *100%* | *24* |
| Rescue Hose | Large Commercial/Industrial (>50 annual MWh) | Fire Station, single meter | *All other industries* | 66.2 | 0.02 | *100%* | *24* |
| Village Hall/Police/Fire Station | Large Commercial/Industrial (>50 annual MWh) | Village Hall/Police/Fire Station, single electric meter | *All other industries* | 321.9 | 0.07 | *100%* | *24* |
| Sleepy Hollow Water Pump Station | Large Commercial/Industrial (>50 annual MWh) | Water Pump Station, single electric meter | *All other industries* | 372.8 | 0.13 | *100%* | *24* |

| Facility Name | Rate Class | Facility/Customer Description (Specify Number of Customers if More Than One) | Economic Sector Code | Average Annual Electricity Usage Per Customer (MWh) | Peak Electricity Demand Per Customer (MW) | Percent of Average Usage Microgrid Could Support During Major Power Outage | Hours of Electricity Supply Required Per Day During Major Power Outage |
|---|---|---|---|---|---|---|---|
| North Tarrytown Housing Authority | Large Commercial/Industrial (>50 annual MWh) | Residential, 86 apartment units, single electric meter | *Residential* | 467.4 | 0.12 | *100%* | *24* |
| | Choose an item. | | Choose an item. | | | | |

2. In the table below, please provide information on the distributed energy resources the microgrid will incorporate. Use the two examples included in the table as a guide.

- **Distributed energy resource name:** Please identify each distributed energy resource with a brief description. In the event that a single facility has multiple distributed energy resources of the same type (e.g., two diesel generators), please use numbers to uniquely identify each (e.g., "Diesel generator 1" and "Diesel generator 2").
- **Facility name:** Please specify the facility at which each distributed energy resource is or would be based.
- **Energy source:** Select the fuel/energy source used by each distributed energy resource from the dropdown list. If you select "other," please type in the energy source used.
- **Nameplate capacity:** Specify the total nameplate capacity (in MW) of each distributed energy resource included in the microgrid.
- **Average annual production:** Please estimate the amount of electricity (in MWh) that each distributed energy resource is likely to produce each year, on average, **under normal operating conditions.** The benefit-cost analysis will separately estimate production in islanded mode in the event of an extended power outage. **If the distributed energy resource will operate only in the event of an outage, please enter zero.**
- **Average daily production in the event of a major power outage:** Please estimate the amount of electricity (in MWh per day) that each distributed energy resource is likely to produce, on average, **in the event of a major power outage.** In developing your estimate for each distributed energy resource, you should consider the electricity requirements of the facilities the microgrid would serve, as specified in your response to Question 1.
- **Fuel consumption per MWh:** For each distributed energy resource, please estimate the amount of fuel required to generate one MWh of energy. This question does not apply to renewable energy resources, such as wind and solar.

| Distributed Energy Resource Name | Facility Name | Energy Source | Nameplate Capacity (MW) | Average Annual Production Under Normal Conditions (MWh) | Average Daily Production During Major Power Outage (MWh) | Fuel Consumption per MWh | |
|---|---|---|---|---|---|---|---|
| | | | | | | Quantity [54,55,56] | Unit |
| *CHP (Proposed)* | Sleepy Hollow Cluster 1 | *Natural Gas* | 0.15 | 1,096.9 | 3.6 | 10.66 | *MMBtu/MWh* |
| *CHP (Proposed)* | Sleepy Hollow Crossover Cluster 1 | *Natural Gas* | 0.3 | 2,193.8 | 7.2 | 10.66 | *MMBtu/MWh* |
| Natural Gas Generator *(Proposed)* | Sleepy Hollow Crossover Cluster 2 | *Natural Gas* | 0.5 | 3,656.4 | 12.00 | 10.66 | *MMBtu/MWh* |
| Back-up Generator (Existing) | Braircliff Manor Water Pump Station | *Diesel* | 0.03 | 0 | 0.72 | 10.66 | *MMBtu/MWh* |
| Back-up Generator (Existing) | Union Hose | *Diesel* | 0.035 | 0 | 0.84 | 10.66 | *MMBtu/MWh* |
| Back-up Generator | Village Hall/Police/Fire | *Diesel* | 0.175 | | 4.20 | 10.66 | *MMBtu/MWh* |

