

22 - Sunnyside Yard (Staten Island)

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Amtrak New York City Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

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Abstract

Together with Amtrak, Consolidated Edison, Inc. (Con Ed), and New York City, Booz Allen Hamilton has completed the feasibility study for a proposed community microgrid. This study summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is feasible, though not without challenges. The commercial and financial viability of the project are summarized in this document. The Amtrak NYC microgrid project faces the challenge of high capital costs, but it is a financially feasible, investable project. New distributed energy resources (DERs), including a combined heat and power (CHP) unit, two natural gas reciprocating generators, a solar photovoltaic (PV) array, and a zinc air battery storage unit, will provide reliable, low-emission electricity and thermal energy to customers while providing a proof of concept for a transit-oriented community microgrid in investor-owned utility (IOU) territory. Two existing standby generators will also be interconnected to improve the resilience of the energy supply in island mode. Many of the takeaways of the feasibility study may be generalized across the spectrum of NY Prize and community microgrids.

Keywords: NY Prize, NYSERDA, distributed energy resources, energy resilience, clean energy, DER, Amtrak, and NYC

Contents

Notice i

Abstract ii

Figures vi

Tables..... vii

Acronyms and Abbreviations ix

Executive Summary xi

1. Introduction..... 1

2. Microgrid Capabilities and Technical Design and Configuration..... 1

 2.1 Project Purpose and Need..... 1

 2.2 Microgrid Required and Preferred Capabilities (Sub Tasks 1.1 and 1.2) 2

 2.2.1 Serving Multiple, Physically Separated Critical Facilities..... 2

 2.2.2 Limited Use of Diesel Fueled Generators..... 2

 2.2.3 Local Power in both Grid-Connected and Island Mode..... 2

 2.2.4 Intentional Islanding..... 3

 2.2.5 Resynchronization to Con Ed Power..... 4

 2.2.6 Standardized Interconnection..... 4

 2.2.7 24/7 Operation Capability..... 6

 2.2.8 Two Way Communication with Local Utility..... 6

 2.2.9 Voltage and Frequency Synchronism When Connected to the Grid 6

 2.2.10 Load Following and Frequency and Voltage Stability When Islanded..... 6

 2.2.11 Diverse Customer Mix..... 6

 2.2.12 Resiliency to Weather Conditions..... 7

 2.2.13 Black Start Capability..... 8

 2.2.14 Energy Efficiency Upgrades 8

 2.2.15 Cyber Security 9

 2.2.16 Use of Microgrid Logic Controllers 9

 2.2.17 Smart Grid Technologies..... 9

 2.2.18 Smart Meters..... 10

 2.2.19 Distribution Automation..... 10

 2.2.20 Energy Storage..... 10

 2.2.21 Active Network Control System 10

 2.2.22 Demand Response..... 10

 2.2.23 Clean Power Sources Integration 11

 2.2.24 Optimal Power Flow..... 11

 2.2.25 Storage Optimization..... 11

 2.2.26 PV Monitoring, Control, and Forecasting..... 11

2.2.27	Protection Coordination.....	12
2.2.28	Selling Energy and Ancillary Services	12
2.2.29	Data Logging Features.....	12
2.2.30	Leverage Private Capital.....	12
2.2.31	Accounting for Needs and Constraints of Stakeholders.....	13
2.2.32	Demonstrate Tangible Community Benefit	13
