49 - County of Albany (Airport)

October 2016

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Albany Community Microgrid

Final Report – NY Prize Stage 1: Feasibility Assessment

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March 2016

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PROJECT STAKEHOLDERS

- Albany International Airport
- Albany County Hockey Facility
- Albany District Youth Center, Incorporated
- Albany County Correctional Facility
- Albany County Nursing Home

ALBANY COMMUNITY MICROGRID - KEY OVERVIEW METRICS

Team

Lead:	County of Albany
Technical Team:	L&S Energy, Hitachi Microgrids

Utilities

Electric:	National Grid
Gas:	National Grid

Microgrid System Design

Size:	3,472	kW
Load Served:	22,970,705	kWh/yr

DER*	Qty	Capacity
Combined Heat & Power:	12	2,447 kW
Photovoltaic:	6	975 kW
Existing Photovoltaic:	1	50 kW
Energy Storage Systems:	7	260 kWh
Existing Emergency Gen:	4	2,700 kW

Microgrid Financials*

Total Installed Cost:	$ 8,016,000
Net Installed Cost:	$ 6,597,000
Resiliency Savings:	$ 230,682 / yr
GHG Offset:	$ 252,000 / yr
Current Avg. Electric Rate:	$ 0 .0922/kWh
Potential Savings with Microgrid	5% - 8%

Supporting Organizations

County of Albany	Albany International Airport
Albany County Correctional Facility	Albany County Juvenile Detention Center
Albany County Nursing Home	

Customer Types

Gov't Administrative:	3
Health Care:	1
Small Commercial:	1
Total:	**5**

Electric Demand & Consumption with Microgrid

Node	Max kW	Avg kW	kWh / yr
1	2,267	1,488	13,031,172
2	1,062	686	6,008,588
3	569	179	1,565,899
4	464	270	2,365,045
Total	**4,362**	**2,622**	**22,970,705**

Benefit Cost Analysis Outputs

	Scenario 1	Scenario 2
Days of Major Outage	0 days/yr	4.8 days/yr
Total Benefits**	$ 30,900,000	$ 41,000,000
Total Costs**	$ 40,800,000	$ 40,800,000
Net Benefits**	$ -9,950,000	$ 424,000
Benefit-Cost Ratio	0.8	1.0

***Net present values*

**Estimates based on economic modelling*

EXECUTIVE SUMMARY

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

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

This report describes the results of Stage 1 of the NY Prize Feasibility Assessment for the Albany Community Microgrid. L&S Energy worked with Hitachi Consulting to develop the microgrid design based both on NYSERDA's requirements and the needs and priorities of Albany County stakeholders. L&S Energy also led the feasibility assessment, in collaboration with Hitachi Consulting and the Albany County government. The Albany County Airport Authority, the Albany County Nursing Home, the Albany County Department of Corrections and the Albany County Hockey Rink lent additional support.

Community Overview

Albany County lies at the confluence of the Mohawk and Hudson Rivers in eastern New York State. The county seat is also the state capital: the City of Albany. The county is the center of New York's capital district, a zone (and metropolitan statistical area) that also includes Schenectady and Troy. In addition to being the seat of government, Albany County is the cultural and economic hub of eastern New York. Thousands of visitors come to Albany each year, and many arrive through Albany International Airport.

The Albany Community Microgrid is centered on this airport and is designed to make airport facilities and the critical transportation service they offer more resilient. The airport handles an average of 62 departures and arrivals per day. The microgrid also serves particularly vulnerable populations living in facilities near the airport, including a juvenile detention facility, a county correctional facility, and a county nursing home.

The microgrid design is based on an overall energy strategy that incorporates both demand-side management and new distributed generation resources to support the microgrid operational objectives. The microgrid operational objectives are to simultaneously improve resiliency, increase energy efficiency, lower emissions, and lower cost to energy users.

Community Requirements and Microgrid Capabilities

The Albany Community Microgrid is designed to meet specific needs within the community. These include the need to harden infrastructure against storm damage and power outages, and to ensure the safety of vulnerable populations.

First, the microgrid is designed to harden infrastructure against damage, particularly damage caused by increasingly frequent severe weather events. The Albany International Airport serves 2.4 million passengers each year and is a key transportation hub for the region. The closest major commercial airports are in Hartford, CT, and Syracuse, NY, both over two hours away by car. The microgrid will allow the airport to continue full operation without interruption or cancelled flights during a power outage. The existing emergency generators have been incorporated into the microgrid design, but their use will be minimized to extend the hours of operation with the existing fuel storage and to minimize emissions.

The microgrid is also designed to protect the safety and welfare of the most vulnerable populations in facilities adjacent to the airport. The Albany County Nursing Home houses 250 residents; the Albany County Correctional Facility houses 800 inmates; and the Capital District Youth Center, Incorporated houses 24 youths. All of these facilities have existing emergency diesel generators, but the microgrid is designed to minimize their use, allowing the facilities to instead remain powered during grid outages using microgrid resources. This decreases the cost and emissions associated with running the diesel generators and will help to extend the life of the equipment.

The Albany Community Microgrid is designed to address resiliency needs with clean, efficient, and cost effective technologies and architecture. Energy produced by the microgrid will reduce greenhouse gas (GHG) emissions and energy costs for microgrid customers.

The microgrid is also designed to provide some benefit to the utility. The substation serving the Microgrid will realize a reduced load by approximately 23 MWh/year, extending its lifetime and deferring the need for investment in transmission and distribution infrastructure. In addition, microgrid resources can help reduce peak demand, variability from other PV within the substation area, and support conservation voltage reduction (CVR), voltage, VAr, and frequency.

Technical Design

Analysis of the Albany Community Microgrid design indicates that the project is technically viable and meets the community's requirements with commercially available and proven technologies. The proposed design for the Albany Community Microgrid is based on the strategic placement of microgrid resources among the included facilities. The resources in the microgrid design include solar photovoltaics (PV), natural gas powered combined heat and power (CHP) systems, energy storage systems (ESS), and existing backup diesel generators. (No new diesel generators will be installed). The microgrid resource selection is based on Hitachi's *Microgrid Portfolio Approach.* This approach uses a careful analysis of energy requirements and the electric load profile of all covered facilities to determine optimal size and specification of equipment. The goal of this approach is to enable microgrid resources to serve the microgrid loads more efficiently, more cost effectively, and with lower emissions per unit of energy consumed.

Under this strategy, base-load CHP will be designed to run at design output for a majority of the hours per year. All critical facility services can be provided by a set of continuously operating microgrid resources operating in conjunction with the grid for the majority of hours in a year. To meet the load that varies above the base load, PV and ESS will be integrated into the system. ESS are specified based on their capability to address PV intermittency support, PV load shifting, peak shaving (to manage utility imports), supporting CHP loading, and stabilize island mode operations. The design also incorporates active microgrid controls that enable optimal operation of energy storage, PV, and building management systems to manage load and reduce the afternoon peak load when needed.

The microgrid is designed to include critical facilities located throughout the Albany community. In order to include non-adjacent facilities, the design is based on four separate nodes, each of which have their own microgrid resources and are able to island individually. In grid connected mode, the resources will be dispatched to minimize costs and emissions. The table below, which also appears in the report that follows, summarizes the DER, new and existing, that will be included in the proposed microgrid design.

Executive Summary Table 1 - Microgrid Resources Comparison

Node	Operation Scenario	Grid	PV		Battery Energy Storage		Natural Gas Engine or CHP		Backup Generators	
		Peak kW	# of Inverters	kW	Qty	kW / kWh	Qty	kW	Qty	kW
1	Business as Usual	2,267	1	50	-	-	-	-	1	1,250
	Microgrid	550	2	250	2	60/120	2	1,524	1	1,250
2	Business as Usual	1,062	-	-	-	-	-	-	2	1,100
	Microgrid	250	3	350	3	30/60	4	623	2	1,100
3	Business as Usual	569	-	-	-	-	-	-	1	400
	Microgrid	220	1	175	1	15/30	2	140	1	400
4	Business as Usual	464	-	-	-	-	-	-	1	350
	Microgrid	170	1	250	1	25/50	4	160	1	350

Executive Summary Table 2, which also appears in Section 2 of this report, gives an overview of the normal operation of the proposed microgrid design in terms of electricity demand and consumption, thermal load, and thermal heat recovery (through new CHP systems) by node.

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

	Electric Demand		Electric Consumption		Thermal Load		Thermal Recovery	
Node	Max (kW)	Avg (kW)	kWh/year	kWh/month	kBTU/year	kBTU/month	kBTU/year	kBTU/month
1	2,267	1,488	13,031,172	1,085,931	35,837,449	2,986,454	23,449,441	1,954,120
2	1,062	686	6,008,588	500,716	46,541,160	3,878,430	18,841,310	1,570,109
3	569	179	1,565,899	130,492	811,626	67,636	709,448	59,121
4	464	270	2,365,045	197,087	13,098,740	1,091,562	5,135,812	427,984
Total	**4,362**	**2,622**	**22,970,705**	**1,914,225**	**96,288,975**	**8,024,081**	**48,136,010**	**4,011,334**

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

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

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

Financial Feasibility

The project team developed a general budget for the Albany Community Microgrid project and incorporated it into the technical model to ensure that the design meets both the technical and economic requirements of the project. This budget includes costs for engineering, permitting, capital equipment, site preparation, construction, controls, start-up, commissioning, and training. The cost associated with "site preparation" includes the addition and modification of electrical infrastructure, PCC controls, monitoring, and protection equipment. Some of these infrastructure costs may be paid to the electric utility. The estimated installed cost for this project is $8,016,000, with an accuracy of +/- 25% (within the +/- 30% set by NYSERDA). The net cost with the federal investment tax credit (ITC) that was recently extended by the US Congress is $6,597,000.

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

Business Model Financial Results: Under the proposed business model, a third party would fund all development and construction of the microgrid, own and operate the assets, and sell the energy generated from the microgrid to community customers through PPAs. The community would incur no costs to build the project and would receive all of the benefits of energy resilience during a grid outage, and improved sustainability. Community stakeholders are deciding between a third party ownership and a shared ownership structure. The current weighted electric rate of the key critical facilities included in the proposed microgrid is approximately $0.092/kWh. Based on the estimated energy savings, assumed project financing costs, and the 25 year contract term, the study supports a PPA electric rate with an electric cost that represents an average discount of approximately 5-8% for the facilities in this project.

Benefit-Cost Analysis Results: NYSERDA contracted with IEc to conduct a benefit-cost analysis. The project team provided detailed information to IEc to support this analysis. IEc ran two scenarios for this proposed microgrid. The first scenario modeled no power outages, and evaluated the grid connected mode of operation. The second scenario modeled the number of days (or partial days) outage at which the costs of the microgrid would be equal to its various benefits, thus yielding a cost benefit ratio of 1. For the Albany Community Microgrid, the breakeven outage case is an average of 4.8 days of outage per year. The cost benefit results are presented in Executive Summary Table 3.

Executive Summary Table 3 – Cost Benefit Analysis Results

	Assumed average duration of major power outages	
Economic Measure	**Scenario 1: 0 DAYS/YEAR**	**Scenario 2: 4.8 DAYS/YEAR**
Net Benefits - Present Value	-$9,950,000	$110,000
Total Costs – Present Value	$40,800,000	$40,800,000
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	-17.9%	5.6%

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

- Gas rates used in IEc's benefit-cost analysis were based on a state-wide average for commercial end-use customers. The rates used in Albany's financial feasibility analysis are based on National Grid's distributed generation rate. This resulted in year 1 gas rates of $6.34 and $4.25, for the benefit-cost analysis and the financial feasibility analysis, respectively. If National Grid's distributed generation rate were applied to the benefit-cost analysis, net benefits would be increased by $4.27M.

- The financial feasibility assessment incorporates the tax benefits of the Federal Investment Tax Credit, whereas the benefit-cost analysis does not. This benefit reduces the capital cost of the project by $1.42M.
- Capital replacement costs used in the BCA were calculated as a full replacement costs, whereas the project team assumed a ‘rebuild’ cost that is not equal to the full cost of replacement. The rebuild cost for the Albany Community Microgrid is $91,000 less than the full cost of replacement.
- The benefit-cost analysis derives a price for electricity based on average wholesale energy costs, whereas the financial feasibility assessment evaluates the savings to the community based on actual costs paid by community participants.
- The period of analysis in the benefit cost analysis is 20 years and the third party ownership model is based on a period of analysis of 25 years.

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

Conclusions and Next Steps

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

1. ***Critical Key Facilities***: The Community Microgrid is built around a set of facilities and institutions that are well established, and committed to the project, all of which are public facilities managed by the county government .
2. ***Efficiently Organized Nodes***: Dividing the microgrid into a number of nodes does not always drive up the total installed cost of the systems. Optimized properly, organizing into nodes resulted in net favorable outcomes where the reduced cost of installing new underground infrastructure offsets the increased cost of additional controls and points of common coupling.
3. ***Natural Gas Costs***: Natural gas is one of the largest cost drivers of this system. Increasing costs for natural gas will have a negative impact on the PPA rates for each of the facilities, but overall electricity cost savings should increase year over year for microgrid customers compared to the cost of electricity from the grid.
4. ***Community Microgrid Financing Costs***: The cost of project financing is typically high for community microgrids. This is due to the fact that there are numerous stakeholders and potential customers that have their own procurement requirements. The project team will need to seek out a financier that is knowledgeable about these projects, and can help keep transaction costs to a minimum. Since all the facilities are under the control of the County, it is assumed that the procurement requirements are the same (or very similar) for all the facilities proposed to be in the microgrid, which is an advantage.

5. ***Financial Prospects:*** The feasibility analysis indicates that the Albany Community Microgrid project meets the financial requirements for third party financing and ownership.

Regulatory and Policy Recommendations

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

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

   At the state level, a program to standardize and expedite the issuance of franchise rights to microgrid developers would significantly reduce associated development costs for community microgrids. For instance, the State Supreme Court in Connecticut ruled that installing a distribution wire from one parcel to another and selling power across that line cannot encroach on a utility franchise (and won't trigger PUC jurisdiction).[1]

2. ***Utility Ownership***: The rules governing utility ownership of microgrids in New York State, and specifically DER within the microgrid, are not clearly defined. After ruling in 1996 that distribution utilities must end all investments in generation assets, the Public Service Commission (PSC) carved out a general criterion for exceptions in a 1998 ruling known as the Vertical Market Power Policy. This policy stated that distribution utilities could own DER if they could demonstrate "substantial ratepayer benefits, together with [market power] mitigation measures."[2] In February, 2015, the PSC published the "Order Adopting Regulatory Policy Framework and Implementation Plan"[3] which described several circumstances when utility ownership of DER would be allowed. One of these circumstances is for a project that is "sponsored for demonstration purposes." This may be applicable to some NY Prize projects, but it is unclear what the criteria would be for an acceptable demonstration project. Also, this does not help drive the broader market for microgrids as this limits the number of systems that will be implemented in the near term.

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

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

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

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

3. ***CHP Natural Gas Tariffs:*** The resilience of natural gas infrastructure to storm damage and other disruption makes it an attractive fuel source for powering microgrid energy resources (such as combined heat and power plants). The economic health of microgrids that use natural gas plants to meet base loads is subject to favorable natural gas tariffs. The application of natural gas generators create benefits in the form of a base natural gas load (including in the summer months when natural gas demand is lowest), and improved system efficiency (through generation located at the load, efficient operation on the power curve, and recovery of heat to offset other heating loads). Most utilities offer specific tariffs for the operation of distributed generation equipment. State support for attractive natural gas tariffs helps to assure viable business models for both CHP and microgrid development.
4. ***Stage 2 and Stage 3 Funding Structure:*** Stage 2 funding should focus on advancing the project towards the construction phase, and less on reporting deliverables. Stage 3 funding sends a poor market signal, indicating that microgrids need subsidies in order to be cost effective, which is often not the case.
5. ***Municipal Lowest Rate Requirement:*** Regulations that require that municipal customers pay the lowest available rate for electricity and gas may prevent investment in microgrid infrastructure and resilience benefits through a PPA in certain cases. Projects that provide other societal benefits (support critical loads, serve the community at times of natural disaster, reduce emissions, etc.) should be eligible for consideration as projects that municipalities may execute.
6. ***Competitive Procurement Requirements*:** Given cost share requirements in Stage 2, development firms are going to hesitate to invest unless they are assured work in Stage 3. This could potentially be mitigated by state-issued guidance for special exemptions for the NY Prize program, or by encouraging a single procurement process for Stage 2 and 3.

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

Albany Community Microgrid
Final Report – NY Prize Stage 1: Feasibility Assessment

TECHNICAL DESIGN OVERVIEW

The proposed microgrid solution focuses on community resiliency based on distributed resources co-located at or near the critical facilities serving the airport, several correctional facilities, and elderly population of Albany. The strategy is to develop a community microgrid that consists of multiple site-specific microgrids that may or may not be connected from an electrical perspective but are controlled as a single entity. One of the challenges of community microgrids is that the facilities and the microgrid resources are distributed. To maximize the economics, reliability, and emissions reduction potential of the community microgrid, the microgrid controller architecture must have the capability to coordinate and control different groups of resources as well as provide control for localized operations.