[54] Source for Diesel Consumption: Cummins specifications and sizing chart www.cumminspower.com and http://www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx
[55] Source for Natural Gas Consumption: http://www.dieselserviceandsupply.com/Natural_Gas_Fuel_Consumption.aspx.
[56] Source for CHP Natural Gas Consumption: http://www.epa.gov/sites/production/files/2015-07/documents/fuel_and_carbon_dioxide_emissions_savings_calculation_methodology_for_combined_heat_and_power_systems.pdf

| Distributed Energy Resource Name | Facility Name | Energy Source | Nameplate Capacity (MW) | Average Annual Production Under Normal Conditions (MWh) | Average Daily Production During Major Power Outage (MWh) | Fuel Consumption per MWh | |
|---|---|---|---|---|---|---|---|
| | | | | | | Quantity [54,55,56] | Unit |
| (Existing) | Station | | | 0 | | | |
| Back-up Generator (Existing) | Sleepy Hollow Water Pump Station | *Diesel* | 0.03 | 0 | 0.72 | 10.66 | *MMBtu/MWh* |

***B.*** *Capacity Impacts*

3. Is development of the microgrid expected to reduce the need for bulk energy suppliers to expand generating capacity, either by directly providing peak load support or by enabling the microgrid's customers to participate in a demand response program?

☐ No – proceed to Question 6

☒ Yes, both by providing peak load support and by enabling participation in a demand response program – proceed to Question 4

☐ Yes, by providing peak load support only – proceed to Question 4

☐ Yes, by enabling participation in a demand response program only – proceed to Question 5

Provision of Peak Load Support

4. Please provide the following information for all distributed energy resources that would be available to provide peak load support:

- **Available capacity:** Please indicate the capacity of each distributed energy resource that would be available to provide peak load support (in MW/year).
- **Current provision of peak load support, if any:** Please indicate whether the distributed energy resource currently provides peak load support.

Please use the same distributed energy resource and facility names from Question 2.

| Distributed Energy Resource Name | Facility Name | Available Capacity (MW/year) | Does distributed energy resource currently provide peak load support? |
|---|---|---|---|
| *CHP* | Sleepy Hollow Cluster 1 | 0.15 | ☐ Yes |
| *CHP* | Sleepy Hollow Crossover Cluster 1 | 0.3 | ☐ Yes |
| Natural Gas Generator | Sleepy Hollow Crossover Cluster 2 | 0.5 | ☐ Yes |

If development of the microgrid is also expected to enable the microgrid's customers to participate in a demand response program, please proceed to Question 5. Otherwise, please proceed to Question 6.

Participation in a Demand Response Program

5. Please provide the following information for each facility that is likely to participate in a demand response program following development of the microgrid:

- **Available capacity:** Please estimate the capacity that would be available to participate in a demand response program (in MW/year) following development of the microgrid.
- **Capacity currently participating in a demand response program, if any:** Please indicate the capacity (in MW/year), if any, that currently participates in a demand response program.

| Facility Name | Capacity Participating in Demand Response Program (MW/year) | |
|---|---|---|
| | Following Development of Microgrid | Currently |
| Sleepy Hollow High School | 0.076975 | 0 |
| W.L. Morse School | 0.037 | 0 |
| Briarcliff Manor Water Pump Station | 0.042 | 0 |
| Union Hose | 0.00265 | 0 |
| Rescue Hose | 0.005025 | 0 |
| Ambulance Corp | 0.0055 | 0 |
| Village Hall/Police/Fire Station | 0.0172 | 0 |
| Sleepy Hollow Water Pump Station | 0.0332 | 0 |
| North Tarrytown Housing Authority | 0.0296 | 0 |

6. Is development of the microgrid expected to enable utilities to avoid or defer expansion of their transmission or distribution networks?