2.3	Distributed Energy Resources Characterization (Sub Task 2.3)	13
2.3.1	Existing Generation Assets	13
2.3.2	Proposed Generation Assets.....	14
2.3.3	Generation Asset Adequacy, Resiliency, and Characteristics	15
2.4	Load Characterization (Sub Task 2.2)	16
2.4.1	Electrical Load	16
2.4.2	Thermal Consumption	21
2.5	Proposed Microgrid Infrastructure and Operations (Sub Task 2.1).....	22
2.5.1	Grid Parallel Mode	22
2.5.2	Intentional Islanded Mode	23
2.6	Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)	23
2.6.1	Electrical Infrastructure	23
2.6.2	Points of Interconnection and Additional Investments in Utility Infrastructure.....	29
2.6.3	Basic Protection Mechanism within the Microgrid Boundary	31
2.6.4	Thermal Infrastructure.....	31
2.7	Microgrid and Building Control Characterization (Sub Task 2.5)	31
2.7.1	Microgrid Supporting Computer Hardware, Software and Control Components.....	33
2.7.2	Grid Parallel Mode Control.....	34
2.7.3	Energy Management in Grid Parallel Mode.....	35
2.7.4	Islanded Mode Control	35
2.7.5	Path to Resolving Traction Challenges.....	38
2.7.6	Energy Management in Islanded Mode	39
2.7.7	Black Start	40
2.7.8	Resynchronization to Con Ed Power	41
2.8	Information Technology and Telecommunications Infrastructure (Sub Task 2.6)	41
2.8.1	Existing IT & Telecommunications Infrastructure.....	42
2.8.2	IT Infrastructure and Microgrid Integration.....	42
2.8.3	Network Resiliency	43
2.9	Microgrid Capability and Technical Design and Characterization Conclusions	44
3.	Assessment of Microgrid’s Commercial and Financial Feasibility (Task 3).....	45
3.1	Commercial Viability – Customers (Sub Task 3.1).....	45
3.1.1	Microgrid Customers.....	45

3.1.2	Benefits and Costs to Other Stakeholders.....	46
3.1.3	Purchasing Relationship	47
3.1.4	Solicitation and Registration.....	49
3.1.5	Energy Commodities	49
3.2	Commercial Viability – Value Proposition (Sub Task 3.2)	50
3.2.1	Business Model	51
3.2.2	Replicability and Scalability	52
3.2.3	Benefits, Costs and Value.....	53
3.2.4	Demonstration of State Policy.....	57
3.3	Commercial Viability – Project Team (Sub Task 3.3).....	57
3.3.1	Stakeholder Engagement	57
3.3.2	Project Team.....	57
3.3.3	Financial Strength	60
3.4	Commercial Viability – Creating and Delivering Value (Sub Task 3.4).....	61
3.4.1	Microgrid Technologies.....	61
3.4.2	Operation	62
3.4.3	Barriers to Completion	63
3.4.4	Permitting	63
3.5	Financial Viability (Sub Task 3.5).....	63
3.5.1	Revenue, Cost, and Profitability.....	64
3.5.2	Financing Structure	66
3.6	Legal Viability (Sub Task 3.6)	66
3.6.1	Ownership and Access.....	66
3.6.2	Regulatory Considerations.....	67
3.7	Project Commercial and Financial Viability Conclusions	68
4.	Cost Benefit Analysis.....	69
4.1	Facility and Customer Description (Sub Task 4.1).....	69
4.2	Characterization of Distributed Energy Resource (Sub Task 4.2).....	71
4.3	Capacity Impacts and Ancillary Services (Sub Task 4.3).....	74
4.3.1	Peak Load Support	74
4.3.2	Deferral of Transmission/Distribution Requirements.....	75
4.3.3	Ancillary Services	75
4.3.4	Development of a Combined Heat and Power System	75
4.3.5	Environmental Regulation for Emission.....	75
4.4	Project Costs (Sub Task 4.4)	77
4.4.1	Project Capital Cost.....	77
4.4.2	Initial Planning and Design Cost.....	80
4.4.3	Operations and Maintenance Cost.....	81