The proposed microgrid includes airport facilities, correctional facilities, a glycol facility, and a nursing home. Collectively, there are a total of 4 "nodes" that make up the Albany Community Microgrid as presented in Table 1.

Table 1 – Overview of Microgrid Nodes

Microgrid Node #	Facilities	Functions
1	• Albany International Airport Terminal 2 • Albany International Airport Terminal 3 • Hockey Facility	• Airport • Emergency morgue • Recreation/sports
2	• Airport Auxiliary Building • Albany Juvenile Detention Facility • Albany County Correctional Facility	• Airport Operations Support • Correctional facilities
3	• Glycol Facility	• Aircraft de-icing
4	• Albany County Nursing Home	• Nursing home

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

The design team met with National Grid to review utility infrastructure that impacts the microgrid design. In general, they understand the proposed design and did not identify any major issues. Table 2 summarizes the overall electrical and thermal infrastructure that is proposed.

Table 2 - Microgrid Electrical and Thermal Infrastructure Plan

Infrastructure	Class	Associated Device	Comment / Description
13.8 kV, 3 phase, Underground Cabling	New	Nodes 1, 2	Added for microgrid nodes that have multiple electric accounts; includes associated trenching in project budget
SCADA Switch	New	All Nodes	Enables sectionalizing of National Grid circuit to support microgrid operations
PCC (All Nodes)	New	13.8 kV line to distribution transformers	Transition from overhead to underground. Cost included in the project budget.
13.8 kV Transformers	Updated	Critical Facilities	Conversion from pole-top to pad mount. Cost included in the project budget.
Synchronizing Switches	New	CHP	Each CHP at a critical facility will require a synchronizing switch with protection to enable remote synchronization with the microgrid bus. Cost included in the project budget.
M, C, P	New	All resources	Monitoring (sensing), Control, and Protection relays for proper management of resources in all modes
Automatic Transfer Switch	Existing	Emergency Generators	All emergency generation (diesel or gas) have automatic transfer switches installed in critical facilities. This will remain unchanged.
Hot Water Supply Connection	New	CHP & heating	Tie-in from CHP to facility thermal loop for each facility with new CHP
Hot Water Return Connection	New	CHP & heating	Tie-in from CHP to facility thermal loop for each facility with new CHP

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

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

Table 3 – Community Stakeholders to Benefit from the Microgrid

Organization	Benefits from Albany Community Microgrid
National Grid	By serving the local load and providing resilient energy, the system will allow the utility to delay potential investments in the existing substation equipment. This system will also help the utility meet its customer-sited renewable energy target under the New York's Renewable Portfolio Standard.
County of Albany	In addition to the all of the passengers from around the world who flow through the Albany International Airport each day, the airport serves the residents of the surrounding county by providing means of supply and quick transportation. In an emergency situation, the microgrid will offer much needed energy resilience to this facility, and support emergency operations.

KEY FEATURES OF THE MICROGRID

Community Microgrid Controller

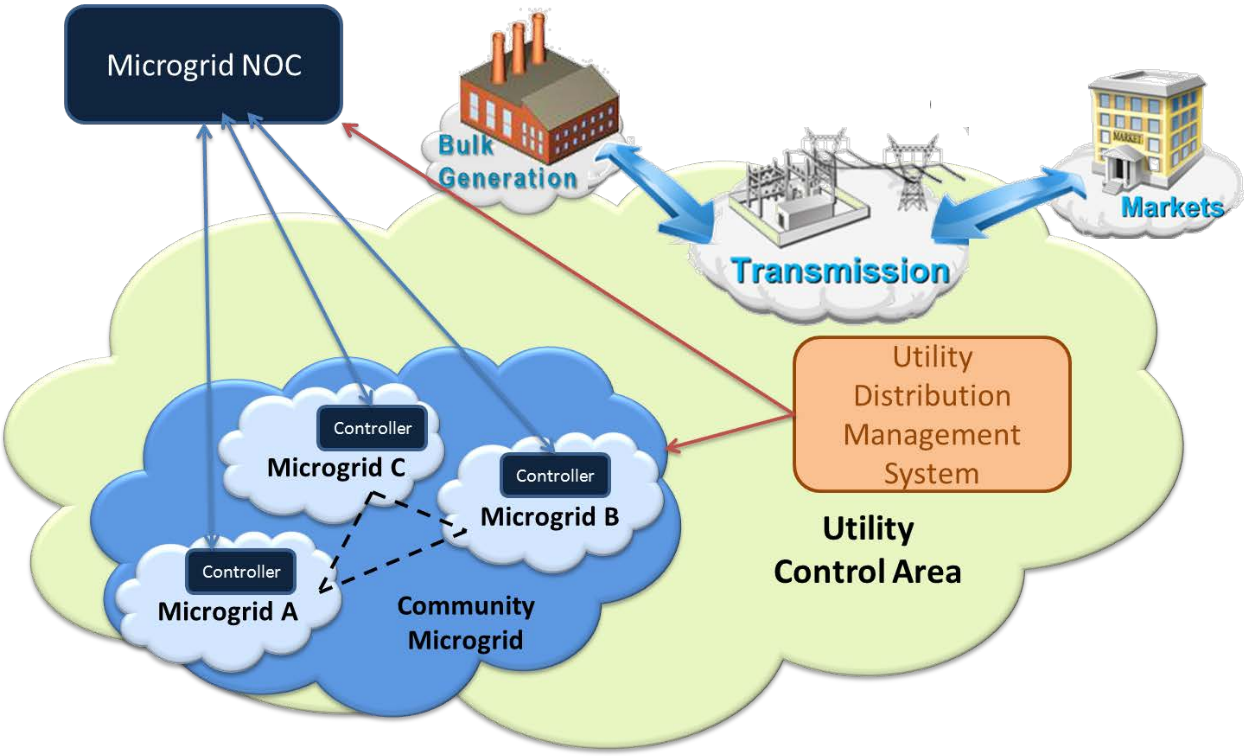
One of the challenges of community microgrids is that the facilities and the microgrid resources are distributed. To maximize the economics, reliability, and emissions reduction potential of the community microgrid, the microgrid controller architecture must have the capability to coordinate and control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

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

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

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

Figure 1: Project Concept for Community Microgrid



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

1. **Frequency control**: In normal operations, the microgrid may not have enough resources to affect frequency on the grid. It could participate in the ancillary services markets by increasing output to support the frequency in the local grid, but total impact would be small. Nevertheless, the system will monitor frequency along several thresholds, providing a discrete high-low range; the system will detect if frequency is out of range and respond by taking resources off-line or dispatch other resources to manage frequency. Also, the system will analyze data to detect subtler trends that do not exceed thresholds but provide evidence of a possible problem.
2. **Voltage control**: In both grid-connected and islanded modes, the voltage control application will be used to provide stability to the microgrid and connected circuits. Voltage control leverages line sensing and metering to provide control actions when necessary. This application will take into account traditional volt/VAr instruments such as tap changers and cap banks along with inverter-based resources, which should provide a greater degree of optimization.
3. **Intentional islanding**: For each microgrid node, the islanding process will be semi-automatic so that a utility operator or local energy manager will be able to move through each step before opening the PCC. The utility operator will provide the appropriate permissives for opening the PCC. The local microgrid controller for each microgrid node will be responsible for setting the voltage source and load following resource.

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

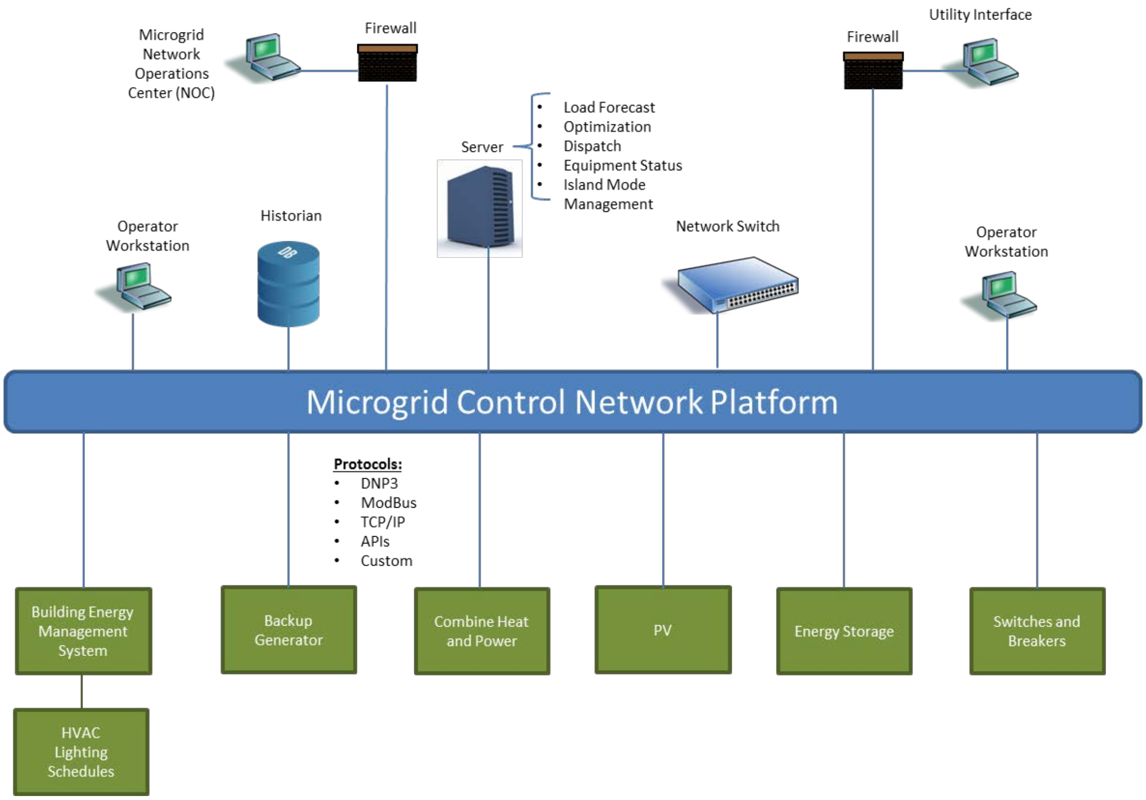
In addition, the microgrid controller will:

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

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

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

Figure 2 – Conceptual Microgrid Controller Topology



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

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

Telecommunications Infrastructure

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

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

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

Communications – Microgrid and Utility

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

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

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

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

DISTRIBUTED ENERGY RESOURCES CHARACTERIZATION

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

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

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

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

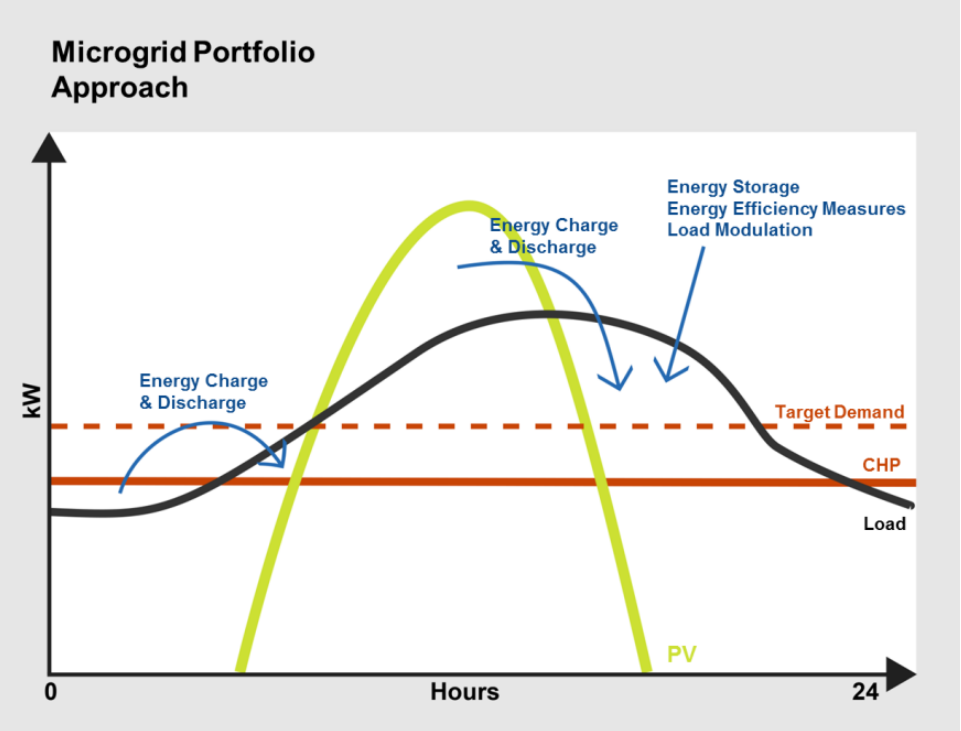
To support steady-state frequency requirements, as well as the ANSI 84.1-2006 standard voltage requirements and to support the customer power quality requirements at PCC, the microgrid controller will actively manage the dispatch of generation resources; actively manage the charge and discharge of energy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

Normal and Emergency Operations

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

Under this strategy, base-load CHP will be designed to run at design output for a majority of the hours per year. All critical facility services can be provided by a set of continuously operating microgrid resources operating in conjunction with the grid for the majority of hours in a year. To meet the load that varies above the base load, PV and ESS will be integrated into the system. ESS are specified based on their capability to address PV intermittency support, PV load shifting, peak shaving (to manage utility imports), supporting CHP loading, and stabilize island mode operations. The design also incorporates active microgrid controls that enable optimal operation of energy storage, PV, and building management systems to manage load and reduce the afternoon peak load when needed. This concept is presented in Figure 3.

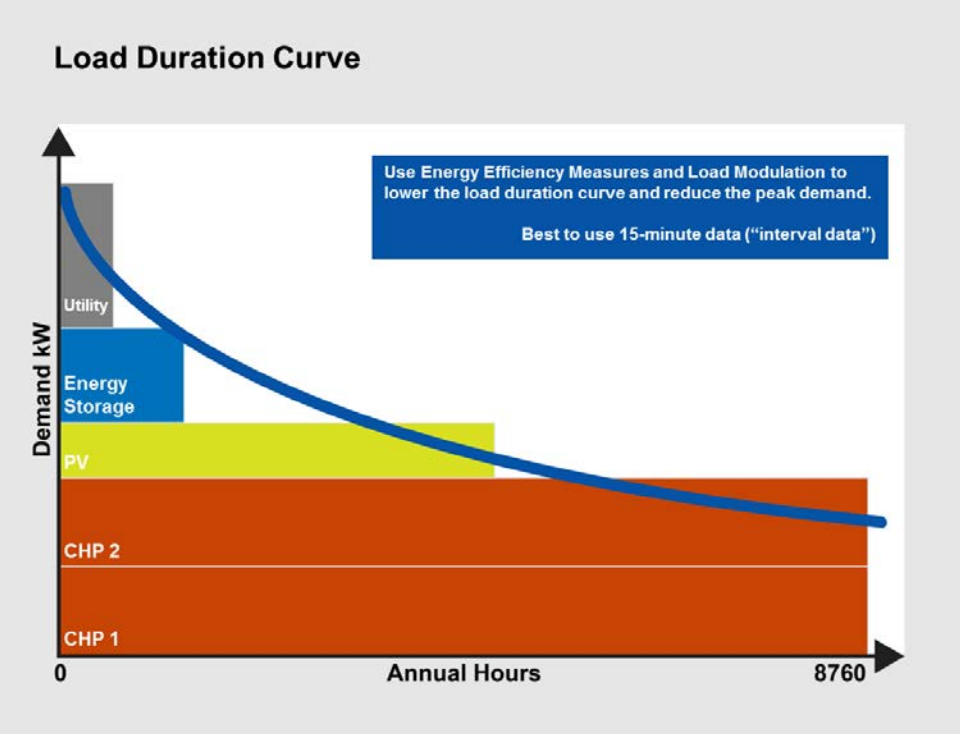
Figure 3 – Microgrid Portfolio Approach



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

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

Figure 4 – Load Duration Curve



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

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

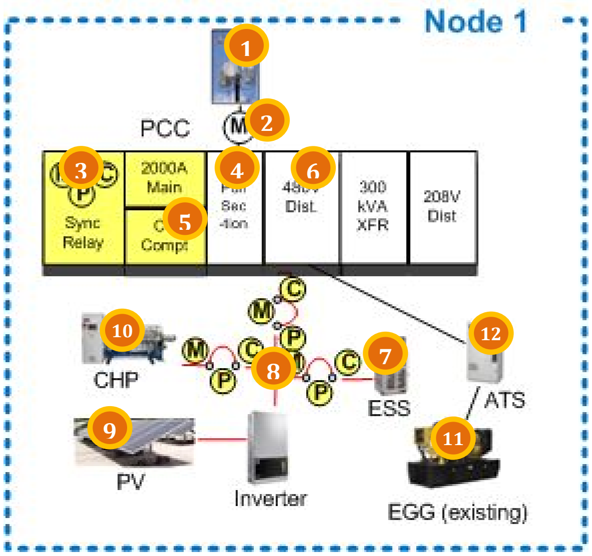
- Unplanned Transition*:* In an unplanned transition, an unanticipated outage takes place such as the loss of a transformer or a car hitting a distribution power pole. Depending on the microgrid resources operating at the time, an outage may take place that requires the microgrid to establish itself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