   ☒ Yes – proceed to Question 7

   ☐ No – proceed to Section C

7. Please estimate the impact of the microgrid on utilities' **transmission** capacity requirements. The following question will ask about the impact on distribution capacity.

| Impact of Microgrid on Utility Transmission Capacity | Unit |
|---|---|
| 1.2 | MW/year |

Please estimate the impact of the microgrid on utilities' **distribution** capacity requirements.

| Impact of Microgrid on Utility Distribution Capacity | Unit |
|---|---|
| 0.25 | MW/year |

### *C. Project Costs*

We are interested in developing a year-by-year profile of project costs over a 20-year operating period. The following questions ask for information on specific categories of costs.

#### Capital Costs

8. In the table below, please estimate the fully installed cost and lifespan of all equipment associated with the microgrid, including equipment or infrastructure associated with power generation (including combined heat and power systems), energy storage, energy distribution, and interconnection with the local utility.

| Capital Component | Installed Cost ($) | Component Lifespan (round to nearest year) | Description of Component |
|---|---|---|---|
| CHP 1 - 150 kW | $ 395,400.00 | 20 | CHP – Sleepy Hollow Cluster 1 |
| CHP 2 - 300 kW | $ 790,800.00 | 20 | CHP - Sleepy Hollow Crossover Cluster 1 |
| Natural Gas Generator - 500 kW | $ 185,500.00 | 20 | Natural Gas Generator - Sleepy Hollow Crossover Cluster 2 |
| Back-up Generator 1 – 30 kW | $ 11,130.00 | 20 | Back-up Generator - Braircliff Manor Water Pump Station |
| Back-up Generator 2 – 35 kW | $ 12,985.00 | 20 | Back-up Generator - Union Hose |
| Back-up Generator 3 – 175 kW | $ 64,925.00 | 20 | Back-up Generator - Village Hall/Police/Fire Station |
| Back-up Generator 4 – 30 kW | $ 11,130.00 | 20 | Back-up Generator - Sleepy Hollow Water Pump Station |
| Manhole 1 | $ 7,500.00 | 30 | Sleepy Hollow Cluster 1 - Manholes |
| SCADA Switch 1 | $ 36,000.00 | 20 | Sleepy Hollow Cluster 1 - Scada Switches |
| S&C PME Switch 1 | $ 18,500.00 | 20 | Sleepy Hollow Cluster 1 - PME Switch |
| Underground Cable 1 | $ 162,000.00 | 40 | Sleepy Hollow Cluster 1 - Cabling |

| Capital Component | Installed Cost ($) | Component Lifespan (round to nearest year) | Description of Component |
|---|---|---|---|
| S&C PME Switch 2 | $ 18,500.00 | 20 | Crossover Cluster 1 - PME Switch |
| Underground Cable and Conduit 1 | $ 220,000.00 | 40 | Crossover Cluster 1 - Cable and Conduit |
| 225 kVA Transformer 1 | $ 10,000.00 | 20 | Crossover Cluster 1 - 225 kVA Transformer |
| SCADA Switch 2 | $ 36,000.00 | 20 | Crossover Cluster 2 - Scada Switches |
| Pole and Riser 1 | $ 22,000.00 | 25 | Crossover Cluster 2 - Poles for Switches |
| Building Controllers | $ 6,000.00 | 15 | Sleepy Hollow and Crossover Cluster 1 - Wired Communication |
| Wired Communication in Buildings | $ 3,750.00 | 15 | Sleepy Hollow and Crossover Cluster 1 - Building Controllers |
| Smart Meters | $ 9,000.00 | 15 | Smart Meters for All Buildings |
| Wireless Access Point | $ 2,500.00 | 15 | System Access Point for Meters and Ebridges |
| E Bridge/Repeater | $ 1,750.00 | 15 | System E Bridge/Repeater to Build out Network |
| Automatic Generation Controllers | $ 7,524.00 | 20 | System Automatic Generation Controllers |
| SCADA Software | $ 100,000.00 | 25 | System SCADA Software |

## Initial Planning and Design Costs

9. Please estimate initial planning and design costs. These costs should include costs associated with project design, building and development permits, efforts to secure financing, marketing the project, and negotiating contracts. Include only upfront costs. Do not include costs associated with operation of the microgrid.

| Initial Planning and Design Costs ($) | What cost components are included in this figure? |
|---|---|
| $361,226 | Audit, Design, Projecty management, Planning, Permits, efforts to secure financing |

Fixed O&M Costs

10. Fixed O&M costs are costs associated with operating and maintaining the microgrid that are unlikely to vary with the amount of energy the system produces each year (e.g., software licenses, technical support). Will there be any year-to-year variation in these costs for other reasons (e.g., due to maintenance cycles)?