4.4.4 Distributed Energy Resource Replenishing Fuel Time..... 82

4.5 Costs to Maintain Service during a Power Outage (Sub Task 4.5) 83

4.5.1 Backup Generation Cost during a Power Outage 83

4.5.2 Cost to Maintain Service during a Power Outage..... 86

4.6 Services Supported by the Microgrid (Sub Task 4.6)..... 86

4.7 Industrial Economics Benefit-Cost Analysis Report 87

4.7.1 Project Overview..... 87

4.7.2 Methodology and Assumptions..... 88

4.7.3 Results 90

5. Summary and Conclusions.....99

5.1 Lessons Learned and Areas for Improvement 99

5.1.1 Amtrak NYC Lessons Learned..... 99

5.1.2 Statewide Replicability and Lessons Learned 100

5.1.3 Stakeholder Lessons Learned 102

5.2 Benefits Analysis..... 104

5.2.1 Environmental Benefits..... 104

5.2.2 Benefits to New York City..... 104

5.2.3 Benefits to Residents in and around New York City 105

5.2.4 Benefits to New York State..... 105

5.3 Conclusion and Recommendations 105

Appendix107

Figures

Figure ES- 1. Schematic of Microgrid with Facilities and DERs..... xiii

Figure 1a. Penn Station Equipment Layout..... 18

Figure 1b. Sunnyside Yard Equipment Layout 18

Figure 2. Typical 24-Hour Cumulative Load Profile from 2014 Metering Data 20

Figure 3. Penn Station Thermal Consumption 21

Figure 4. Penn Station PPDS One-Line Diagram..... 25

Figure 5. Penn Station Chiller Plant One-Line Diagram 26

Figure 6. Penn Station Service Building Emergency Switchboard One-Line Diagram 27

Figure 7. Amtrak Sunnyside Yard Train Traction Electrical System One-Line Diagram..... 29

Figure 8. High School and College Distribution System One-Line Diagram 29

Figure 9. Amtrak Sunnyside Yard 60 Hz Substation One-Line Diagram..... 29

Figure 10. Diagram of Representative Microgrid Control System Hierarchy 32

Figure 11. Normal Operation Purchasing Relationship 48

Figure 12. Islanded Operation Purchasing Relationship..... 49

Figure 13. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)..... 90

Figure 14. Present Value Results, Scenario 2 (Major Power Outages Averaging 4.9 Days/Year; 7 Percent Discount Rate)97

Tables

Table ES- 1. Prospective Microgrid Facilities.....	xii
Table ES-2. Sunnyside Yard Generation Assets	xii
Table 1. Microgrid Capabilities Matrix.....	3
Table 2. New York State Interconnection Standards	5
Table 3. Existing Distributed Energy Resource	14
Table 4. Proposed Generation Assets.....	15
Table 5. Prospective Microgrid Facilities and Train Traction Systems.....	17
Table 6. Sunnyside Yard’s 2014 Microgrid Load Points	19
Table 7. Sunnyside Yard’s Network Switch Description	24
Table 8. Sunnyside Yard’s Server Description.....	24
Table 9. List of Components	30
Table 10. List of Automated Switches	30
Table 11. Microgrid Customers	46
Table 12. Microgrid SWOT Analysis	51
Table 13. Benefits, Costs, and Value Proposition to SPV	54
Table 14. Benefits, Costs, and Value Proposition to Con Ed.....	54
Table 15. Benefits, Costs, and Value Proposition to Long Island City	55
Table 16. Benefits, Costs, and Value Proposition to Connected Facilities	55
Table 17. Benefits, Costs, and Value Proposition to the Larger Community	56
Table 18. Benefits, Costs, and Value Proposition to New York State.....	56
Table 19. Project Team	58
Table 20. Project Team Roles and Responsibilities.....	59
Table 21. Savings and Revenues	64
Table 22. Capital, Design, and Operating Costs.....	65
Table 23. Available Incentive Programs	66
Table 24. Facility and Customer Detail Benefit	70
Table 25. Distributed Energy Resources.....	73
Table 26. Distributed Energy Resource Peak Load Support	74
Table 27. Emission Rates	77
Table 28. Distributed Equipment Capital Cost.....	78
Table 29. Capital Cost of Proposed Generation Units	80
Table 30. Initial Planning and Design Cost.....	81
Table 31. Fixed Operating and Maintenance Cost.....	82
Table 32. Maximum Fuel Operating Time for Distributed Energy Resource.....	83
Table 33. Cost of Generation during a Power Outage	85
Table 34. Critical Services Supported.....	87
Table 35. BCA Results (Assuming 7 Percent Discount Rate)	90
Table 36. Detailed BCA Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)	91
Table 37. Backup Power Costs and Level of Service, Scenario 2.....	95

Table 38. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 4.9 Days/Year;
7 Percent Discount Rate)98