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

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

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

Figure 5 – One-Line Diagram Explanation



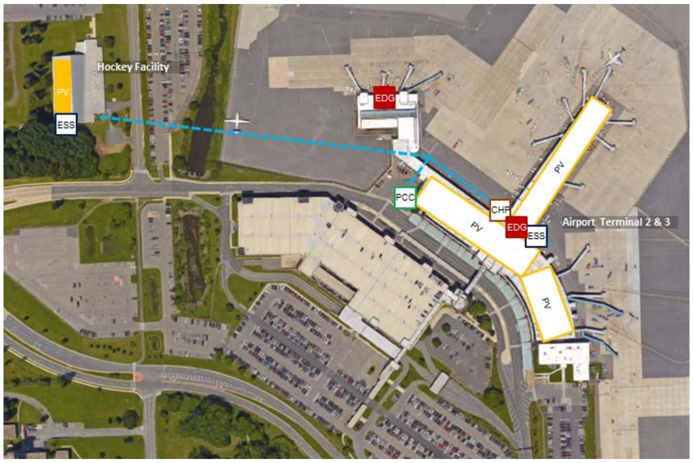
1. Transformer to the critical facility
2. Utility meter
3. Synchronizing relay controls / main breaker with monitoring (M), protection relays (P), and controls (C)
4. Main disconnect (pull section)
5. Instrument current transformer compartment
6. Main 480 Volt 3-phase distribution panel; step-down transformer and 208V 1-phase distribution panel
7. Energy storage system (ESS) with M, P, C
8. New 480 Volt 3-phase cable (red)
9. Solar PV array and associated inverter with M, P, C
10. Combined Heat & Power (CHP) with M, P, C
11. Emergency generators: Emergency Gas Generator (EGG) or Emergency Diesel Generator (EDG)
12. Automatic Transfer Switch (ATS)

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

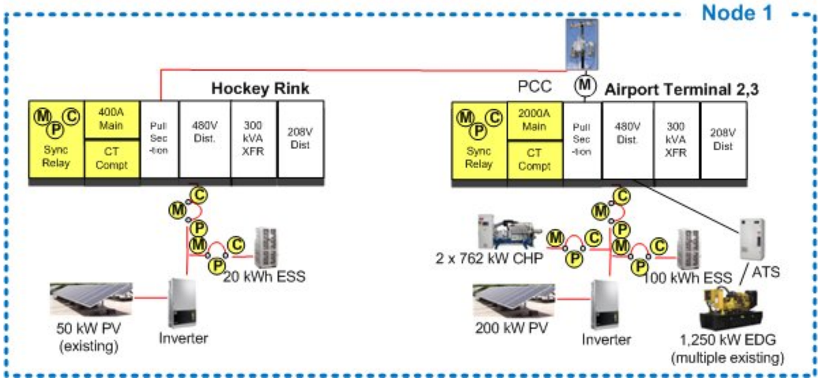
Geospatial Diagrams and One-Line Subsections

Node 1 System Configuration

Geospatial Diagram



One-Line Diagram Excerpt*



*See appendix B for full one-line diagram

Facilities

- Albany International Airport Terminal 2
- Albany International Airport Terminal 3
- Hockey Facility

Description

The point of common coupling (PCC) will be located at the west end of airport terminal building. The node contains 1,476 feet of new underground infrastructure. The following infrastructure will be included in the microgrid:

Airport Terminal 2 & 3:

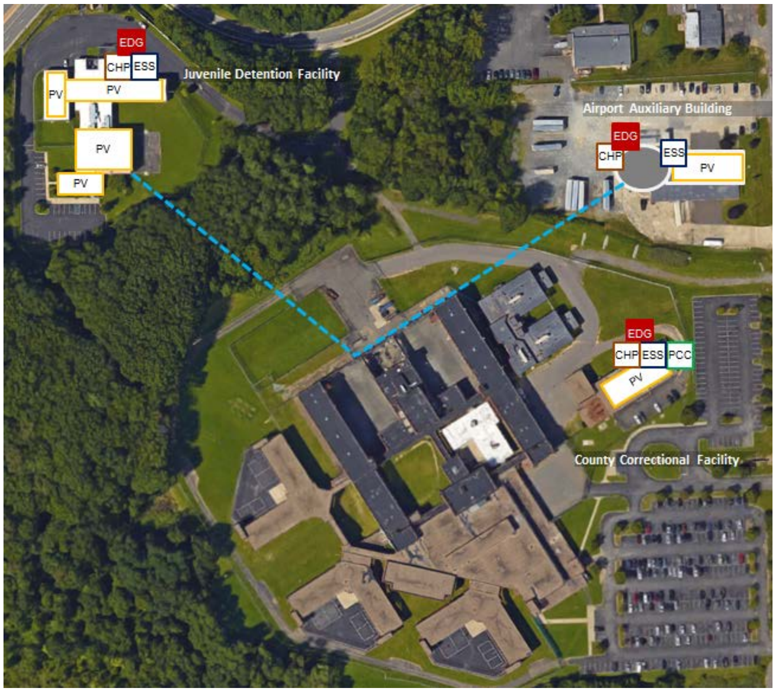
- Rooftop PV (200 kW)
- CHP (1,524 kW)
- ESS (100 kWh)
- Existing EDG (1,250 kW)

Hockey Facility:

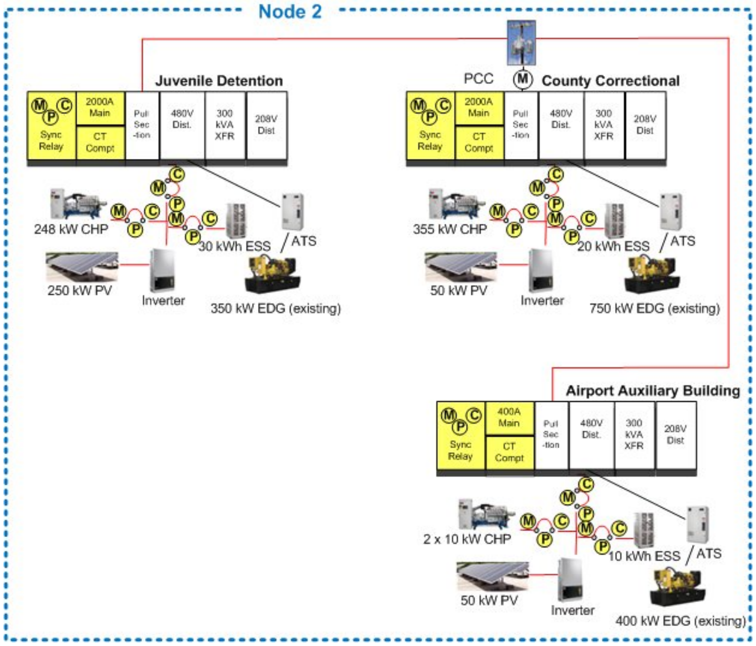
- Existing Rooftop PV (50 kW)
- ESS (20 kWh)

Node 2 System Configuration

Geospatial Diagram



One-Line Diagram Excerpt*



*See appendix B for full one-line diagram

Facility

- Albany Juvenile Detention Facility
- Albany County Correctional Facility
- Airport Auxiliary Building

Description

The PCC is located near the central plant facility at the County Correctional Facility. This node contains 1,082 feet of new underground infrastructure. The following infrastructure will be included in the microgrid:

County Correctional Facility (central plant building):

- Rooftop PV (50 kW)
- CHP (355 kW)
- ESS (20 kWh)
- Existing EDG (750 kW)

Juvenile Detention Facility

- Rooftop PV (250 kW)
- CHP (248 kW)
- ESS (30 kWh)
- Existing EDG (350 kW)

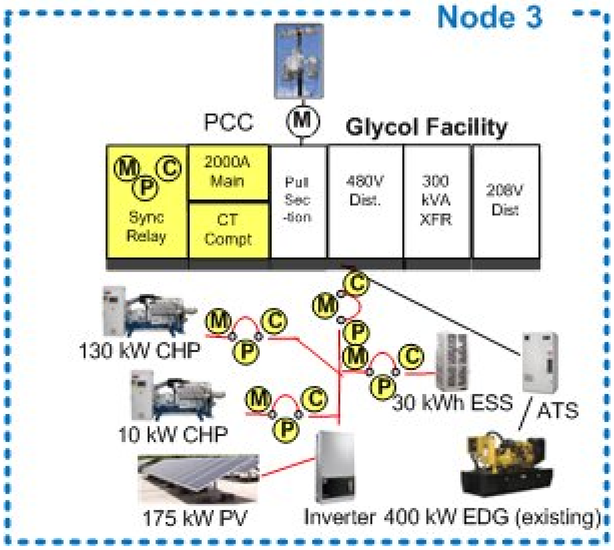
Airport Auxiliary Building

- Rooftop PV (50 kW)
- CHP (20 kW)
- ESS (10 kWh)
- Existing EDG (400 kW)

Node 3 System Configuration

Geospatial Diagram

One-Line Diagram Excerpt*



*See appendix B for full one-line diagram

Facilities

- Glycol Facility

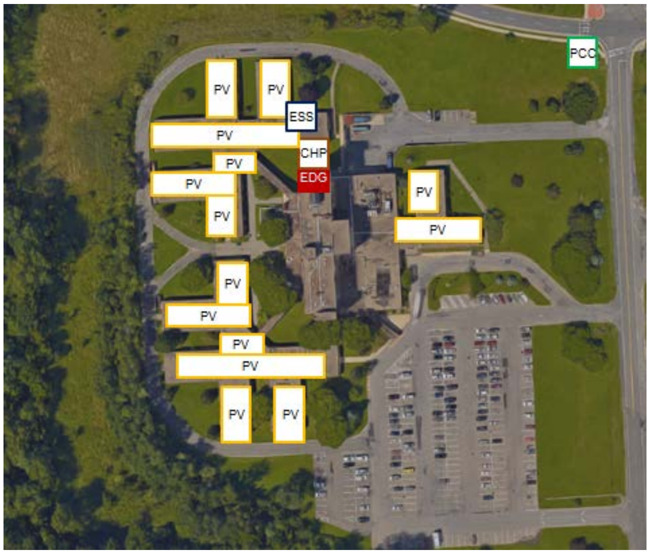
Description

The PCC is located in front of the facility east of Albany Airport County Rd. The following infrastructure will be included in the microgrid:

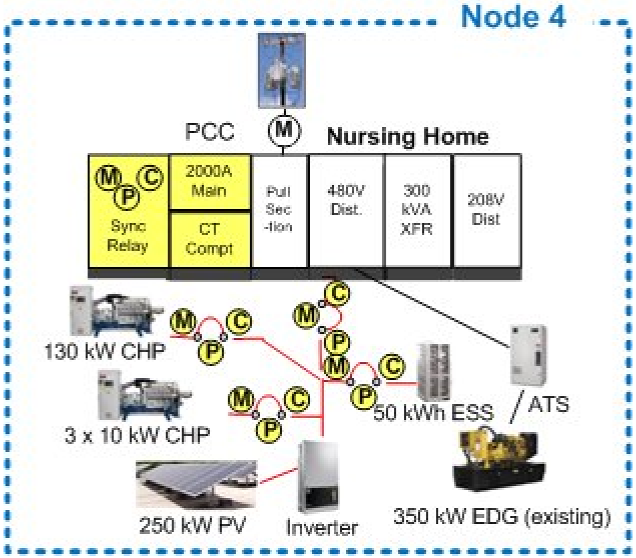
- Rooftop & Ground-Mounted PV (175 kW)
- CHP (140 kW)
- ESS (30 kWh)

Node 4 System Configuration

Geospatial Diagram



One-Line Diagram Excerpt*



*See appendix B for full one-line diagram

Facilities

- Albany County Nursing Home

Description

The PCC is located near the intersection of Albany Shaker Rd & Heritage Ln. The following infrastructure will be included in the microgrid:

- Rooftop PV (250 kW)
- CHP (160 kW)
- ESS (50 kWh)
- Existing EDG (350 kW)

Modeling Methodology

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

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

Load Description

The microgrid design team modeled and optimized each of the four nodes separately. Table 4 presents an overview of the energy operations of the microgrid by node. The microgrid will have a maximum demand of 4,362 kW and an average demand of 2,622 kW. The microgrid will deliver approximately 23,000,000 kWh per year. The thermal loads in the microgrid will be approximately 96,000,000 kBTU per year, of which approximately 48,000,000 kBTU will be recovered from the CHP systems and reused to support on-site thermal loads.

Table 4 –Microgrid Energy Overview: Grid Connected Operation

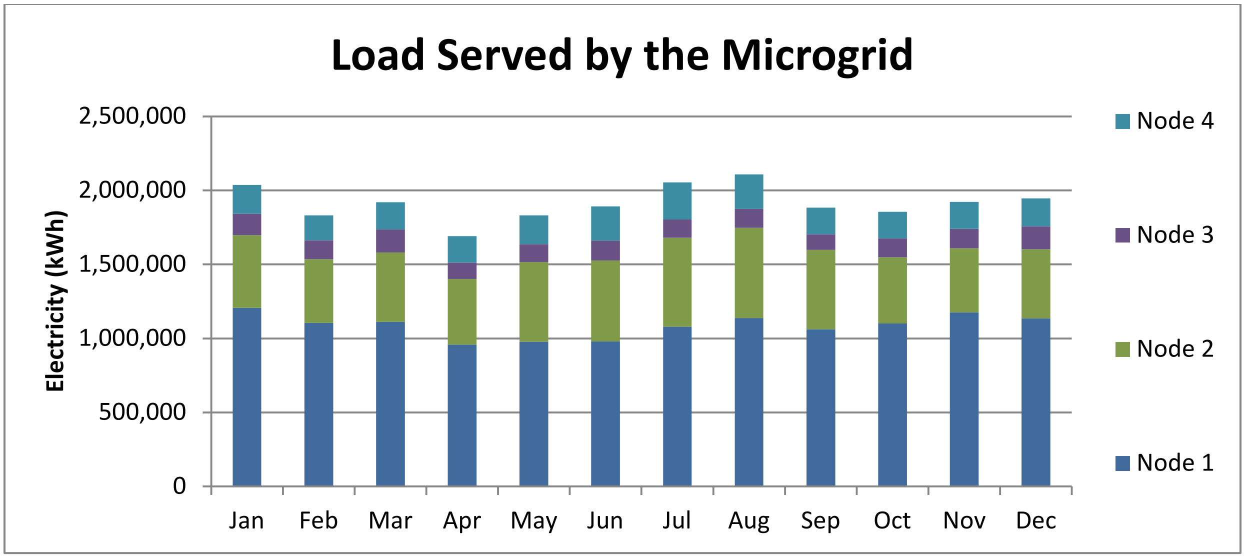
	Electric Demand		Electric Consumption		Thermal Load		Thermal Recovery	
Node	Max (kW)	Avg (kW)	kWh/year	kWh/month	kBTU/year	kBTU/month	kBTU/year	kBTU/month
1	2,267	1,488	13,031,172	1,085,931	35,837,449	2,986,454	23,449,441	1,954,120
2	1,062	686	6,008,588	500,716	46,541,160	3,878,430	18,841,310	1,570,109
3	569	179	1,565,899	130,492	811,626	67,636	709,448	59,121
4	464	270	2,365,045	197,087	13,098,740	1,091,562	5,135,812	427,984
Total	**4,362**	**2,622**	**22,970,705**	**1,914,225**	**96,288,975**	**8,024,081**	**48,136,010**	**4,011,334**

The monthly energy delivery by microgrid node is presented in Table 5 and presented graphically in Figure 6.