☒ No – proceed to Question 12

☐ Yes – proceed to Question 13

11. Please estimate any costs associated with operating and maintaining the microgrid that are unlikely to vary with the amount of energy the system produces each year.

| Fixed O&M Costs ($/year) | What cost components are included in this figure? |
|---|---|
| $131,355 | Labor, Maintenance, Monitoring, Indirect O&M |

Please proceed to Question 14.

12. For each year over an assumed 20-year operating life, please estimate any costs associated with operating and maintaining the microgrid that are unlikely to vary with the amount of energy the system produces.

| Year | Fixed O&M Cost ($) | What cost components are included in this figure? |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

## Variable O&M Costs (Excluding Fuel Costs)

13. Please estimate any costs associated with operating and maintaining the microgrid (excluding fuel costs) that are likely to vary with the amount of energy the system produces each year. Please estimate these costs per unit of energy produced (e.g., $/MWh).

| Variable O&M Costs ($/Unit of Energy Produced) | Unit | What cost components are included in this figure? |
|---|---|---|
| $15 for Backup disel generators | $/MWh | Purchase power, demand charge, and related utilities, lubricants, consumable materials and supplies |
| $11<br>For CHP and natural gas fired generators | $/MWh | Purchase power, demand charge, and related utilities, lubricants, consumable materials and supplies |

## Fuel Costs

14. In the table below, please provide information on the fuel use for each distributed energy resource the microgrid will incorporate. Please use the same distributed energy resource and facility names from Question 2.

- **Duration of design event:** For each distributed energy resource, please indicate the maximum period of time in days that the distributed energy resource would be able to operate in islanded mode without replenishing its fuel supply (i.e., the duration of the maximum power outage event for which the system is designed). **For renewable energy resources, your answer may be "indefinitely."**
- **Fuel consumption:** For each distributed energy resource that requires fuel, please specify the quantity of fuel the resource would consume if operated in islanded mode for the assumed duration of the design event.

| Distributed Energy Resource Name | Facility Name | Duration of Design Event (Days) | Quantity of Fuel Needed to Operate in Islanded Mode for Duration of Design Event | Unit |
|---|---|---|---|---|
| *CHP* | Sleepy Hollow Cluster 1 | 7 | 263,437.28 | Cubic feet |
| *CHP* | Sleepy Hollow Crossover Cluster 1 | 7 | 526,874.56 | Cubic feet |
| Natural Gas Generator | Sleepy Hollow Crossover Cluster 2 | 7 | 878,124.26 | Cubic feet |
| Back-up Generator | Braircliff Manor Water Pump Station | 7 | 386.63 | Gallons |
| Back-up Generator | Union Hose | 7 | 451.07 | Gallons |
| Back-up Generator | Village Hall/Police/Fire Station | 7 | 2,255.33 | Gallons |
| Back-up Generator | Sleepy Hollow Water Pump Station | 7 | 386.63 | Gallons |

15. Will the project include development of a combined heat and power (CHP) system?

☒ Yes – proceed to Question 17

☐ No – proceed to Question 18

16. If the microgrid will include development of a CHP system, please indicate the type of fuel that will be offset by use of the new CHP system and the annual energy savings (relative to the current heating system) that the new system is expected to provide.

| Type of Fuel Offset by New CHP System | Annual Energy Savings Relative to Current Heating System | Unit |
|---|---|---|
| No. 4 Fuel Oil | 18,830.9 | MMBtu |

## Emissions Control Costs

17. We anticipate that the costs of installing and operating emissions control equipment will be incorporated into the capital and O&M cost estimates you provided in response to the questions above. If this is not the case, please estimate these costs, noting what cost components are included in these estimates. For capital costs, please also estimate the engineering lifespan of each component.

| Cost Category | Costs ($) | Description of Component(s) | Component Lifespan(s) (round to nearest year) |
|---|---|---|---|
| Capital Costs ($) | | | |
| Annual O&M Costs ($/MWh) | | | |
| Other Annual Costs ($/Year) | | | |

18. Will environmental regulations mandate the purchase of emissions allowances for the microgrid (for example, due to system size thresholds)?