Acronyms and Abbreviations

AC	Alternating Current
AMI	Advanced Metering Infrastructure
ATS	Automatic Transfer Switch
BCA	Benefit Cost Analysis
BEMS	Building Energy Management Systems
BTU	British thermal unit
CAIDI	Customer Average Interruption Duration Index
CHP	Combined Heat and Power
Con Ed	Consolidated Edison, Inc.
CSRP	Commercial System Relief Program
DC	Direct Current
DER	Distributed Energy Resources
DNP3	Distributed Network Protocol
DR	Demand Response
DSP	Distributed System Platform
EE	Energy Efficiency
EMS	Energy Management System
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
Hz	Hertz
ICCP	Inter-Control Center Communications Protocol
IEc	Industrial Economics
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor-Owned Utility
ISM	Industrial Scientific and Medical
IT	Information Technology
ITC	Investment Tax Credit
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hour
LAN	Local Area Network
LBMP	Location-Based Marginal Price
LCC	LaGuardia Community College
LIRR	Long Island Rail Road
Mcf	One Thousand Cubic Feet of Natural Gas
MCHS	Middle College High School
MCS	Microgrid Control System
MHz	Megahertz
MMBTU	One Million British Thermal Units
MMTCO ₂ e	Million Metric Tons CO ₂ Equivalent
MTCO ₂ e	Metric Tons CO ₂ Equivalent
MW	Megawatt

MWh	Megawatt-hour
NJT	New Jersey Transit
NYISO	New York Independent System Operator
NYPSC	New York Public Service Commission
NYS DEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
OPC	Open Platform Communication or OLE (Object Link Embedded) Process Control
OPF	Optimal Power Flow
PCC	Point of Common Coupling
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PV	Photovoltaic
RAID	Redundant Array of Independent Disks
REV	Reforming the Energy Vision
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCOPF	Security Constrained Optimal Power Flow
SOA	Service Oriented Architecture
SOW	Statement of Work
SPV	Special Purpose Vehicle
TCP/IP	Transmission Control Protocol/Internet Protocol
T&D	Transmission and Distribution
VAC	Volt Alternating Current

Executive Summary

Booz Allen Hamilton was awarded a contract by the New York State Energy Research and Development Authority (NYSERDA) through its New York Prize initiative to conduct a feasibility study of a community microgrid concept in New York City. This deliverable presents the findings and recommendations from the previous four tasks, discusses the results and lessons learned from the project, and lays out the environmental and economic benefits for the project. The design demonstrates that Amtrak, Penn Station, and two local schools can improve energy resilience with intentional and emergency island mode capabilities and comply with the greater New York REV (Reforming the Energy Vision) program by constructing 17.2 megawatts (MW) of energy generation capacity and 4 megawatt-hour MWh of storage capacity. The study concludes the technical design is technically and financially feasible, and would be enhanced with the addition of NY Prize.

The proposed microgrid includes Amtrak facilities at and near Penn Station and Sunnyside Yard as well as a nearby college and high school. The facilities are separated into three footprints based on the existing electrical infrastructure. The Penn Station footprint, which includes electrical loads from tunnel fans, chillers, lighting, and the propulsion system at Penn Station, is electrically separated from the other two footprints (across the East River). The Sunnyside Yard 25 Hertz (Hz) Substation footprint (SSY-B footprint) includes the Amtrak train traction system, LaGuardia Community College (LCC), and Middle College High School (MCHS). The Sunnyside Yard 60 Hz Substation footprint (SSY-A footprint) includes non-traction Amtrak loads at Sunnyside Yard.

Three critical facilities and two schools will be incorporated into the Amtrak New York City microgrid (see Table ES-1). Five new DERs and two existing diesel generators will supply the microgrid's energy. The local utility, Con Ed, and the main stakeholder, Amtrak, have each indicated that they do not wish to own nor operate any microgrid equipment or DERs. The team therefore proposes a single ownership model wherein a special purpose vehicle (SPV) owns and operates DERs and microgrid equipment.

According to the NY Prize definition, critical facilities are those facilities whose “disruption, incapacitation, or destruction... could jeopardize the health, safety, welfare or security of the state, its residents or its economy.” Amtrak's non-traction loads provide critical maintenance and support services to trains and local transportation infrastructure. Transit systems are critical to emergency evacuation operations, and as such are important to the health, safety, and welfare of the community's residents. Further, the Project Team expects to develop a solution in Phase II of the NY Prize competition that will allow at least partial operation of the traction system.