Table 5 –Monthly Grid Connected Operation by Node

Month	Node 1	Node 2	Node 3	Node 4	Node 5
	(kWh)				
Jan	1,207,417	489,804	144,915	194,074	2,036,211
Feb	1,104,260	430,617	127,692	169,661	1,832,231
Mar	1,111,970	467,589	156,692	184,656	1,920,908
Apr	957,874	444,217	109,154	179,937	1,691,183
May	977,057	538,039	121,448	193,944	1,830,488
Jun	980,436	546,758	134,113	231,418	1,892,725
Jul	1,078,822	601,549	123,026	250,789	2,054,187
Aug	1,138,284	608,638	128,170	233,422	2,108,513
Sep	1,062,370	535,924	104,323	179,524	1,882,140
Oct	1,101,498	445,563	128,599	178,778	1,854,437
Nov	1,176,113	432,177	132,929	180,584	1,921,803
Dec	1,135,070	467,712	154,839	188,258	1,945,879
Total	**13,031,172**	**6,008,588**	**1,565,899**	**2,365,045**	**22,970,705**

Figure 6 - Monthly Grid Connected Operation by Node



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

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

- The use of multiple, distributed, smaller unit sizes to help minimize generation loss and ensure that the microgrid can gracefully accommodate the failure

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

These techniques are employed in the Albany Community Microgrid design so that equipment loss is mitigated or accommodated in the specific microgrid nodes for this community, under grid-connected and islanded modes of operation. Table 6 summarizes the microgrid resources in each node in terms of number of devices and the total installed capacity by technology.

Table 6 - Microgrid Resources Comparison

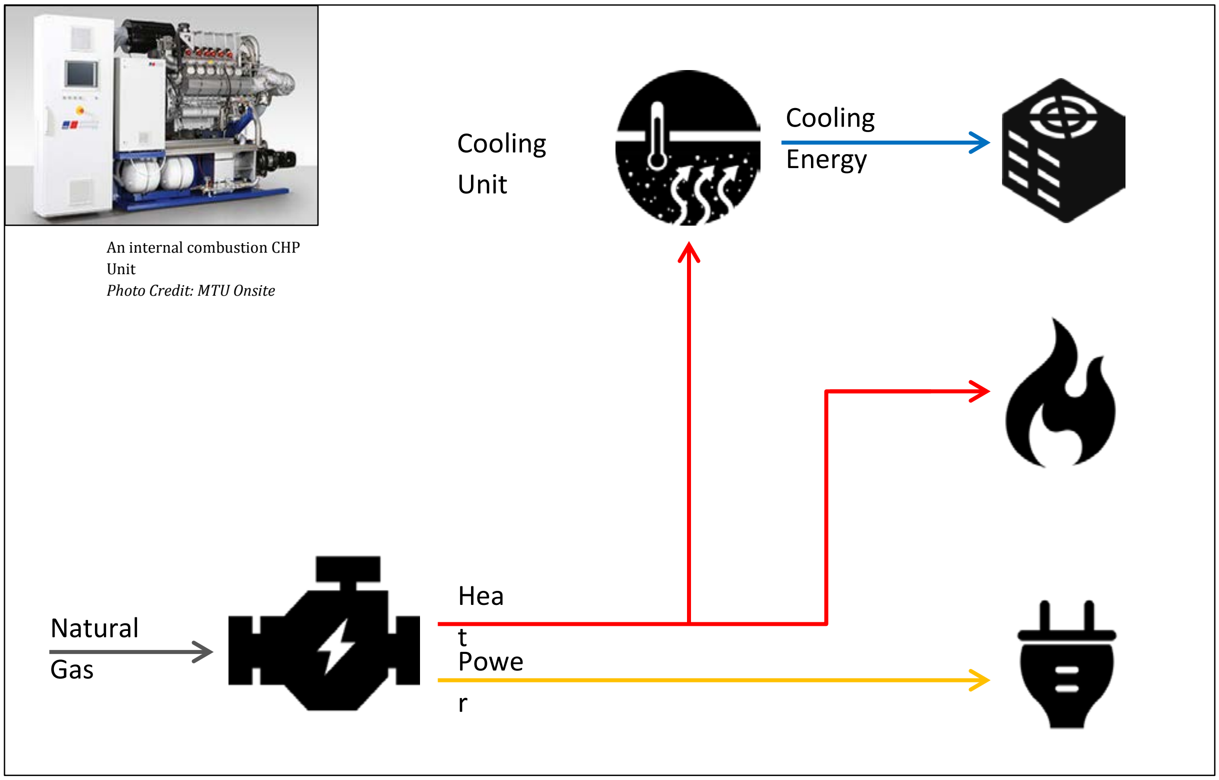
Node	Operation Scenario	Grid	PV		Battery Energy Storage		Natural Gas Engine or CHP		Backup Generators	
		Peak kW	# of Inverters	kW	Qty	kW / kWh	Qty	kW	Qty	kW
1	Business as Usual	2,267	1	50	-	-	-	-	1	1,250
	Microgrid	550	2	250	2	60/120	2	1,524	1	1,250
2	Business as Usual	1,062	-	-	-	-	-	-	2	1,100
	Microgrid	250	3	350	3	30/60	4	623	2	1,100
3	Business as Usual	569	-	-	-	-	-	-	1	400
	Microgrid	220	1	175	1	15/30	2	140	1	400
4	Business as Usual	464	-	-	-	-	-	-	1	350
	Microgrid	170	1	250	1	25/50	4	160	1	350

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

CHP

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

Figure 7 – CHP System Overview


An internal combustion CHP Unit
Photo Credit: MTU Onsite

Benefits of CHP

- Reduces utility costs and improves economic competitiveness
- Increases power reliability and self-sufficiency
- Reduces GHG emissions and other pollutants
- Reduces demand for imported energy supplies
- Capable of operating on renewable or nonrenewable resources
- Suite of proven, commercially available technologies for various applications
- Additional financial incentives through the NYSERDA and investment tax credits available for eligible customers

CHP Approach

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

CHP in the Microgrid

The size and location of the planned CHP units is presented in the layout diagram and single-line diagram presented in the Appendix. Table 7 summarizes the CHP components by node of the microgrid.

Table 7 - Microgrid CHP Resources by Node

Node	Natural Gas Engine or CHP	
	Qty	Total kW
1	2	1,524
2	4	623
3	2	140
4	4	160
Total	**12**	**2,447**

The below tables and figures describe the annual operation of the CHP fleet in the Albany microgrid.

Table 8 - Microgrid CHP Electric Production by Node

Month	Node 1	Node 2	Node 3	Node 4	Total
	Electric Production (kWh)				
Jan	1,084,346	433,362	91,652	116,049	1,725,408
Feb	978,843	382,555	81,948	103,259	1,546,605
Mar	1,019,279	410,259	90,621	110,888	1,631,047
Apr	900,065	387,963	79,421	110,597	1,478,047
May	944,785	427,801	82,855	97,515	1,552,956
Jun	947,044	422,106	79,992	97,570	1,546,711
Jul	1,011,784	444,016	82,744	108,255	1,646,799
Aug	1,082,636	452,172	82,904	104,466	1,722,178
Sep	1,021,161	418,308	76,522	93,841	1,609,832
Oct	1,040,316	395,751	86,165	114,182	1,636,414
Nov	1,063,236	393,784	83,365	112,120	1,652,506
Dec	925,323	372,420	84,651	114,257	1,496,651
Total	**12,018,817**	**4,940,495**	**1,002,841**	**1,283,000**	**19,245,153**

Figure 8 – Microgrid CHP Electric Production

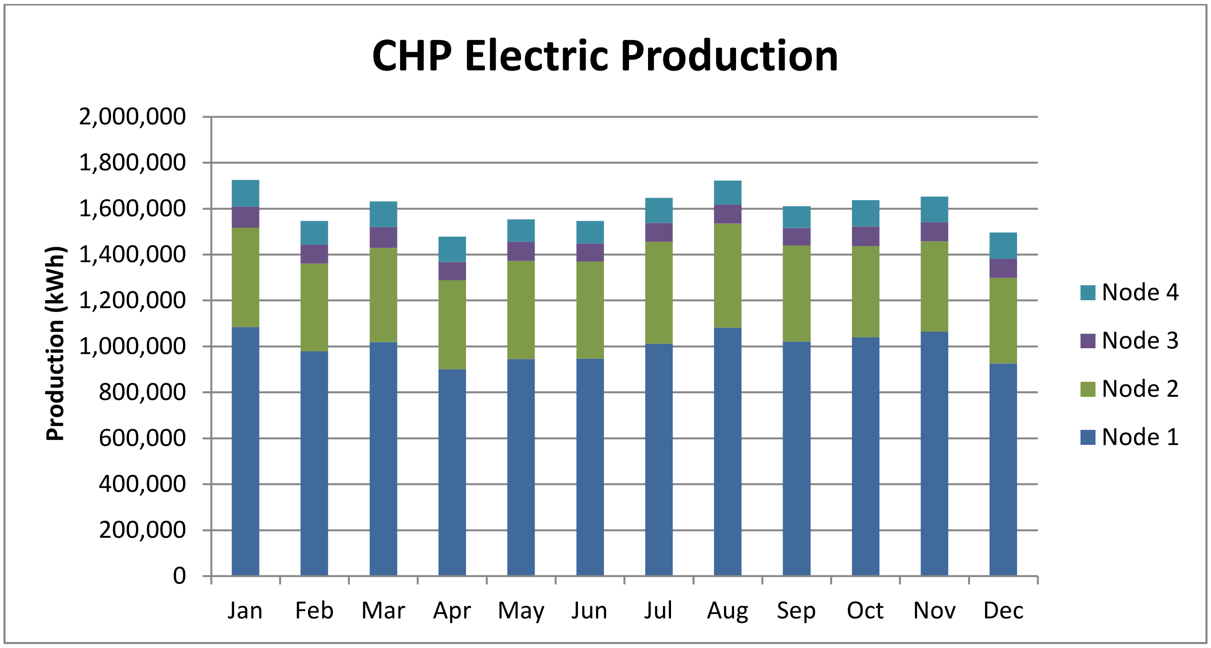


Table 9 - Microgrid CHP Heat Recovery by Node

Month	Node 1	Node 2	Node 3	Node 4	Total
	Heat Recovery (kBTU)				
Jan	2,419,874	2,155,529	23,571	543,906	5,142,880
Feb	2,200,170	1,900,800	70,369	485,148	4,656,488
Mar	2,037,917	2,028,044	133,921	521,435	4,721,317
Apr	1,829,312	1,598,679	39,122	519,872	3,986,984
May	1,753,051	1,330,796	23,163	333,948	3,440,959
Jun	1,500,923	1,313,839	10,002	242,653	3,067,417
Jul	1,584,205	1,185,303	7,004	228,567	3,005,079
Aug	1,857,833	1,119,261	8,780	230,843	3,216,718
Sep	1,737,435	1,068,762	6,961	432,646	3,245,803
Oct	1,994,908	1,552,674	49,271	536,713	4,133,566
Nov	2,298,180	1,756,029	76,358	525,573	4,656,140
Dec	2,235,633	1,831,593	260,924	534,507	4,862,658
Total	**23,449,441**	**18,841,310**	**709,448**	**5,135,812**	**48,136,010**

Figure 9 – Microgrid CHP Heat Recovery

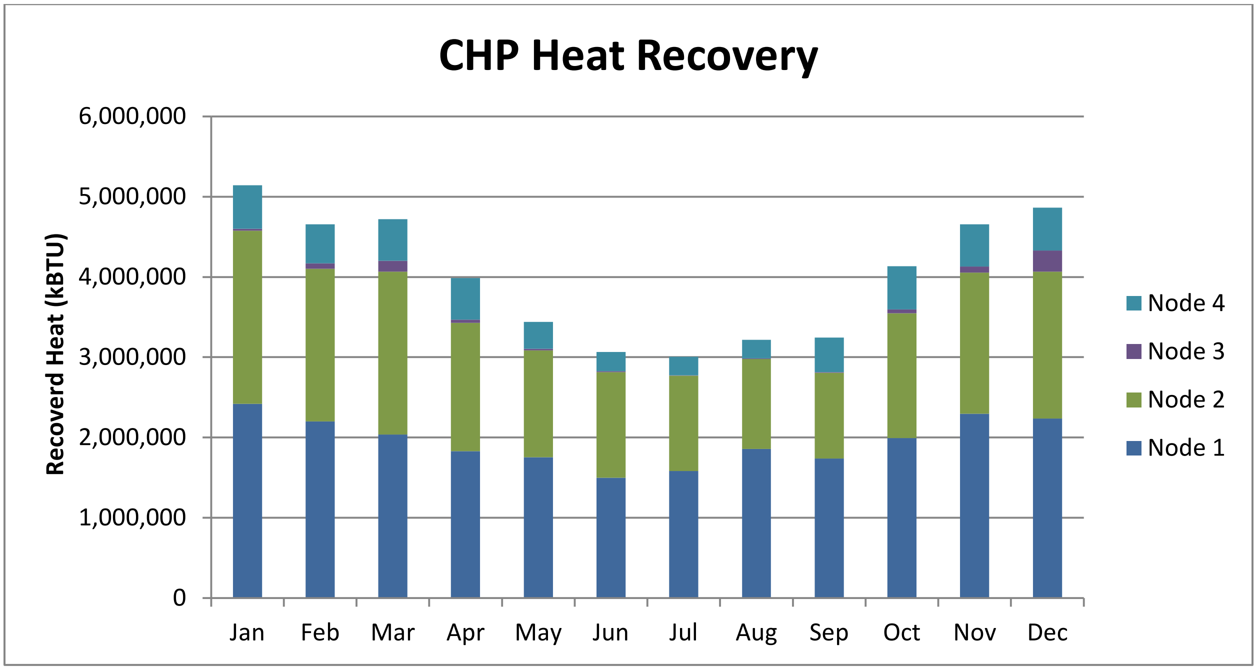
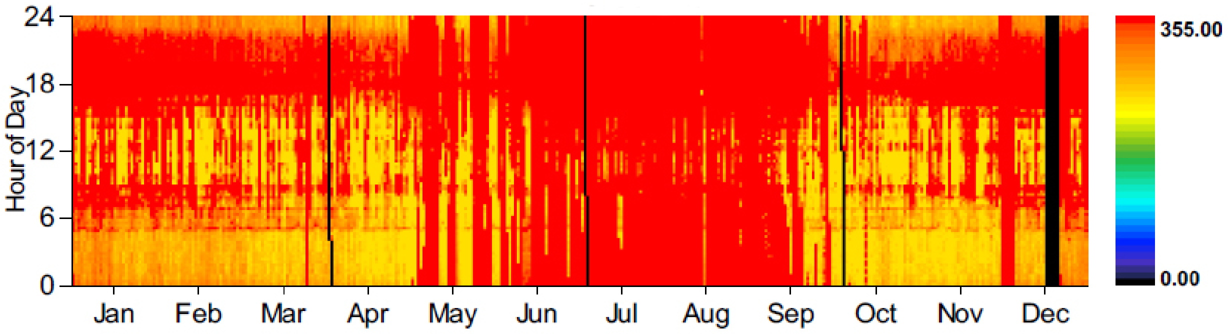


Figure 10 presents the hourly operation of the CHP in a sample node in the form of a heat map. This representation demonstrates that the CHP unit is operating near full capacity for a majority of hours (red), then does some electric load following during the other hours (orange) but is loaded at an overall high level of output during the course of the year.