☐ Yes

☒ No

## *D. Environmental Impacts*

19. For each pollutant listed below, what is the estimated emissions rate (e.g., tons/MWh) for the microgrid?

| Emissions Type | Emissions per MWh | Unit |
|---|---|---|
| $CO_2$ | 0.199609885 | Short tons/MWh |
| $SO_2$ | 1.70607E-06 | Short tons/MWh |
| $NO_x$ | 1.27955E-05 | Short tons/MWh |
| PM | 1.27119E-05 | Short tons/MWh |

## *E. Ancillary Services*

20. Will the microgrid be designed to provide any of the following ancillary services? If so, we may contact you for additional information.

| Ancillary Service | Yes | No |
|---|---|---|
| Frequency or Real Power Support | ☒ | ☐ |
| Voltage or Reactive Power Support | ☒ | ☐ |
| Black Start or System Restoration Support | ☐ | ☒ |

***F. Power Quality and Reliability***

21. Will the microgrid improve power quality for the facilities it serves?

☒ Yes – proceed to Question 23

☐ No – proceed to Question 24

22. If the microgrid will result in power quality improvements, how many power quality events (e.g., voltage sags, swells, momentary outages) will the microgrid avoid each year, on average? Please also indicate which facilities will experience these improvements.

| Number of Power Quality Events Avoided Each Year | Which facilities will experience these improvements? |
|---|---|
| 0.99 | Sleepy Hollow High School, Sleepy Hollow Water Pump Station,<br>Briarcliff Water Pump Station<br>Rescue Hose Fire Co, Police Department/Village Hall/<br>Fire Department, Union Hose Fire Hose, North Tarrytown Housing<br>Authority |

23. The benefit-cost analysis model will characterize the potential reliability benefits of a microgrid based, in part, on standard estimates of the frequency and duration of power outages for the local utility. In the table below, please estimate your local utility's average **outage frequency per customer** (system average interruption frequency index, or SAIFI, in events per customer per year) and average **outage duration per customer** (customer average interruption duration index, or CAIDI, in hours per event per customer).

For reference, the values cited in the Department of Public Service's 2014 Electric Reliability Performance Report are provided on the following page. If your project would be located in an area served by one of the utilities listed, please use the values given for that utility. If your project would be located in an area served by a utility that is not listed, please provide your best estimate of SAIFI and CAIDI values for the utility that serves your area. In developing your estimate, please *exclude* outages caused by major storms (a major storm is defined as any storm which causes service interruptions of at least 10 percent of customers in an operating area, and/or interruptions with duration of 24 hours or more). This will ensure that your estimates are consistent with those provided for the utilities listed on the following page.[57]

[57] The DPS service interruption reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment;

| Estimated SAIFI | Estimated CAIDI |
|---|---|
| 0.11 | 3.09 |

SAIFI and CAIDI Values for 2014, as reported by DPS

| Utility | SAIFI (events per year per customer) | CAIDI (hours per event per customer) |
|---|---|---|
| Central Hudson Gas & Electric | 1.62 | 3.74 |
| ConEdison | 0.11 | 3.09 |
| PSEG Long Island | 0.76 | 1.42 |
| National Grid | 1.17 | 2.87 |
| New York State Electric & Gas | 1.34 | 2.97 |
| Orange & Rockland | 1.19 | 2.4 |
| Rochester Gas & Electric | 0.85 | 2.32 |
| *Statewide* | *0.68* | *2.7* |
| Source: New York State Department of Public Service, Electric Distribution Systems Office of Electric, Gas, and Water. June 2015. 2014 Electric Reliability Performance Report, accessed at: http://www3.dps.ny.gov/W/PSCWeb.nsf/All/D82A200687D96D3985257687006F39CA?OpenDocument. | | |

## *G. Other Information*

24. If you would like to include any other information on the proposed microgrid, please provide it here.

lightning; and unknown (there are an additional seven cause codes used exclusively for Con Edison's underground network system). SAIFI and CAIDI 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 contro. The BCA model treats the benefits of averting lengthy outages caused by major storms as a separate category; therefore, the analysis of reliability benefits focuses on the effect of a microgrid on SAIFI and CAIDI values that exclude outages caused by major storms.