Table ES- 1. Prospective Microgrid Facilities

Table lists the facilities in the proposed microgrid, including their economic classifications. The table also denotes critical and important facilities.

Name on Map	Property	Classification
F1	Penn Station (PS footprint)	Private*
F2	Amtrak’s Sunnyside Yard Facility (SSY-A footprint)	Private*
F3	Amtrak’s Train Traction System at Sunnyside Yard (SSY-B footprint)	Private*
F4	LaGuardia Community College (SSY-B footprint)	School**
F5	Middle College High School at LaGuardia (SSY-B footprint)	School**
		* Critical Facility ** Important Facility

In addition to the facilities listed in Table ES-1, Madison Square Garden at Penn Station and public housing and new developments near Sunnyside Yard will be considered for microgrid inclusion in Phase II. Table ES-2 provides a list of proposed and existing generation assets within the footprint.

Table ES-2. Sunnyside Yard Generation Assets

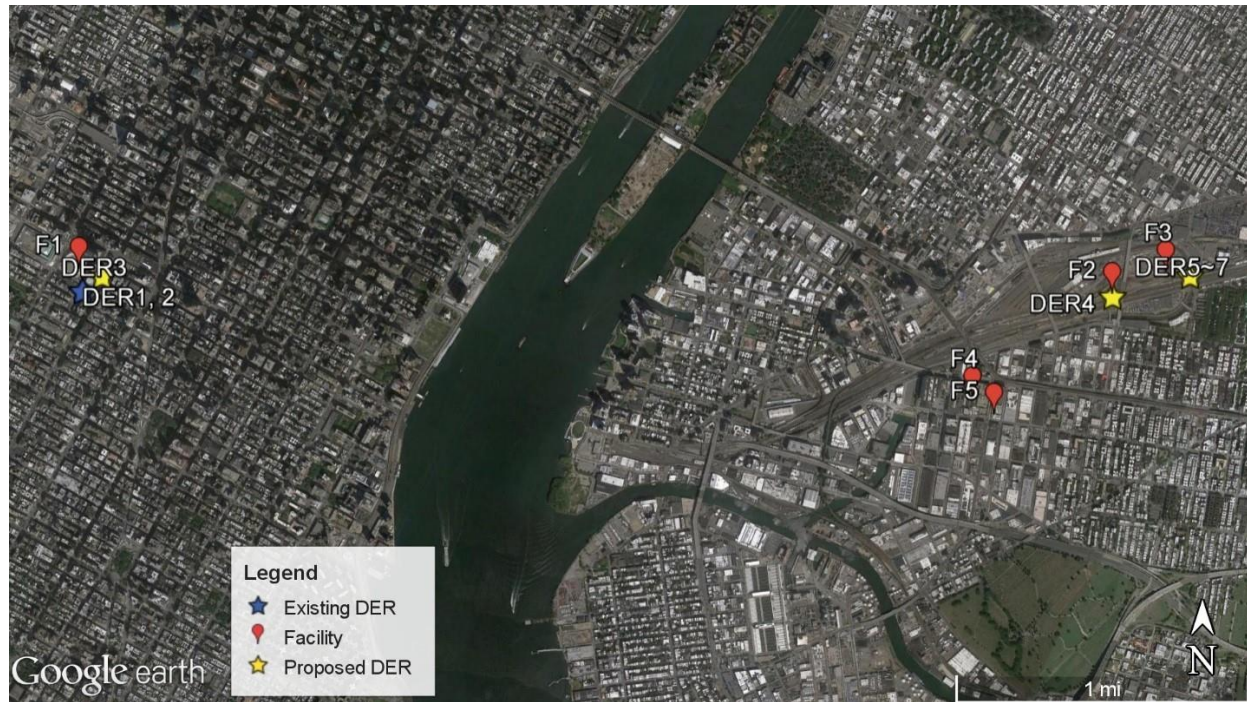
Table lists the DERs that will be included in the Sunnyside Yard microgrid, including their address, fuel source, and nameplate capacity. The table also provides their labels for Figure ES-1.