Figure 10 – Sample Node CHP Operational Summary

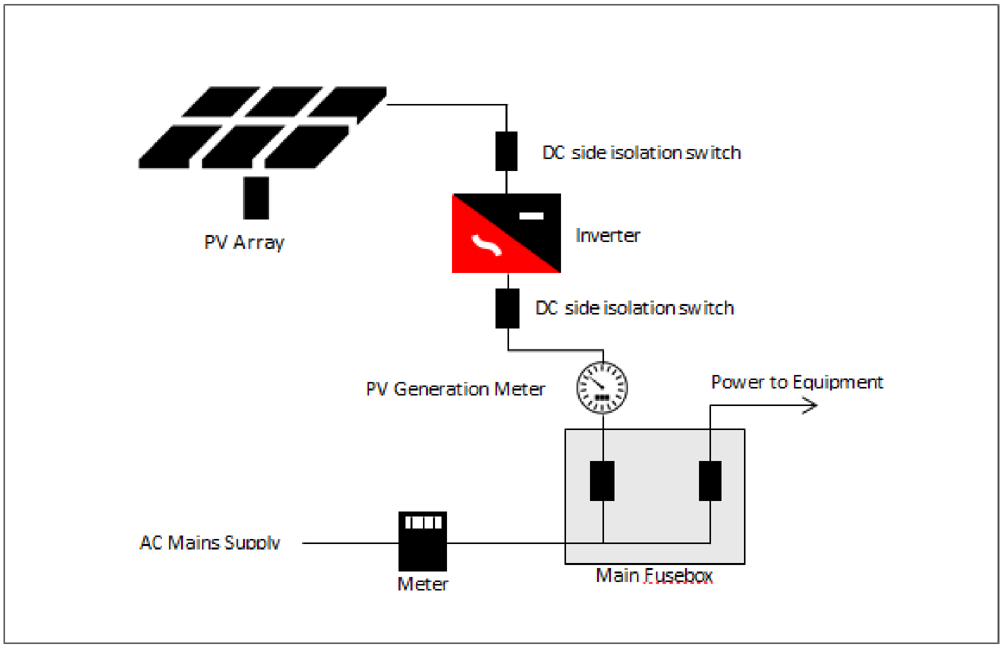
CHP Output



Solar Photovoltaics

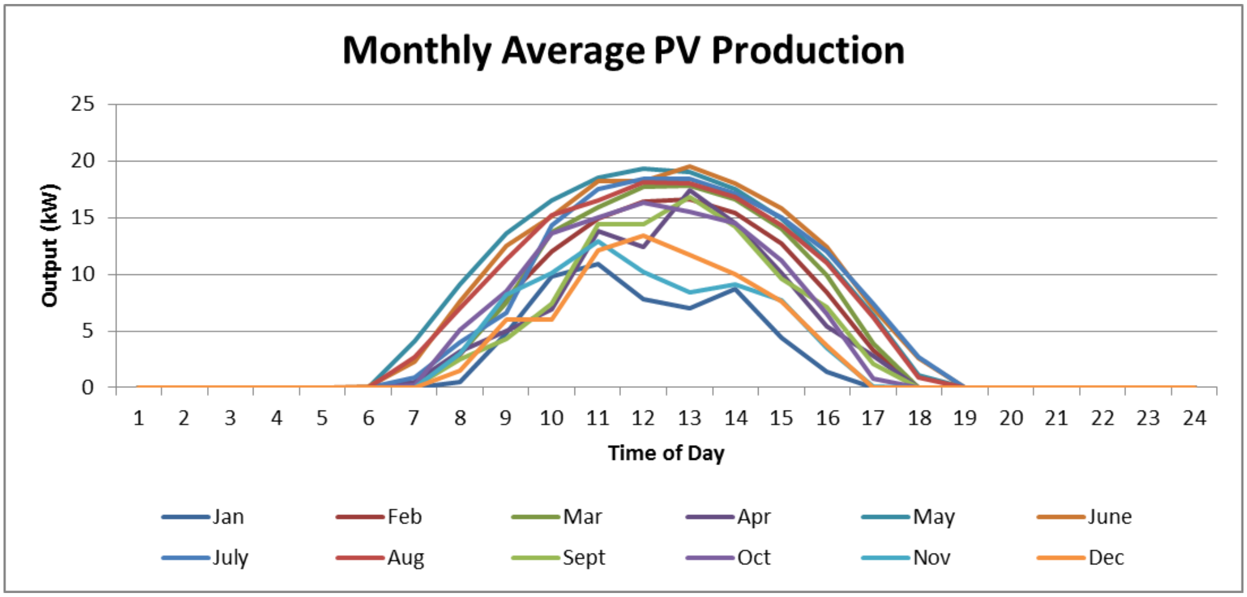
The solar PV will be rooftop, parking lot, or ground mounted using hail-rated solar panels. PV devices generate electricity directly from sunlight via an electronic process that occurs naturally in certain types of material, called semiconductors. Electrons in these materials are freed by photons and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

Figure 12 – PV Installation Diagram (Customer Side of Meter)



Since the PV systems are driven by sunlight, the electric production profile varies with the position of the sun and is impacted by the level of cloud cover. Figure 13 presents the typical average daily PV generation profiles by month and demonstrates the seasonal variation of PV as a generation resource. The HOMER model takes this variability into account when simulating and optimizing the sizing of PV as a microgrid resource.

Figure 13 – Typical PV Daily Generation Profiles



PV systems are planned for rooftops, parking spaces, and ground-mount configurations. Figure 14 presents examples of each these types of installations

Figure 14 – PV Installation Options.

Benefits of PV

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

PV Approach

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

PV in the Microgrid

The size and locations of the planned PV systems is presented in the layout diagram and single-line diagram in the Appendix. Table 10 summarizes the PV components by node of the microgrid.

Table 10 - Microgrid PV Resources by Node

Node	PV	
	# of Inverters	Total kW
1	2	250
2	3	350
3	1	175
4	1	250
Total	**7**	**1,025**

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

Table 11 – Microgrid PV Fleet Electric Production

Month	Node 1	Node 2	Node 3	Node 4	Total
Electric Production (kWh)					
Jan	21,675	29,901	15,769	21,358	88,703
Feb	24,892	34,582	17,879	24,702	102,055
Mar	32,227	45,651	23,105	32,608	133,592
Apr	30,393	44,371	21,552	31,693	128,009
May	32,190	48,343	22,649	34,531	137,714
Jun	30,783	47,322	21,551	33,802	133,458
Jul	32,184	49,965	22,446	35,689	140,285
Aug	31,259	48,285	21,844	34,490	135,878
Sep	29,562	44,796	20,749	31,997	127,104
Oct	25,356	37,359	17,925	26,685	107,325
Nov	18,726	26,864	13,411	19,189	78,190
Dec	18,382	25,729	13,200	18,378	75,689
Total	**327,877**	**483,171**	**232,080**	**345,122**	**1,388,250**

Figure 15 – Microgrid PV Fleet Electric Production

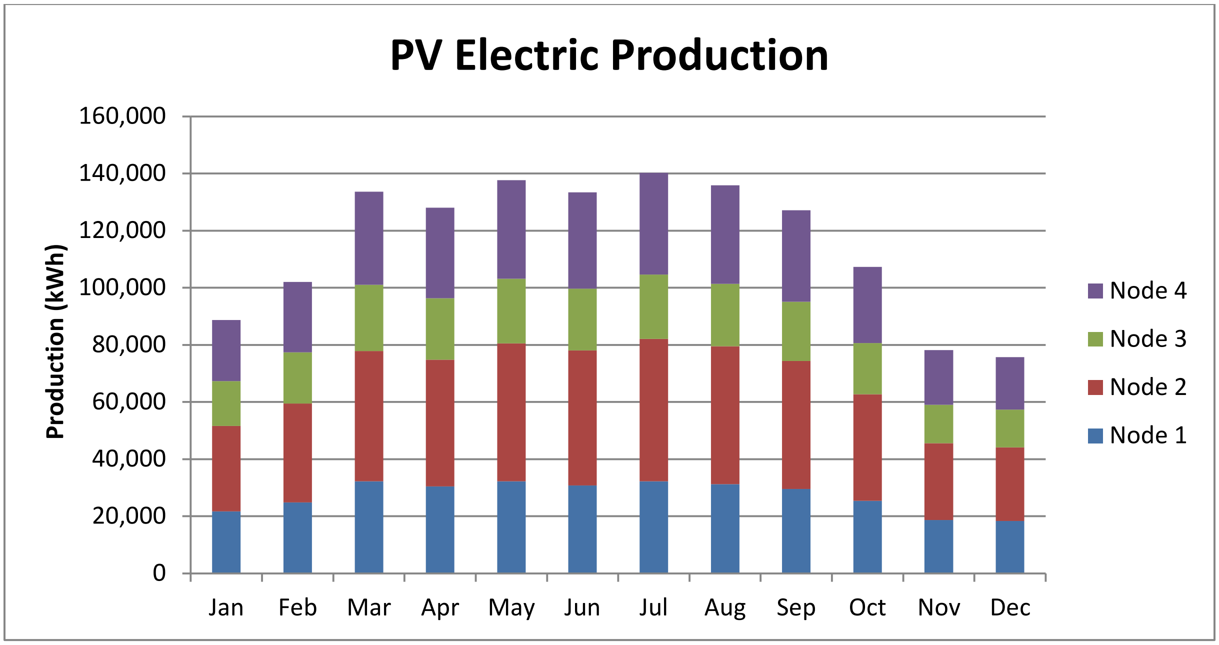
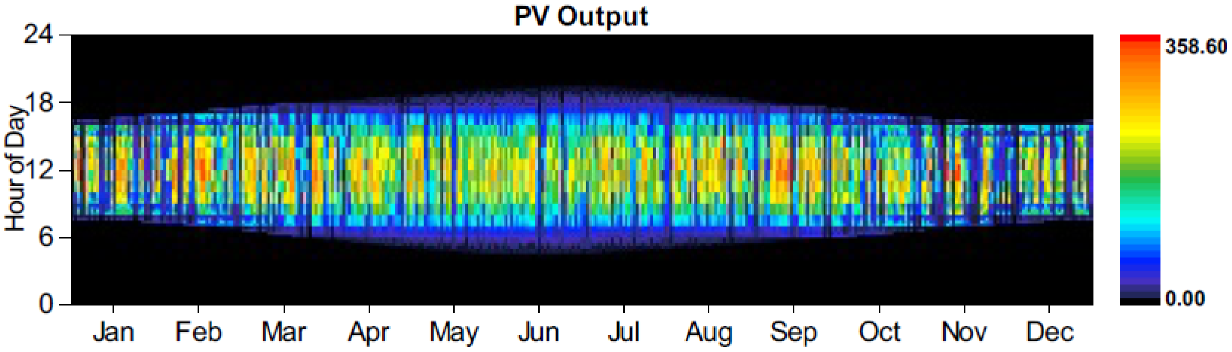


Figure 16 presents the hourly operation of the PV in a sample node in the form of a heat map. This representation demonstrates how the PV units operate during hours of sunshine with maximum production in the middle of the day, ramping up in the mornings and ramping down in the afternoon hours. This also illustrates the trend of narrower daily bands of production in the winter and then expansion to maximum production in the summer.

Figure 16 – Sample Node PV Operational Summary



Energy Storage Systems

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

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

Benefits of Energy Storage

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

Figure 17 presents examples of energy storage installations for the technologies addressed for this microgrid design.

Figure 17 – Example ESS Installations

25 kW / 75 kWh pad mount system

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

Multiple 5 kW / 12 kWh systems

Energy Storage Approach

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

ESS in the Microgrid

The size and location of the planned ESS systems is presented in the layout diagram and single-line diagram presented in the Appendix. Table 12 summarizes the ESS components by node of the microgrid.

Table 12 - Microgrid ESS Resources by Node

Node	Battery Energy Storage		
	Qty	kW	kWh
1	2	60	120
2	3	30	60
3	1	15	30
4	1	25	50
Total	**7**	**130**	**260**

Unlike the other microgrid resources, the ESS both consumes and produces energy. When properly used, the net energy consumed is very small. The annual operation of the ESS in a sample node is presented in Table 13, which shows both the charge and discharge modes of operation. The net value is positive which takes into account the operational losses for the systems.

Table 13 – Microgrid ESS Operation Sample Node

Month	Charge	Discharge	Net
	(kWh)		
Jan	260	44	216
Feb	1	1	0
Mar	326	300	26
Apr	285	262	23
May	1,859	1,710	149
Jun	2,707	2,491	217
Jul	4,418	4,064	353
Aug	6,289	5,786	503
Sep	4074	3,748	326
Oct	552	508	44
Nov	39	196	-157
Dec	775	552	222
Total	**21,585**	**19,663**	**1,922**

Figure 18 – Microgrid ESS Operation

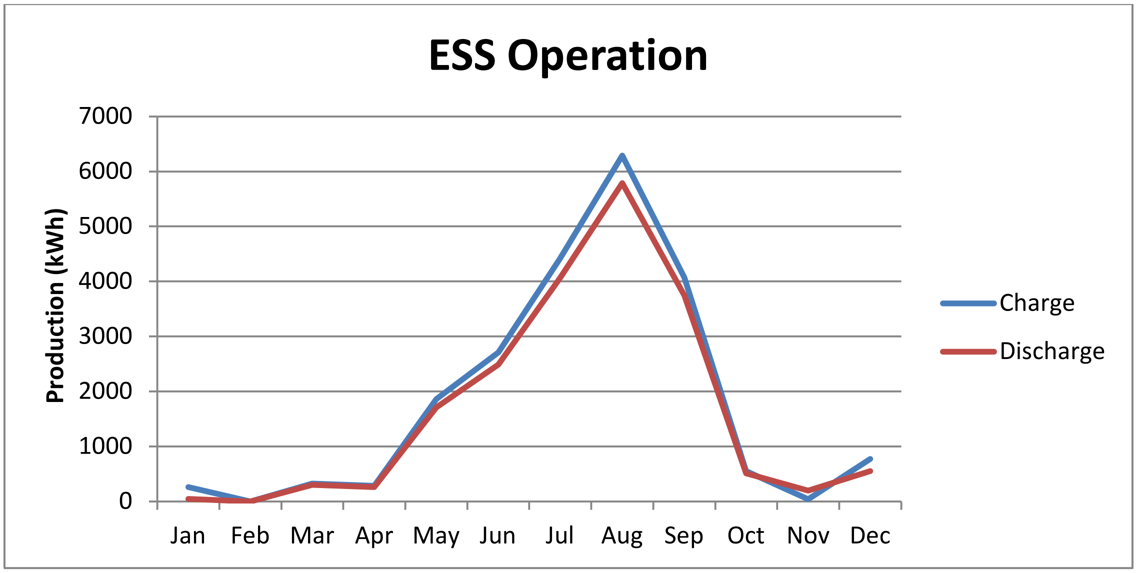
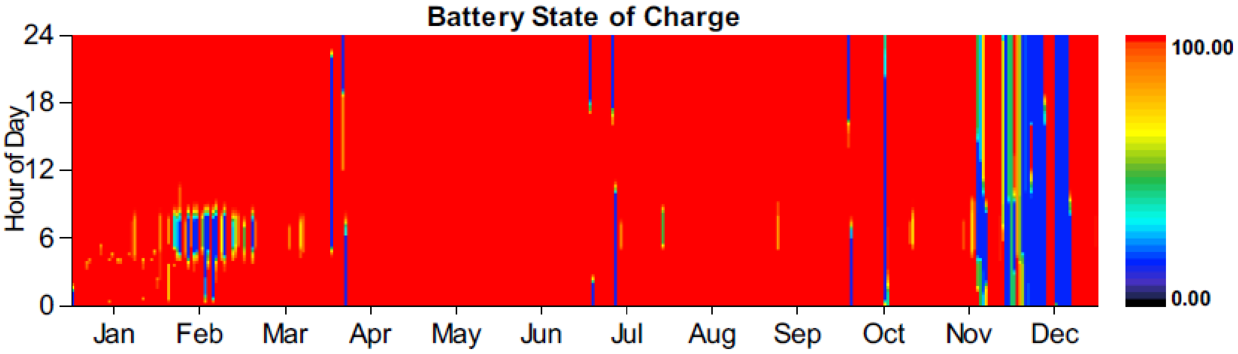


Figure 19 presents the hourly operation of the ESS in a sample node in the form of a heat map. This representation demonstrates how the ESS units operate. Typically, the units are charged to a high SOC in the middle of the day. The operations represent PV intermittency support, PV load shifting, peak shaving (to manage utility imports), and supporting CHP loading.

Figure 19 – Sample Node ESS Operational Summary



Island Mode Modeling Results

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

The design strategy for the Albany Community Microgrid is to supply the critical load at a level that enables the critical services that keep the community functioning at a sufficient level throughout the entire event duration. This provides full functionality for police, fire, and emergency services while also providing some level of heat and power to other facilities and residents. Each node was modeled for operation during an extended outage (one week) to evaluate and optimize microgrid resources operating in island mode. Two outage events were modeled to represent an outage during the winter and an outage during the summer. Energy flows during the outages are presented as weekly averages in Table 14.

Table 14 –Microgrid Energy Overview: Island Mode Operation

Node	Season	Electric Demand		Electric Consumption	Thermal Load	Thermal Recovery
		Max (kW)	Avg (kW)	kWh/week	kBTU/week	kBTU/week
1	Winter	2,255	437	73,371	291,578	155,669
	Summer	1,751	388	65,200	106,850	101,982
2	Winter	857	184	30,983	515,429	132,706
	Summer	985	207	34,804	80,369	77,478
3	Winter	406	199	33,515	6,188	6,188
	Summer	367	170	28,590	1,770	1,770
4	Winter	332	68	11,498	133,750	29,732
	Summer	378	61	10,211	14,632	14,632
Total	**Winter**	**3,850**	**889**	**149,367**	**946,945**	**324,295**
	Summer	**3,481**	**826**	**138,806**	**203,621**	**195,862**

FINANCIAL FEASIBILITY

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

Installed Cost

At this feasibility stage of the project, a high-level project budget for the Albany Community Microgrid project was developed and incorporated into the technical model to ensure that the design meets both the technical and economic requirements of the project. This budget includes costs for engineering, permitting, capital equipment, site preparation, construction, controls, start-up, commissioning, and training. The cost associated with "site preparation" includes the addition and modification of electrical infrastructure, PCC controls, monitoring, and protection equipment. Some of these infrastructure costs may be paid to the electric utility. The estimated installed cost for this project is $8,016,000, with an accuracy of +/- 25% (within the +/- 30% set by NYSERDA). The net cost with the federal investment tax credit (ITC) that was recently extended by the US Congress is $6,597,000. This cost does not include incentives that may be applicable to the project.