# Sleepy Hollow

# NY Prize Benefit-Cost Analysis: Facility Questionnaire

This questionnaire requests information needed to estimate the impact that a microgrid might have in protecting the facilities it serves from the effects of a major power outage (i.e., an outage lasting at least 24 hours). The information in this questionnaire will be used to develop a preliminary benefit-cost analysis of the community microgrid you are proposing for the NY Prize competition. Please provide as much detail as possible.

For each facility that will be served by the microgrid, we are interested in information on:

I. Current backup generation capabilities.

II. The costs that would be incurred to maintain service during a power outage, both when operating on its backup power system (if any) and when backup power is down or not available.

III. The types of services the facility provides.

If you have any questions regarding the information requested, please contact Industrial Economics, Incorporated, either by email (NYPrize@indecon.com) or phone (929-445-7641).

Microgrid site: 26. Village of Sleepy Hollow

Point of contact for this questionnaire:

Name: Kathryn Zilka

Address: 88 Pine Street, 18th Floor, New York, NY 10005

Telephone: 646-640-6571

Email: kzilka@willdan.com

Backup Generation Capabilities

1. Do any of the facilities that would be served by the microgrid currently have backup generation capabilities?
   a. ☐ No - proceed to Question 4
   b. ☒ Yes - proceed to Question 2

2. For each facility that is equipped with a backup generator, please complete the table below, following the example provided. Please include the following information:
   a. **Facility name:** For example, "Main Street Apartments."
   b. **Identity of backup generator:** For example, "Unit 1."
   c. **Energy source:** Select the fuel/energy source used by each backup generator from the dropdown list. If you select "other," please type in the energy source used.
   d. **Nameplate capacity:** Specify the nameplate capacity (in MW) of each backup generator.
   e. **Standard operating capacity:** Specify the percentage of nameplate capacity at which the backup generator is likely to operate during an extended power outage.
   f. **Average electricity production per day in the event of a major power outage**: Estimate the average daily electricity production (MWh per day) for the generator in the event of a major power outage. In developing the estimate, please consider the unit's capacity, the daily demand at the facility it serves, and the hours of service the facility requires.
   g. **Fuel consumption per day:** Estimate the amount of fuel required per day (e.g., MMBtu per day) to generate the amount of electricity specified above. This question does not apply to renewable energy resources, such as wind and solar.
   h. **One-time operating costs:** Please identify any one-time costs (e.g., labor or contract service costs) associated with connecting and starting the backup generator.
   i. **Ongoing operating costs:** Estimate the costs ($/day) (e.g., maintenance costs) associated with operating the backup generator, excluding fuel costs.

   Note that backup generators may also serve as distributed energy resources in the microgrid. Therefore, there may be some overlap between the information provided in the table below and the information provided for the distributed energy resource table (Question 2) in the general Microgrid Data Collection Questionnaire.

| Facility Name | Generator ID | Energy Source | Nameplate Capacity (MW) | Standard Operating Capacity (%) | Avg. Daily Production During Power Outage (MWh/Day) | Fuel Consumption per Day | | One-Time Operating Costs ($) | Ongoing Operating Costs ($/Day) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Quantity | Unit | | |
| Briarcliff Manor Water Pump Station | Unit 1 | Diesel | 0.03 | 100 | 0.72 | 55.2 | *Gal/day* | $300 | $0 |
| Union Hose | Unit 1 | Diesel | 0.035 | 100 | 0.84 | 64.4 | *Gal/day* | $300 | $0 |

| Facility Name | Generator ID | Energy Source | Nameplate Capacity (MW) | Standard Operating Capacity (%) | Avg. Daily Production During Power Outage (MWh/Day) | Fuel Consumption per Day | | One-Time Operating Costs ($) | Ongoing Operating Costs ($/Day) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Quantity | Unit | | |
| Village Hall/Police/Fire | Unit 1 | Diesel | 0.175 | 100 | 4.20 | 322.2 | *Gal/day* | $300 | $0 |
| Sleepy Hollow Water Pump Station | Unit 1 | Diesel | 0.03 | 100 | 0.72 | 55.2 | *Gal/day* | $300 | $0 |
| | | Choose an item. | | | | | | | |