Map Label	Description	Fuel Source	Capacity (MW)	Address
DER1	Backup Generator at Penn Station	Diesel	0.930	266 W 31 st St
DER2	Backup Generator at Penn Station	Diesel	0.930	266 W 31 st St
DER3	Proposed CHP at Penn Station	Natural Gas	6	266 W 31 st St
DER4	Proposed Natural Gas Generator at Sunnyside Yard – SSY-A footprint	Natural Gas	3	43 rd St
DER5	Proposed Natural Gas Generator at Sunnyside Yard – SSY-B footprint	Natural Gas	8	43 rd St
DER6	Proposed Solar PV Array at Sunnyside Yard - SSY-B footprint	Solar	0.20	43 rd St
DER7	Proposed Battery Storage at Sunnyside Yard - SSY-B footprint	Storage	1	43 rd St

While the existing electrical infrastructure requires relatively few modifications and additions to support the proposed microgrid, thermal infrastructure will need to be expanded. The Project Team estimates around 2000 feet of new natural gas line will be necessary to provide the proposed generators with an adequate fuel supply.

Figure ES- 1. Schematic of Microgrid with Facilities and DERs

Figure ES-1 shows the proposed microgrid and the locations of facilities and DERs.



In grid-connected mode, the 6 MW CHP will operate continuously, selling electricity to Con Ed under a long term power purchase agreement (PPA) and selling thermal energy to Penn Station. The 3 MW natural gas generator at the SSY-A footprint will follow the footprint’s non-traction loads, selling electricity directly to Amtrak at approximately 90% of the local industrial electricity rate. The 8 MW natural gas generator at the SSY-B footprint will support the Amtrak traction system, selling electricity directly to Amtrak at approximately 90% of the local industrial rate.¹ The solar PV array will sell electricity to Con Ed under a long term PPA—it will not qualify for net metering as the SPV does not own a metered facility in the area. The battery will participate in the Con Ed Commercial System Relief Program (CSR) from May-September and will be deployed for time-of-use (TOU) bill management at Amtrak facilities during the remainder of the year.

In island mode, the 6 MW CHP will follow electric loads at Penn Station, selling co-generated thermal energy whenever it is available. The 3 MW natural gas generator will continue to follow the SSY-A footprint’s non-traction loads. However, the 8 MW natural gas generator at the SSY-B footprint will not be able to fully support Amtrak’s traction system, and instead will provide electricity directly to LaGuardia Community College and Middle College High School. All

¹ The SPV will sell electricity to Amtrak at a discount to encourage Amtrak to purchase electricity from the microgrid. This price will still produce positive returns for SPV shareholders. The Project Team estimated the local industrial rate to be ~\$0.106/kWh, obtained from www.electricitylocal.com. A Tetra Tech report found that Amtrak was paying ~\$0.16/kWh for electricity in 2009. If this rate increased in concert with the average New York City residential electricity rates, Amtrak may be paying well over \$0.20/kWh in 2016. The Project Team’s estimate is therefore conservative, and still produces positive financial returns.

energy transactions in island mode will be captured by microgrid software, and payments for electricity and thermal energy will accrue directly to the SPV.

The SPV will receive all revenues associated with operation of the microgrid, but will also bear all of the capital and operating costs. Shareholders will receive revenue from electricity sales to the utility, electricity sales to Amtrak, thermal energy sales to Penn Station, and savings and demand response (DR) payments from the battery storage units. In island mode, shareholders will also receive revenue from electricity sales to the college and high school, but the Project Team expects this value stream to be relatively small because the microgrid will most often operate in grid-connected mode.

The microgrid will incur initial capital costs of \$31.3 million as well as yearly operation, maintenance, and fuel costs totaling \$7.2 million per year. Overall revenue streams from the project are estimated at \$10 million per year and will be captured primarily through the sale of electricity to Amtrak and Con Ed in grid-connected mode.

1. Introduction

Amtrak and Long Island City are seeking to develop a community microgrid to improve energy service resilience, accommodate distributed energy resources, stabilize energy prices, and expand local energy generation from low-emission, reliable sources. Working with representatives from Amtrak, Long Island City, and Con Ed, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a microgrid that will connect three critical facilities and two schools with five new generation assets and two existing standby diesel generators. The design proposes a natural gas CHP unit, two natural gas reciprocating generators, a solar PV array, a zinc air battery storage unit, and interconnection of two existing diesel generators. In this document, the Project Team discusses the observations, findings, and recommendations from the entirety of the analysis. Within the document, the Project Team also explores avenues for further development, discusses project results, and shares lessons learned regarding configuration, capabilities, environmental and economic benefits, and implementation scenarios.