The project team evaluated several available financial incentives when performing the financial analysis for the Albany Community Microgrid. The following programs[1] were evaluated and will be explored in more detail during the detailed design stage:

- **Demand Response**: National Grid's demand response programs pay customers who are able to temporarily reduce electric usage when requested. This capability will be improved by the existence of the microgrid.
- **Sales Tax Exemption**: Solar photovoltaic systems are 100% free from state and local taxes.
- **Business Energy Investment Tax Credit (ITC):** The ITC includes a 30% tax credit for solar or fuel cell systems on residential and commercial properties and 10% tax credit for CHP systems. In December, the ITC was extended for three years, with a ramp-down through 2022.
- **NYSERDA PON 2568 CHP Acceleration Program**: This program provides financial incentives for the installation of CHP systems at customer sites that pay the SBC surcharge on their electric bill, and will be fueled by natural gas that is subject to the SBC surcharge on the gas bill.
- **NYSERDA PON 2701 Combined Heat and Power Performance Program:** This program offers incentives to promote the installation of clean, efficient, and commercially available Combined Heat and Power systems with an aggregate nameplate greater than 1.3 megawatts (MW) that provide summer on-peak demand reduction.
- **NY SUN initiative:** This program provides rebates and performance incentives for new residential and commercial solar PV installations. The program provides up to $0.34 per watt for new installed PV that displaces existing usage. An additional incentive of $50,000 applies if the project includes energy storage. An additional incentive of $50,000 applies if the project includes integrated energy efficiency. The program will provide up to 50% of the total installed system cost.
- **New York Power Authority – Energy Services Program for Public Utilities**: This program provides various rebates on energy efficient equipment.
- **NYSERDA Sub Metering Program**: This program will provide $250 incentive for each advanced sub meter and $1,500 for each master meter.
- **Federal Energy-Efficient Commercial Buildings Tax Deduction**: This deduction provides $0.30-$1.80 per square foot, depending on technology and amount of energy reduction for buildings that become certified as meeting specific energy reduction targets as a result of improvements in interior lighting; building envelope; or heating, cooling, ventilation, or hot water systems.

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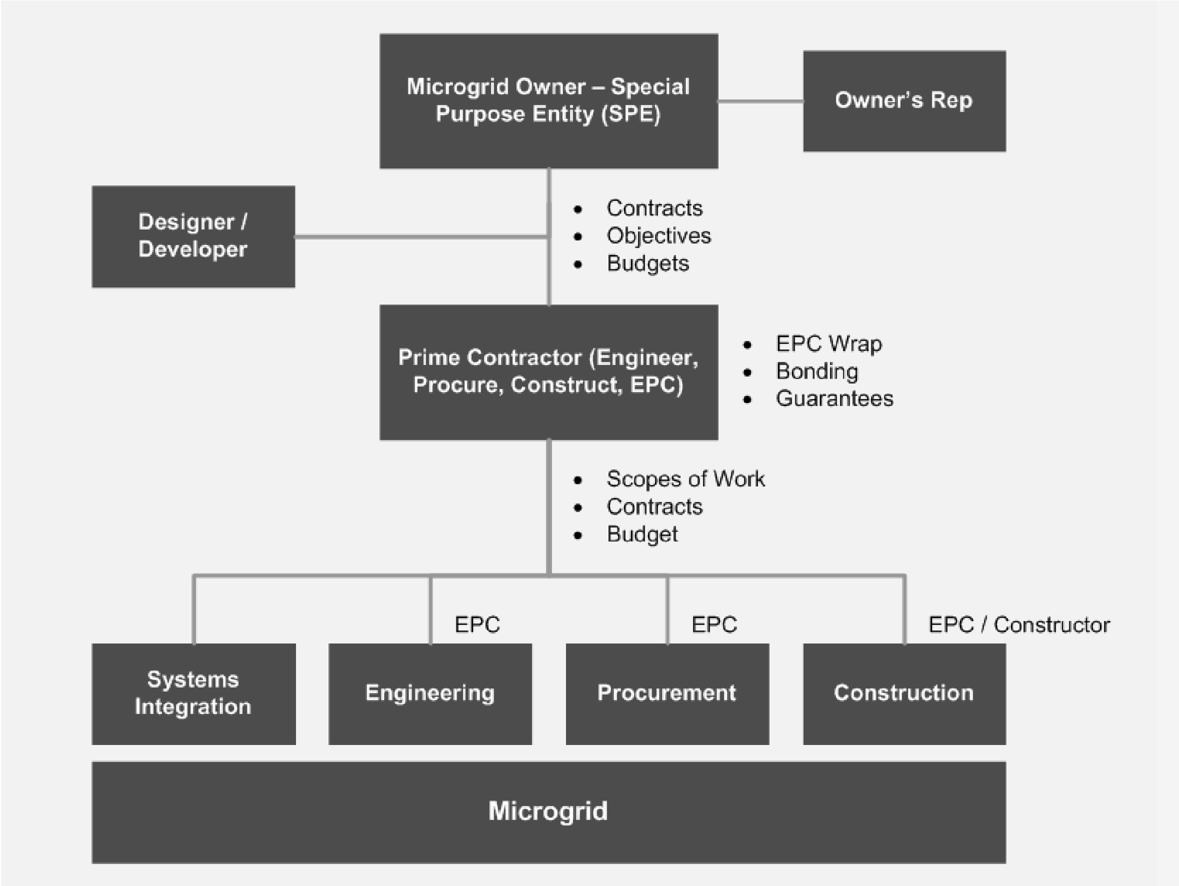
[1] Identified from the DSIRE database as of December 2015. http://programs.dsireusa.org/system/program?state=NY

Third Party Ownership

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

The SPE will engage the design team to finalize the construction drawings and utility interconnection agreements. The SPE will engage an engineering, procurement, and construction firm to build the microgrid, and will be financially responsible for all engineering, procurement, and construction for the system. The SPE will also be financially responsible for integrating the controls and communications systems. This process is presented in the Figure 20.

Figure 20: Microgrid Development Relationships



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

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

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

The current weighted electric rate of the key critical facilities included in the proposed microgrid is approximately $0.092/kWh. Based on the estimated energy savings, assumed project financing costs, and the 25 year contract term, the study supports a PPA electric rate with an electric cost that represents an average discount of approximately 5-8% for the facilities in this project.

Benefit Cost Analysis

The project team provided detailed information to IEc to support this analysis. IEc ran two scenarios for this proposed microgrid. The first scenario modeled no power outages, and evaluated the grid connected mode of operation. The second scenario modeled the number of days (or partial days) outage at which the costs of the microgrid would be equal to its various benefits, thus yielding a cost benefit ratio of 1. For the Albany Community Microgrid, the breakeven outage case is an average of 4.8 days of outage per year. The cost benefit results are presented in Table 15. The analyses indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 4.8 days per year (Scenario 2).

Table 15– Cost Benefit Analysis Results

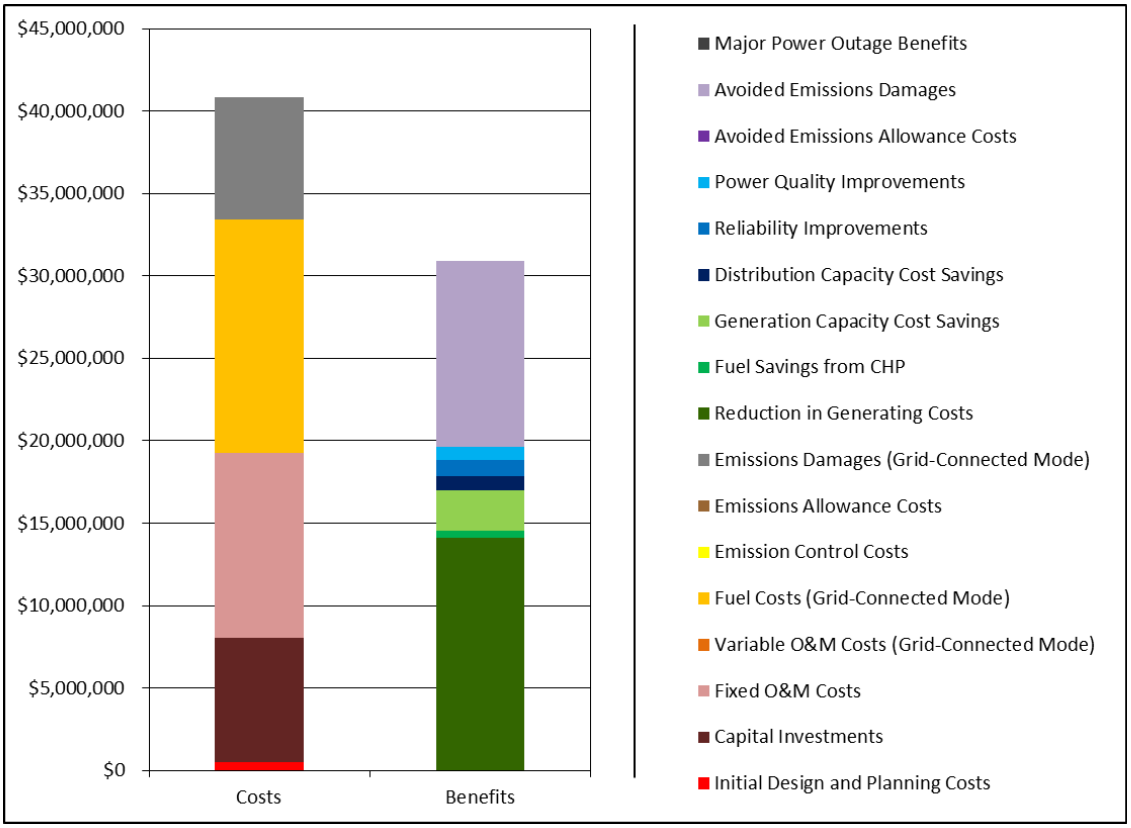
Economic Measure	Assumed average duration of major power outages	
	Scenario 1: 0 DAYS/YEAR	Scenario 2: 4.8 DAYS/YEAR
Net Benefits - Present Value	-$9,950,000	$110,000
Total Costs – Present Value	$40,800,000	$40,800,000
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	-17.9%	5.6%

The cost benefit analysis results for scenario 1 are presented in Table 16.

Table 16 – Cost Benefit Analysis Scenario 1
(No Major Power Outages; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$7,570,000	$752,000
Fixed O&M	$11,200,000	$990,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$14,200,000	$1,250,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$7,410,000	$483,000
Total Costs	**$40,800,000**	
Benefits		
Reduction in Generating Costs	$14,100,000	$1,240,000
Fuel Savings from CHP	$480,000	$42,300
Generation Capacity Cost Savings	$2,430,000	$215,000
Distribution Capacity Cost Savings	$840,000	$74,100
Reliability Improvements	$1,000,000	$88,500
Power Quality Improvements	$784,000	$69,200
Avoided Emissions Allowance Costs	$7,310	$645
Avoided Emissions Damages	$11,300,000	$735,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$30,900,000**	
Net Benefits	**-$9,950,000**	
Benefit/Cost Ratio	**0.8**	
Internal Rate of Return	**-17.9%**	

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

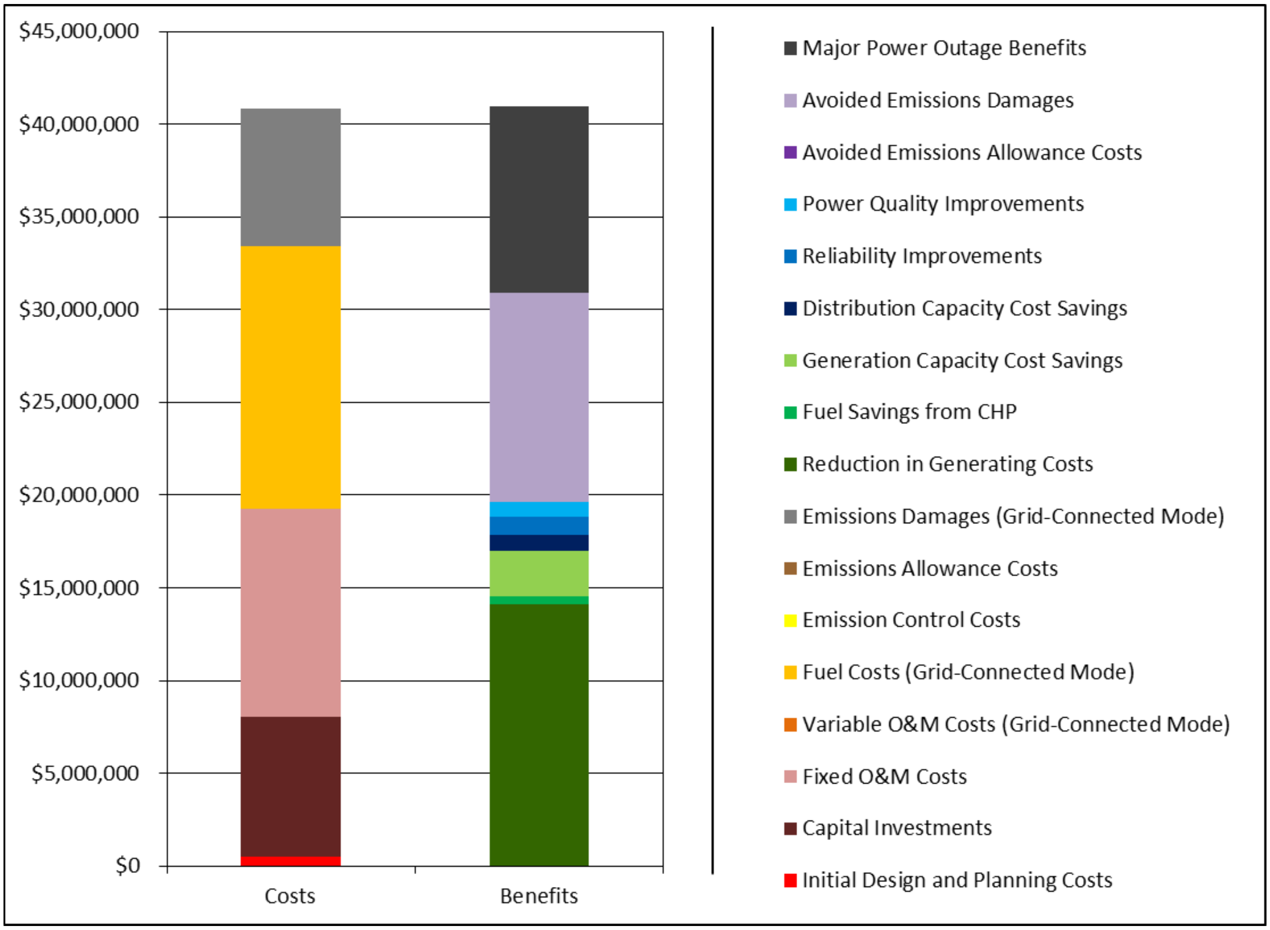


The major drivers of costs are the O&M costs and fuel, where the major benefits are reduction in generation costs and avoided emissions damages.

Table 17 – Cost Benefit Analysis Scenario 2
(Major Power Outages Averaging 4.8 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$7,570,000	$752,000
Fixed O&M	$11,200,000	$990,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$14,200,000	$1,250,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$7,410,000	$483,000
Total Costs	**$40,800,000**	
Benefits		
Reduction in Generating Costs	$14,100,000	$1,240,000
Fuel Savings from CHP	$480,000	$42,300
Generation Capacity Cost Savings	$2,430,000	$215,000
Distribution Capacity Cost Savings	$840,000	$74,100
Reliability Improvements	$1,000,000	$88,500
Power Quality Improvements	$784,000	$69,200
Avoided Emissions Allowance Costs	$7,310	$645
Avoided Emissions Damages	$11,300,000	$735,000
Major Power Outage Benefits	$10,100,000	$890,000
Total Benefits	**$41,000,000**	
Net Benefits	**$110,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**5.6%**	

Figure 22 – Cost Benefit Analysis Scenario 2
(Major Power Outages Averaging 4.8 Days/Year; 7 Percent Discount Rate)



The benefits from the 4.8 days outages result in $10,100,000 during the life of the microgrid. The entirety of the IEC analysis can be found in Appendix D of this report.