Costs of Emergency Measures Necessary to Maintain Service

We understand that facilities may have to take emergency measures during a power outage in order to maintain operations, preserve property, and/or protect the health and safety of workers, residents, or the general public. These measures may impose extraordinary costs, including both one-time expenditures (e.g., the cost of evacuating and relocating residents) and ongoing costs (e.g., the daily expense of renting a portable generator). The questions below address these costs. We begin by requesting information on the costs facilities would be likely to incur when operating on backup power. We then request information on the costs facilities would be likely to incur when backup power is not available.

***A.*** *Cost of Maintaining Service while Operating on Backup Power*

3. Please provide information in the table below for each facility the microgrid would serve which is currently equipped with some form of backup power (e.g., an emergency generator). For each facility, please describe the costs of any emergency measures that would be necessary in the event of a widespread power outage (i.e., a total loss of power in the area surrounding the facility lasting at least 24 hours). In completing the table, please assume that the facility's backup power system is fully operational. In your response, please describe and estimate the costs for:
    a. One-time emergency measures (total costs)
    b. Ongoing emergency measures (costs per day)

    Note that these measures do not include the costs associated with running the facility's existing backup power system, as estimated in the previous question.

    In addition, for each emergency measure, please provide additional information related to when the measure would be required. For example, measures undertaken for heating purposes may only be required during winter months. As another example, some commercial facilities may undertake emergency measures during the work week only.

    As a guide, see the examples the table provides.

| Facility Name | Type of Measure (One-Time or Ongoing) | Description | Costs | Units | When would these measures be required? |
|---|---|---|---|---|---|
| | Choose an item. | | | | |

***B. Cost of Maintaining Service while Backup Power is Not Available***

4. Please provide information in the table below for each facility the microgrid would serve. For each facility, please describe the costs of any emergency measures that would be necessary in the event of a widespread power outage (i.e., a total loss of power in the area surrounding the facility lasting at least 24 hours). In completing the table, please assume that service from any backup generators currently on-site is not available. In your response, please describe and estimate the costs for:
   a. One-time emergency measures (total costs)
   b. Ongoing emergency measures (costs per day)

   In addition, for each emergency measure, please provide additional information related to when the measure would be required. For example, measures undertaken for heating purposes may only be required during winter months. As another example, some commercial facilities may undertake emergency measures during the work week only.

   As a guide, see the examples the table provides.

| Facility Name | Type of Measure (One-Time or Ongoing) | Description | Costs | Units | When would these measures be required? |
|---|---|---|---|---|---|
| Sleepy Hollow High School | *Ongoing Measures* | *Renting additional portable generator* | 6158 | *$/day* | *Year-round* |
| Briarcliff Manor Water Pump Station | *Ongoing Measures* | *Renting additional portable generator* | 2760 | *$/day* | *Year-round* |
| Union Hose | Ongoing Measures | *Renting additional portable generator* | 0 | *$/day* | *Year-round* |
| Rescue Hose | Ongoing Measures | *Renting additional portable generator* | 402 | *$/day* | *Year-round* |
| Village Hall/Police/Fire Station | Ongoing Measures | *Renting additional portable generator* | 0 | *$/day* | *Year-round* |
| Sleepy Hollow Water Pump Station | Ongoing Measures | *Renting additional portable generator* | 2056 | *$/day* | *Year-round* |

| Facility Name | Type of Measure (One-Time or Ongoing) | Description | Costs | Units | When would these measures be required? |
|---|---|---|---|---|---|
| North Tarrytown Housing Authority | Ongoing Measures | *Renting additional portable generator* | 2368 | *$/day* | *Year-round* |

Services Provided

We are interested in the types of services provided by the facilities the microgrid would serve, as well as the potential impact of a major power outage on these services. As specified below, the information of interest includes some general information on all facilities, as well as more detailed information on residential facilities and critical service providers (i.e., facilities that provide fire, police, hospital, water, wastewater treatment, or emergency medical services (EMS)).