2. Microgrid Capabilities and Technical Design and Configuration

This section provides a combined overview of the criteria assessed in Microgrid Capabilities and Technical Design and Configuration. The tasks were combined and address all of the criteria in the following order: microgrid capabilities, DER characterization, load characterization, proposed microgrid infrastructure and operations, electric and thermal infrastructure characterization, microgrid building and controls, and IT and telecommunications infrastructure.

2.1 Project Purpose and Need

Amtrak, Penn Station, LaGuardia Community College, and Middle College High School seek to improve the resilience of energy service, stabilize costs, and expand local energy generation. More specifically, the area faces several challenges that could be mitigated with a community microgrid:

- Power outages: Long Island City, which hosts the 25 Hz footprint and the 60 Hz footprint, has experienced chronic power reliability issues in recent years. Various storms and non-storm events have caused significant power outages. For example, in the aftermath of Hurricane Sandy, half of Amtrak's Sunnyside Yard lost power due to wind damage to a transmission line, and was forced to rely on portable backup generators for a month. During July 2006, approximately 25,000 customers in Long Island City lost power for over five days due to equipment failures.
- Lack of emergency back-up generators: The Amtrak facilities at Sunnyside Yard do not have adequate on-site emergency back-up generation. In previous outages, Sunnyside Yard facilities have used portable diesel backup generators that are unreliable, temporary,

small capacity solutions. The microgrid will provide a low-emission, more reliable alternative to portable diesel backup generators.

- **Cost:** Energy prices in New York City are among the highest in the state and are relatively unstable. In January 2014, supply charges for Con Ed customers had risen 83% since the previous year. The high prices and volatility impose financial strain on public and private customers.

Additionally, a community microgrid can take advantage of existing opportunities:

- **Sunnyside Yard Energy Master Plan:** Amtrak’s Sunnyside Yard Master Plan emphasizes incorporating sustainable design wherever possible. Amtrak believes building a microgrid supports this guiding principle. A recent energy audit identified over 3,247 MWh in energy conservation opportunities per year that could enhance the facility’s energy resilience in tandem with a community microgrid. These opportunities include lighting retrofit and control projects, and reduction of ground power use.
- **Penn Station Energy Audit:** A similar energy audit at Penn Station identified over 2,326 MWh in energy conservation opportunities per year that could also enhance the facility’s energy resilience in tandem with a community microgrid. These opportunities include lighting retrofit and control projects, compressed air system optimization, replacement of motor and fan drivers with variable frequency drives (VfDs), and optimization of the steam system.
- **Distributed energy resources and ancillary services:** A microgrid project could improve the financial case for services such as demand response, frequency regulation, and spinning reserve, and will expand distributed energy resources in the area. The microgrid’s scalability and interoperability will allow future entities the prospect of integrating with the microgrid.

Implementing a community microgrid will improve energy resiliency and reduce congestion on the local transmission and distribution (T&D) system. Co-generated steam from the CHP unit will supply the thermal load from Penn Station.

2.2 Microgrid Required and Preferred Capabilities (Sub Tasks 1.1 and 1.2)

The NYSEERDA statement of work (SOW) 66263 outlines 15 required capabilities and 18 preferred capabilities each NY Prize microgrid feasibility study must address. Table 1 summarizes required and preferred capabilities met by the proposed microgrid design in greater detail.

Table 1. Microgrid Capabilities Matrix

Table lists NYSERDA’s required and preferred capabilities and annotations of whether or not the Sunnyside microgrid will meet these criteria.