Model Comparisons

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

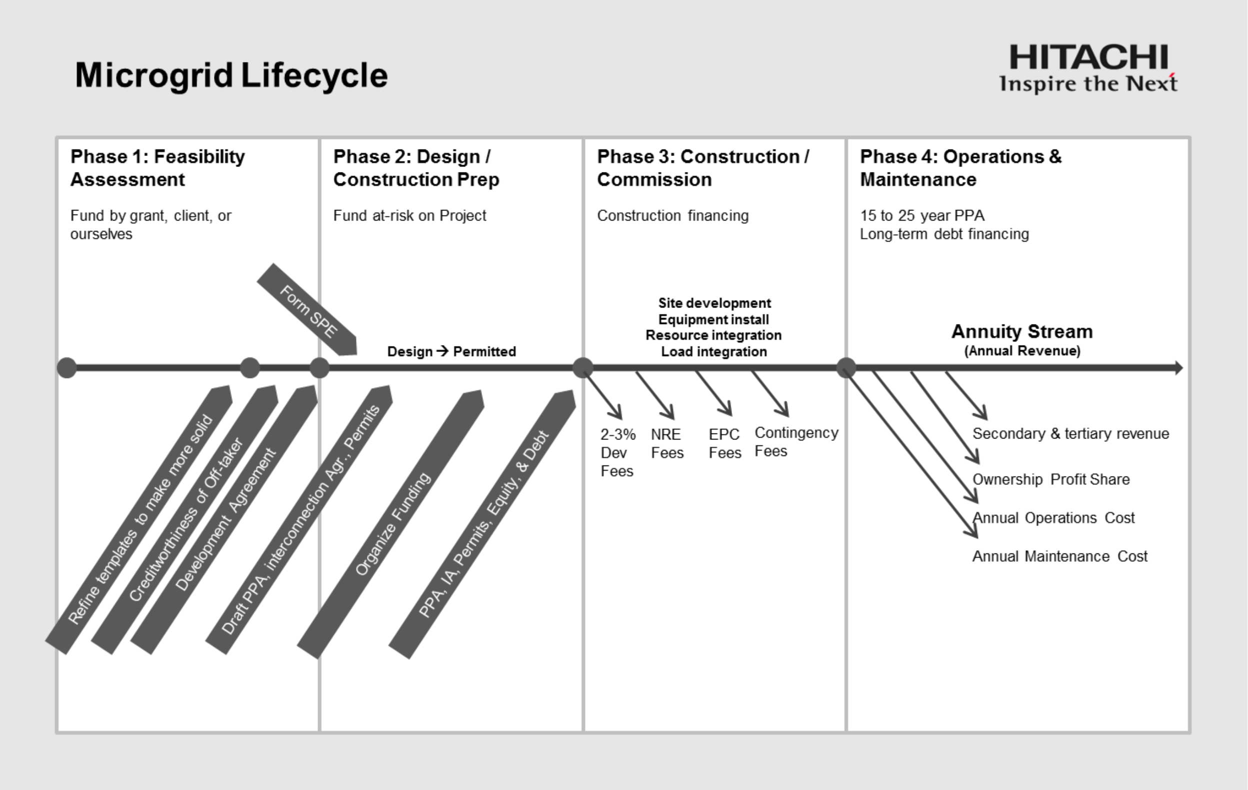
- Gas rates used in IEC's benefit-cost analysis were based on a state-wide average for commercial end-use customers. The rates used in Albany's financial feasibility analysis are based on National Grid's distributed generation rate. This resulted in year 1 gas rates of $6.34 and $4.25, for the benefit-cost analysis and the financial feasibility analysis, respectively. If National Grid's distributed generation rate were applied to the benefit-cost analysis, net benefits would be increased by $4.27M.

- The financial feasibility assessment incorporates the tax benefits of the Federal Investment Tax Credit, whereas the benefit-cost analysis does not. This benefit reduces the capital cost of the project by $1.42M.
- Capital replacement costs used in the BCA were calculated as a full replacement costs, whereas the project team assumed a ‘rebuild’ cost that is not equal to the full cost of replacement. The rebuild cost for the Albany Community Microgrid is $91,000 less than the full cost of replacement.
- The benefit-cost analysis derives a price for electricity based on average wholesale energy costs, whereas the financial feasibility assessment evaluates the savings to the community based on actual costs paid by community participants.
- The period of analysis in the benefit cost analysis is 20 years and the third party ownership model is based on a period of analysis of 25 years.

Development, Construction, and Operating Approach

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

Figure 23: Hitachi Microgrid Lifecycle



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

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

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

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

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

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

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

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

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

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

Operation of the microgrid will include several key components:

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

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

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

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

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

PROJECT TEAM

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

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

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

Project Leader: A team of L&S Energy and the Hitachi Microgrid Solutions Business is a candidate to lead system design in Stage 2. These firms have extensive experience in microgrid design and operation. Hitachi also has access to the capital, at a competitive rate, needed to finance the system and set up an SPE to operate the equipment and manage PPAs. The team has designed over 50 microgrids and overseen the construction of several microgrids. The Hitachi Microgrid Solutions Business will also leverage its close partnership with other Hitachi Companies to support faster microgrid development and deployment. These include:

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

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

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

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

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

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

EPC Contractor: The EPC will be responsible for detailed engineering drawings of the system, purchasing the equipment specified in the design, and overseeing construction and commissioning of the microgrid system itself. Both L&S Energy Services and Hitachi Microgrid Solutions Business have long-term and strong relationships with many EPCs in New York and have had discussions with several regarding Albany's microgrid project. A final evaluation and selection will be made during the proposal process for Stage 2.

CHP Design Firm: To ensure optimal design and placement of the generation and heat sources in the microgrid, L&S Energy Services will manage the design and leverage other engineering design firms that specialize in CHP engineering designs. The team is currently in discussions with multiple CHP design and installation firms to determine which one would be an ideal partner to execute the CHP portion of microgrid projects in the State of New York. The team will develop a competitive RFP process to identify and select the CHP firm with the most attractive combination of experience, skillsets, and price.

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

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

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

LEGAL VIABILITY

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

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

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

Market Barriers

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

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

Stage 2 NY Prize Funding: Stage 1 funding was not sufficient to cover the costs of a comprehensive feasibility study. This was anticipated, and many organizations involved in the delivery engaged in cost sharing and were prepared to make significant investments to deliver a high quality and reliable study for the Albany feasibility study. However, given the levels of investment required of vendors in Stage 1, there will be little appetite or ability to incur additional cost share or risk in Stage 2. This is exacerbated by the inherent risks and known and unknown costs associated with the next phase of development, many of which are specific to community microgrids. Stage 2 funding is critical to moving forward to the next stage of project development.

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

Utility Cooperation: The negotiation of interconnection agreements with local utilities can cause significant delays and lead to new costs when the proposed microgrid concepts are unfamiliar to the utility's staff and engineering contractors. To date, National Grid has demonstrated general understanding of the approach and has not identified any deal killers so far. They will provide more detailed input to the design and interface requirements in the detailed engineering stage following this study. Through continued collaboration and sharing of design details, Albany can expect this risk to be fairly small in the next phase.

Regulatory Issues

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

The system will not be considered an electric distribution company by the public services commission because it utilizes qualifying forms of generation,[4] is under 80 MW,[5] serves a qualifying number of users, and its related facilities (including any private distribution infrastructure) are located "at or near" its generating facilities. This saves the system from a raft of burdensome regulatory requirements.

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

Privacy

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

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[4] Qualifying generation facilities are defined in PSL § 2 as those falling under the definitions of "Co-generation facilities," "Small hydro facilities," or "Alternate energy production facilities." A qualifying co-generation [4]

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

[5] Id.

CONCLUSIONS AND NEXT STEPS

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

1. ***Critical Key Facilities*****:** The Community Microgrid is built around a set of facilities and institutions that are well established, and committed to the project, all of which are public facilities managed by the county government .
2. ***Efficiently Organized Nodes***: Dividing the microgrid into a number of nodes does not always drive up the total installed cost of the systems. Optimized properly, organizing into nodes resulted in net favorable outcomes where the reduced cost of installing new underground infrastructure offsets the increased cost of additional controls and points of common coupling.
3. ***Natural Gas Costs***: Natural gas is one of the largest cost drivers of this system. Increasing costs for natural gas will have a negative impact on the PPA rates for each of the facilities, but overall electricity cost savings should increase year over year for microgrid customers compared to the cost of electricity from the grid.
4. ***Community Microgrid Financing Costs***: The cost of project financing is high for community microgrids. This is due to the fact that there are numerous stakeholders and potential customers that have their own procurement requirements. The project team will need to seek out a financier that is knowledgeable about these projects, and can help keep transaction costs to a minimum. Since all the facilities are under the control of the County, it is assumed that the procurement requirements are the same for all the facilities proposed to be in the microgrid.
5. ***Financial Prospects:*** The feasibility analysis indicates that the Albany Community Microgrid project meets the financial requirements for third party financing and ownership.

Regulatory and Policy Recommendations

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

1. ***Franchises and Rights-of-Way***: Community microgrids almost always include critical facilities that are not co-located on the same parcel of land. To interconnect these facilities requires the crossing of one or more public right of ways. The installation of electrical distribution lines (above or below ground) or thermal distribution infrastructure across a public right of way will usually infringe on an existing franchise, or require a new one to be

issued. In New York State, each municipality (town, village, city, etc.) has the statutory authority to grant franchise rights or similar permissions. In many cases, these franchise rights have already been granted to the distribution utility, and the installation of microgrid infrastructure by a third party may represent an infringement of that franchise.

At the state level, a program to standardize and expedite the issuance of franchise rights to microgrid developers would significantly reduce associated development costs for community microgrids. For instance, the State Supreme Court in Connecticut ruled that installing a distribution wire from one parcel to another and selling power across that line cannot encroach on a utility franchise (and won't trigger PUC jurisdiction).[6]

2. ***Utility Ownership***: The rules governing utility ownership of microgrids in New York State, and specifically DER within the microgrid, are not clearly defined. After ruling in 1996 that distribution utilities must end all investments in generation assets, the Public Service Commission (PSC) carved out a general criterion for exceptions in a 1998 ruling known as the Vertical Market Power Policy. This policy stated that distribution utilities could own DER if they could demonstrate "substantial ratepayer benefits, together with [market power] mitigation measures."[7] In February, 2015, the PSC published the "Order Adopting Regulatory Policy Framework and Implementation Plan"[8] which described several circumstances when utility ownership of DER would be allowed. One of these circumstances is for a project that is "sponsored for demonstration purposes." This may be applicable to some NY Prize projects, but it is unclear what the criteria would be for an acceptable demonstration project. Also, this does not help drive the broader market for microgrids as this limits the number of systems that will be implemented in the near term.

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

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

4. ***Stage 2 and Stage 3 Funding Structure:*** Stage 2 funding should focus on advancing the project towards the construction phase, and less on reporting deliverables. Stage 3 funding

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

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

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

sends a poor market signal, indicating that microgrids need subsidies in order to be cost effective, which is often not the case.

5. ***Municipal Lowest Rate Requirement:*** Regulations that require that municipal customers pay the lowest available rate for electricity and gas may prevent investment in microgrid infrastructure and resilience benefits through a PPA in certain cases. Projects that provide other societal benefits (support critical loads, serve the community at times of natural disaster, reduce emissions, etc.) should be eligible for consideration as projects that municipalities may execute.
6. ***Competitive Procurement Requirements*****:** Given cost share requirements in Stage 2, development firms are going to hesitate to invest unless they are assured work in Stage 3. This could potentially be mitigated by state-issued guidance for special exemptions for the NY Prize program, or by encouraging a single procurement process for Stage 2 and 3.

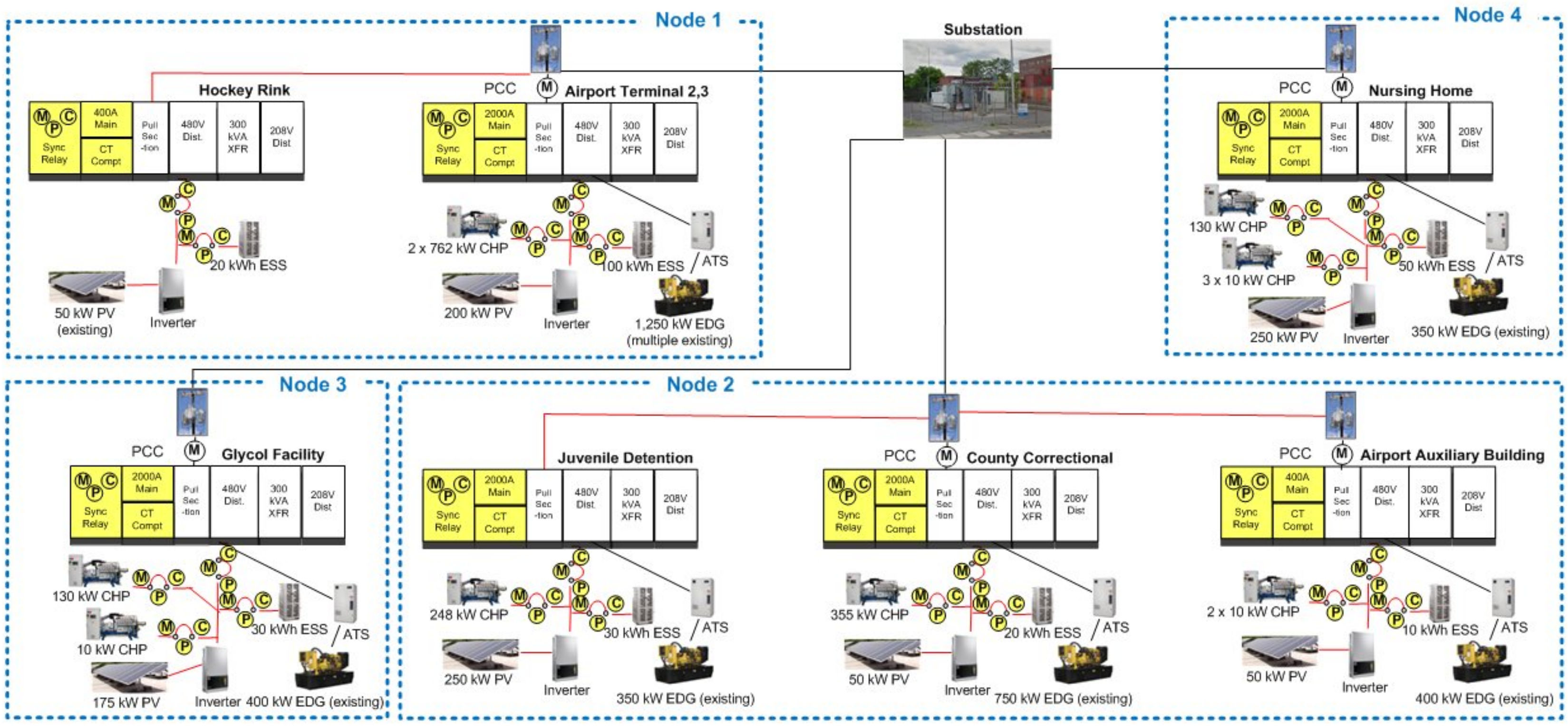
The next steps that the Albany Community will need to undertake are to finalize the ownership structure to be proposed, and identify a team of partners to engage in the detailed design phase of the project. Once these decisions are made, the project team will draft a proposal to NYSERDA to compete in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

[End of Report]

APPENDIX A: ALBANY MICROGRID LAYOUT DIAGRAM

SHEET TITLE Microgrid Geospatial Diagram	PROJECT Community Microgrid – Albany

APPENDIX B: ALBANY MICROGRID ONE-LINE DIAGRAM



Legend

NCL = Non-Critical Loads
ESS = Energy Storage System
CHP = Combined Heat & Power
EDG = Emergency Diesel Generator
EGG = Emergency Gas Generator
PV = Solar Photovoltaic Array
PCC = Point of Common Coupling
ATS = Automatic Transfer Switch

Existing Cable
New Underground Cable
M P C   M C P   New Control, Monitoring, & Protection as required

SHEET TITLE
Microgrid One-Line Diagram

PROJECT
Community Microgrid – Albany

APPENDIX C: ACRONYM GLOSSARY

- ATS- automatic transfer switch
- BCA – Benefit cost analysis
- BTU – British Thermal Unit
- CCA- community choice aggregation
- CHP- combined heat and power plants
- DER- Distributed Energy Resources
- DHW- domestic hot water
- DMS- distribution management system
- EDG- emergency diesel generator
- EEM- energy efficiency measures
- EGG- emergency gas generator
- EPC- Engineering Procurement Contractor
- EPRI- Electric Power Research Institute
- ESS- energy storage systems
- GHG- greenhouse gases
- Hr - hour
- IEEE- Institute of Electrical and Electronics Engineers
- ISO- independent system operators
- IT – information technology
- ITC- Investment Tax Credit
- kBTU – 1,000 BTU
- kV - kilovolt
- kW – kilowatt
- kWh – kilowatt-hour
- LAN- local area network
- Li-ion- lithium ion
- MW - megawatt
- NOC - Network Operations Center
- NREL- National Renewable Energy Laboratory
- NYSERDA- New York State Energy Research and Development Authority
- O&M- operations and maintenance
- ORNL- Oak Ridge National Laboratory

- PCC - point of common coupling
- PLC- programmable logic controller
- PPA- power purchase agreement
- PV- solar photovoltaics
- REV- Reforming the Energy Vision
- RFI- request for information
- RFP- request for proposals
- RTO- Regional Transmission Organizations
- SCADA – supervisory control and data acquisition
- SGIP- Smart Grid Interoperability Panel
- SOC- state of charge
- SPE- special purpose entity

APPENDIX D: BENEFIT-COST ANALYSIS

Site 49 – County of Albany

PROJECT OVERVIEW

As part of NYSERDA's New York Prize community microgrid competition, Albany County has proposed development of a microgrid that would serve the following facilities:

- Albany International Airport (Airport tower and Terminals 2 and 3);
- Glycol Farm facility;
- A hockey rink;
- Albany County Nursing Home;
- Albany County Correctional Facility; and
- Capital District Youth Detention Center.