***A. Questions for: All Facilities***

5. During a power outage, is each facility able to provide the same level of service when using backup generation as under normal operations? If not, please estimate the percent loss in the services for each facility (e.g., 20% loss in services provided during outage while on backup power). As a guide, see the example the table provides.

| Facility Name | Percent Loss in Services When Using Backup Gen. |
|---|---|
| Sleepy Hollow High School | 22.8% |
| Briarcliff Manor Water Pump Station | 4.6% |
| Union Hose | 0% |
| Rescue Hose | 0% |
| Village Hall/Police/Fire Station | 0% |
| Sleepy Hollow Water Pump Station | 4.6% |
| North Tarrytown Housing Authority | 0% |

6. During a power outage, if backup generation is not available, is each facility able to provide the same level of service as under normal operations? If not, please estimate the percent loss in the services for each facility (e.g., 40% loss in services provided during outage when backup power is not available). As a guide, see the example the table provides.

| Facility Name | Percent Loss in Services When Backup Gen. is Not Available |
|---|---|
| Sleepy Hollow High School | 22.8% |
| W.L. Morse School | 100% |
| Briarcliff Manor Water Pump Station | 19.9% |

| Facility Name | Percent Loss in Services When Backup Gen. is Not Available |
|---|---|
| Union Hose | 41.3% |
| Rescue Hose | 41.3% |
| Ambulance Corp | 100% |
| Village Hall/Police/Fire Station | 41.3% |
| Sleepy Hollow Water Pump Station | 19.9% |
| North Tarrytown Housing Authority | 41.3% |

***B. Questions for facilities that provide: Fire Services***

7. What is the total population served by the facility?

 10,000

8. Please estimate the percent increase in average response time for this facility during a power outage:

 Customers is unsure

9. What is the distance (in miles) to the nearest backup fire station or alternative fire service provider?

 0.5 miles

***C. Questions for facilities that provide: Emergency Medical Services (EMS)***

10. What is the total population served by the facility?

 N/A

11. Is the area served by the facility primarily (check one):

 ☐ Urban

 ☐ Suburban

 ☐ Rural

 ☐ Wilderness

12. Please estimate the percent increase in average response time for this facility during a power outage:

 Click here to enter text.

13. What is the distance (in miles) to the next nearest alternative EMS provider?

Click here to enter text.

## ***D. Questions for facilities that provide: Hospital Services***

14. What is the total population served by the facility?

N/A

15. What is the distance (in miles) to the nearest alternative hospital?

Click here to enter text.

16. What is the population served by the nearest alternative hospital?

Click here to enter text.

## ***E. Questions for facilities that provide: Police Services***

17. What is the total population served by the facility?

10,000

18. Is the facility located in a (check one): Village (unsure what this falls into)

☐ Metropolitan Statistical Area

☐ Non-Metropolitan City

☐ Non-Metropolitan County

19. Please estimate:
    a. The number of police officers working at the station under normal operations.

    4

    b. The number of police officers working at the station during a power outage.

    8

    c. The percent reduction in service effectiveness during an outage.

    10%

***F. Questions for facilities that provide: Wastewater Services***

20. What is the total population served by the facility?

| N/A |
|---|

21. Does the facility support (check one):
☐ Residential customers

☐ Businesses

☐ Both

***G. Questions for facilities that provide: Water Services***

22. What is the total population served by the facility?

| 10,000 |
|---|

23. Does the facility support (check one):
☐ Residential customers

☐ Businesses

☒ Both

***H. Questions for: Residential Facilities***

24. What types of housing does the facility provide (e.g., group housing, apartments, nursing homes, assisted living facilities, etc.)?

| Municipal Housing Authority |
|---|

25. Please estimate the number of residents that would be left without power during a complete loss of power (i.e., when backup generators fail or are otherwise not available).

| Unsure of exact number – roughly 80-100 units |
|---|