The microgrid would include several new distributed energy resources (DERs): combined heat and power (CHP) units with a total capacity of approximately 2.4 MW; and solar photovoltaic (PV) panels with a combined capacity of 1.0 MW. The microgrid would also incorporate several existing DERs, including diesel powered emergency generators with a combined capacity of 3.5 MW and a solar PV array with a capacity of 0.05 MW.

To assist with completion of the project's NY Prize Stage 1 feasibility study, IEc conducted a screening-level analysis of its 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.[9] 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.[10]

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

[10] The New York State Department of Public Service (DPS) requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions. The reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and

RESULTS

Table 1 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 4.8 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

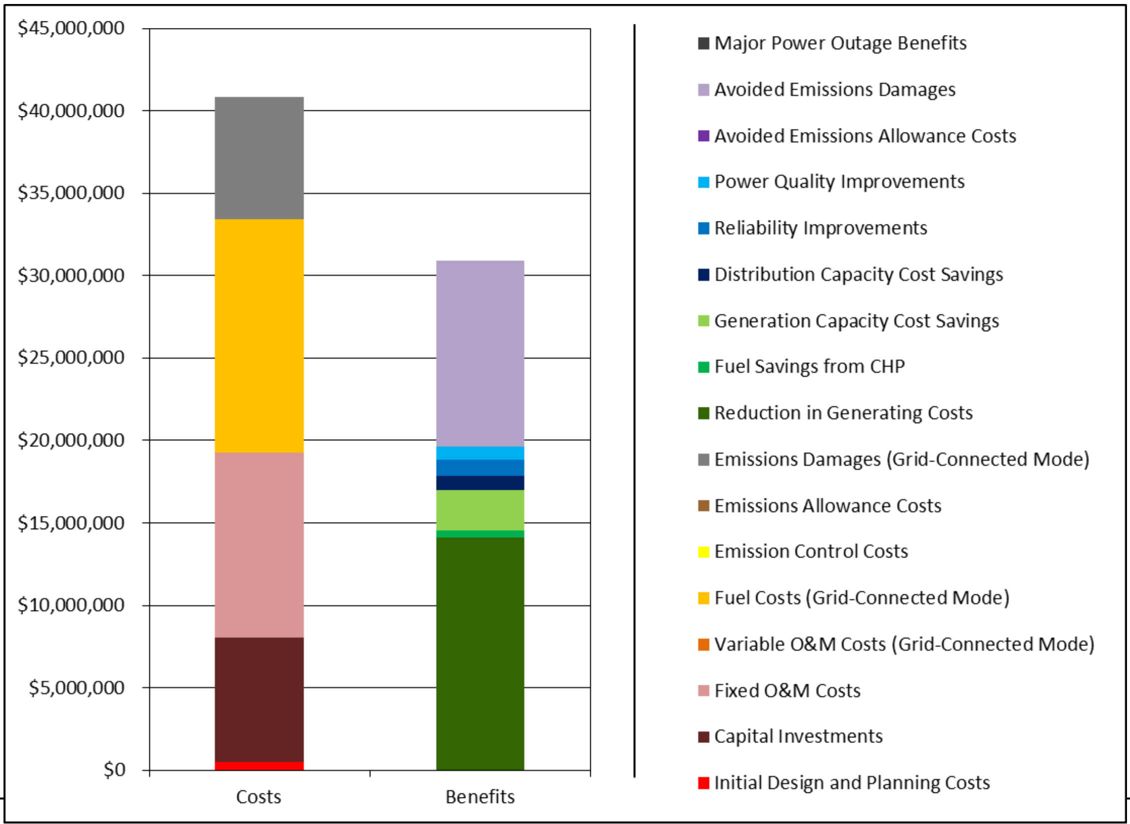
Table 1. BCA Results (Assuming 7 Percent Discount Rate)

ECONOMIC MEASURE	EXPECTED DURATION OF MAJOR POWER OUTAGES	
	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 4.8 DAYS/YEAR
Net Benefits - Present Value	-$9,950,000	$110,000
Benefit-Cost Ratio	0.8	1.0
Internal Rate of Return	-17.9%	5.6%

Scenario 1

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

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



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excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. In estimating the reliability benefits of a microgrid, the BCA employs metrics that exclude outages caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

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

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$7,570,000	$752,000
Fixed O&M	$11,200,000	$990,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$14,200,000	$1,250,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$7,410,000	$483,000
Total Costs	**$40,800,000**	
Benefits		
Reduction in Generating Costs	$14,100,000	$1,240,000
Fuel Savings from CHP	$480,000	$42,300
Generation Capacity Cost Savings	$2,430,000	$215,000
Distribution Capacity Cost Savings	$840,000	$74,100
Reliability Improvements	$1,000,000	$88,500
Power Quality Improvements	$784,000	$69,200
Avoided Emissions Allowance Costs	$7,310	$645
Avoided Emissions Damages	$11,300,000	$735,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$30,900,000**	
Net Benefits	**-$9,950,000**	
Benefit/Cost Ratio	**0.8**	
Internal Rate of Return	**-17.9%**	

Fixed Costs

The BCA relies on information provided by the project team to estimate the fixed costs of developing the microgrid. The project team estimates initial design and planning costs to be $475,000. The present value of the project’s capital costs is estimated to be $7.6 million, including costs associated with the installation of CHP units, solar PV, controllers and software, battery storage, and energy efficiency upgrades. The project team also estimates $990,000 a year in fixed O&M costs for the maintenance of CHP units, solar PV, energy storage, and system software and controls. These costs have a present value of $11.2 million over 20 years.

Variable Costs

The project team does not specify variable costs with the exception of fuel costs. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the project team and projections of fuel costs from New York's State Energy Plan (SEP), adjusted to reflect recent market prices.[11] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $14.2 million.

The analysis of variable costs also considers the environmental damages associated with pollutant emissions from the distributed energy resources that serve the microgrid, based on the operating scenario and emissions rates provided by the project team and the understanding that none of the system's generators would be subject to emissions allowance requirements. 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 $7.4 million.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. For Albany County's proposed project, a major source of cost savings would be a reduction in demand for electricity from bulk energy suppliers, with a resulting reduction in generating costs. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $14.1 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based.[12] The CHP units would also provide savings on heating costs due to a reduction in fuel consumption; the present value of these savings is approximately $480,000. These changes would curtail emissions of CO_2, SO_2, NO_x, and particulate matter from the university's heating system and from bulk energy suppliers, yielding emissions allowance cost savings with a present value of approximately $7,000 and avoided emissions damages with a present value of approximately $11.3 million.[13]

In addition to the savings noted above, development of a microgrid could yield cost savings by avoiding or deferring the need to invest in expansion of the conventional grid's energy generation or distribution capacity.[14] The project team estimates the project's impact on demand for generating capacity to be approximately 2.9 MW per year, and its impact on distribution capacity requirements to be approximately 2.0 MW per year. Based on these figures, the BCA estimates the present value of the project's generating capacity benefits to be approximately $2.4 million over a 20-year operating period, and the present value of its distribution capacity benefits to be approximately $840,000.

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[11] 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.

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

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

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

The project team has indicated that the proposed microgrid would be designed to provide ancillary services, including frequency regulation, reactive power support, and black start support, to the New York Independent System Operator (NYISO). Whether NYISO would select the project to provide these services depends on NYISO's requirements and the ability of the project to provide support at a cost lower than that of alternative sources. Based on discussions with NYISO, it is our understanding that the 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 $90,000 per year, with a present value of approximately $1.0 million over a 20-year operating period. This estimate is calculated using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[15]

- System Average Interruption Frequency Index (SAIFI) – 0.96 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 116.4 minutes.[16]

The estimate takes into account the number of large commercial or industrial customers the project would serve; the distribution of these customers by economic sector; average annual electricity usage per customer, as provided by the project team; and the prevalence of backup generation among these customers. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.[17] 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 estimate of the number of power quality events that development of the microgrid would avoid each year. In the case of Albany County, the project team has indicated that approximately 1.7 power quality events would be avoided each year. Assuming that each customer in the proposed microgrid would experience these improvements in power quality, the model estimates the present value of this benefit to be approximately $784,000 over a 20-year operating period.

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[15] www.icecalculator.com.

[16] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for National Grid.

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

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.8; i.e., the estimate of project benefits is approximately 80 percent of project costs. Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

Scenario 2

Benefits in the Event of a Major Power Outage

The estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[18,19]

As noted above, Albany County's microgrid project would serve an airport, hockey rink, glycol farm, nursing home, correctional facility, and juvenile detention facility. The project's consultants indicate that at present, all facilities with the exception of the hockey rink are equipped with backup generators. All are sufficient to support ordinary levels of service with the exception of the airport terminals' generator, which is capable of maintaining 90 percent of normal levels of service. Table 3 lists the costs associated with the use of these generators, the cost of renting a portable generator for the hockey rink, and the level of service these generators are capable of maintaining.[20] In the absence of backup power – i.e., if the backup generators failed and no replacements were available – all the facilities would experience a 100 percent loss in service capabilities (see Table 3).

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

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

[20] We calculate fuel costs based on the fuel consumption specifications provided by the project team.

Table 3. Backup Power Costs and Level of Service, Scenario 2

FACILITY NAME	COST OF MAINTAINING SERVICE WITH EXISTING GENERATION ($/DAY)	COST OF MAINTAINING SERVICE WITH PORTABLE GENERATOR ($/DAY)	PERCENT LOSS IN SERVICE WHEN BACKUP GENERATION IS AVAILABLE	PERCENT LOSS IN SERVICE WHEN BACKUP GENERATION IS NOT AVAILABLE
Airport Terminals	$2,500	NA	10%	100%
Airport Tower	$250	NA	0%	100%
Glycol Farm	$600	NA	0%	100%
Nursing Home	$700	NA	0%	100%
Correctional Facility	$1,600	NA	0%	100%
Juvenile Detention Facility	$280	NA	0%	100%
Hockey Facility	NA	$890	0%	100%

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

- All facilities currently equipped with backup generators would rely on them, maintaining the levels of service shown above while the backup generator operates. If their backup generators fail, all facilities would experience a total loss of service.
- The hockey facility would rent a portable generator, maintaining full capabilities while this generator operates. If the backup generator fails, this facility would experience a total loss of service.
- In all cases, the supply of fuel necessary to operate backup generators would be maintained indefinitely.
- At each facility, there is a 15 percent chance that the backup generator would fail.

The consequences of a major power outage also depend on the economic costs of a sustained interruption of service at the facilities of interest. The analysis employs the approach described below to estimate these costs.

- We use Bureau of Transportation Statistics data and Department of Transportation standard values to approximate the value of lost passenger time that would result from an outage at the airport.[21, 22] Based on this methodology, we estimate the impact of an outage at the airport at

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[21] The analysis does not pro-rate this value for individual terminals or the control tower, assuming that if the control tower were unable to operate, all flights scheduled to and from the airport would be cancelled.

[22] The analysis assumes that while a major storm is in progress, all flights to and from the airport would be cancelled regardless of the presence of a microgrid. However, outages may continue once a storm event is over, contributing to continued travel delays. For the baseline scenario (i.e., in the absence of a microgrid), we assume that an outage at the airport in the aftermath of a storm would lead to the cancellation of all flights. In contrast, for the microgrid scenario, we assume that the ability to keep the airport operating while the outage persists

approximately $570,000 per day. For the nursing home, we calculate the daily value of service by multiplying the estimated annual cost of nursing home services in the Albany area ($140,000 per resident) by the 250 residents served by the facility.[23] We then convert this annual value to a daily value of approximately $94,000.

- For the correctional facility, the analysis assumes that the economic value of maintaining its operations is $127,000 per day. This figure is based on the facility's budget for 2014, divided by 365 days to calculate a daily value.
- For the juvenile detention facility, glycol farm and hockey rink, the cost of an interruption in electrical service is estimated using the U.S. Department of Energy's ICE Calculator.[24] The daily costs for these facilities are respectively $66,000, $113,000 and $90,000.[25]

Summary

Figure 2 and Table 4 present the results of the BCA for Scenario 2. The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 4.8 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

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would reduce the share of flights cancelled to 70 percent; i.e., the median of the share of flights cancelled during a storm event (100 percent) and the share of flights typically cancelled in a storm's aftermath (40 percent.

[23] https://www.genworth.com/corporate/about-genworth/industry-expertise/cost-of-care.html.

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

[25] The project team specifies that in major outage situations, the hockey rink could potentially be utilized as a morgue. Since we lack data to evaluate the value of this particular service, we rely instead on the ICE Calculator.

Figure 2. Present Value Results, Scenario 2 (Major Power Outages Averaging 4.8 Days/Year; 7 Percent Discount Rate)

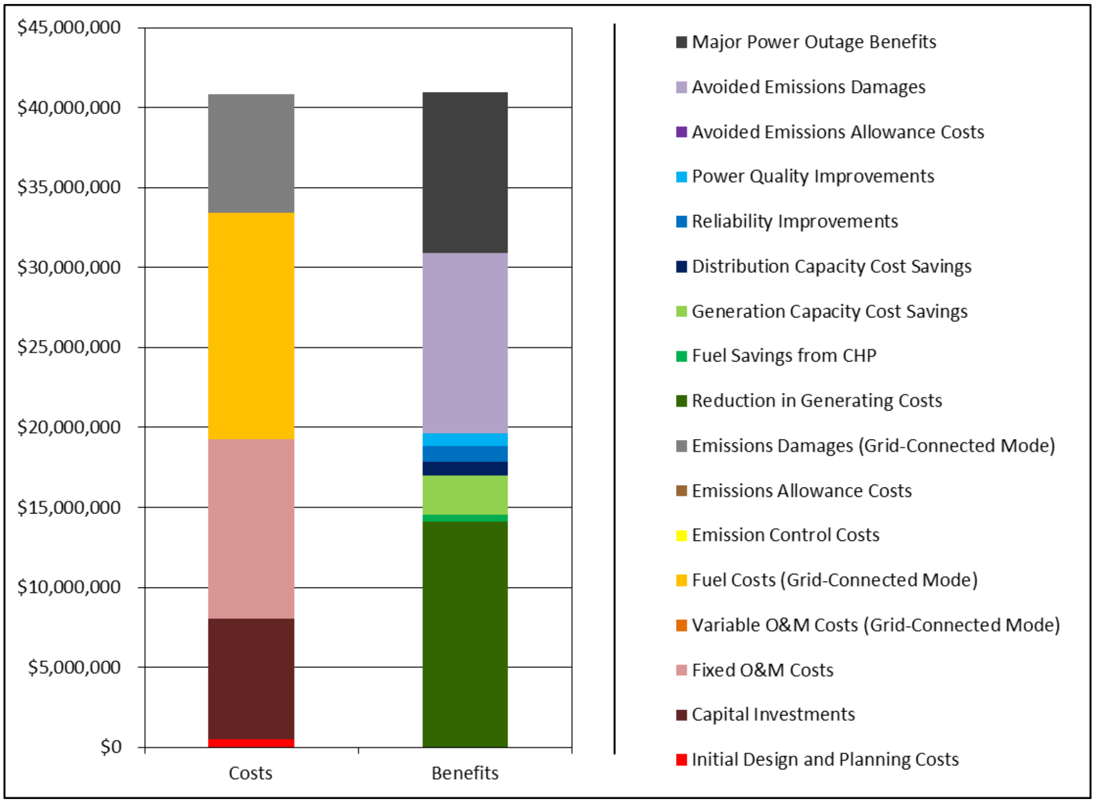

Table 4. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 4.8 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$475,000	$41,900
Capital Investments	$7,570,000	$752,000
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Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$14,200,000	$1,250,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$7,410,000	$483,000
Total Costs	**$40,800,000**	
Benefits		
Reduction in Generating Costs	$14,100,000	$1,240,000
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Distribution Capacity Cost Savings	$840,000	$74,100
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Power Quality Improvements	$784,000	$69,200
Avoided Emissions Allowance Costs	$7,310	$645
Avoided Emissions Damages	$11,300,000	$735,000
Major Power Outage Benefits	$10,100,000	$890,000
Total Benefits	**$41,000,000**	
Net Benefits	**$110,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**5.6%**	