Capability	Required/ Preferred	Microgrid will meet (Y/N)
Serves more than one, physically separated critical facilities	Required	Y
Primary generation source not totally diesel fueled	Required	Y
Provides on-site power in both grid-connected and islanded mode	Required	Y
Intentional islanding	Required	Y
Seamless and automatic grid separation/restoration	Required	Y
Meets state and utility interconnection standards	Required	Y
Capable of 24/7 operation	Required	Y
Operator capable of two-way communication and control with local utility	Required	Y
Load following while maintaining the voltage and frequency when running in parallel to grid	Required	Y
Load following and maintaining system voltage when islanded	Required	Y
Diverse customer mix (residential, commercial, industrial)	Required	Y
Resiliency to wind, rain, and snow storms	Required	Y
Provide black-start capability	Required	Y
Energy efficiency (EE) upgrades	Required	Y
Cyber secure and resilient to cyber intrusion/disruption	Required	Y
Microgrid logic controllers	Preferred*	Y
Smart grid technologies	Preferred*	Y
Smart meters	Preferred	N
Distribution automation	Preferred*	Y
Energy storage	Preferred	Y
Active network control system	Preferred*	Y
Demand response	Preferred	Y ²
Clean power sources integrated	Preferred	Y
Optimal power flow (OPF)	Preferred	Y
Storage optimization	Preferred	Y
PV observability, controllability, and forecasting	Preferred	Y
Coordination of protection settings	Preferred	Y
Selling energy and ancillary services	Preferred	Y ³
Data logging features	Preferred	Y
Leverage private capital	Preferred	Y
Accounting for needs and constraints of all stakeholders	Preferred	Y
Demonstrate tangible community benefit	Preferred	Y
Identify synergies with Reforming the Energy Vision	Preferred	Y

*Capability is characterized as preferred by NYSERDA but is a required component in this design

The following section demonstrates how the design concept meets the required and select preferred capabilities provided by NYSERDA.

² The proposed battery storage unit will participate in the Con Ed Commercial System Relief Program, but the microgrid will not enter island mode for demand response.

³ Microgrid has the *capability* to sell energy and ancillary services, but may only sell energy in reality.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

Booz Allen, in cooperation with Con Ed, has identified five facilities that will be connected to the microgrid. Three facilities will provide critical services to the community in the case of an outage. See Table ES-1 for a full list of prospective facilities to be tied into the microgrid.

The Penn Station footprint is about 3.3 miles west of the Sunnyside Yard A and B footprints. The Sunnyside Yard 25 Hz Substation is about 0.2 miles away from the Sunnyside Yard 60 Hz Substation. The two geographic footprints will be interconnected via Amtrak's existing electric distribution system, although the 25 Hz and 60 Hz systems are separate. The Project Team proposes new medium voltage lines to connect the microgrid distribution system to the existing Con Ed lines that serve LaGuardia Community College and Middle College High School. Facilities and microgrid equipment will communicate over Amtrak's WAN (utilizing the existing IT fiber optic backbone) by using industry standard protocols, such as Distributed Network Protocol (DNP3), Open Platform Communication (OPC), Modbus, 61850, and Inter-Control Center Communications Protocol (ICCP) (IEC 60870-6) will enable the remote monitoring and control of distributed devices, regardless of manufacturer. The microgrid is designed with flexibility and scalability in order to accommodate future expansion and technologies.

2.2.2 Limited Use of Diesel Fueled Generators

Amtrak has established a preference for a natural gas-fired generator to serve as the primary energy source. As a comparatively low-emission, high reliability fuel, natural gas is an ideal source of energy for the proposed community microgrid. The proposed 8 MW reciprocating generator at the SSY-B footprint will be supported by a 200 kilowatt (kW) solar array and a 1 MW battery storage unit. The solar array will operate at maximum capacity during the summer and will offset some of the greenhouse gasses (GHGs) emitted by the natural gas generators.

The Project Team does not expect that the existing diesel generators at Penn Station will need to come online during an outage. The proposed CHP unit is sized to meet Penn Station's entire load.

2.2.3 Local Power in both Grid-Connected and Island Mode

The microgrid will provide on-site power in both grid-connected and island mode. In island mode, the microgrid control system (MCS) will optimize on-site generation and automatically shed non-critical loads as needed to maintain a stable and reliable power flow. In grid-connected mode, the microgrid will optimize the use of available assets to reduce energy costs when possible.

The proposed 8 MW reciprocating generator at the SSY-B footprint will be able to partially supply Amtrak's traction system loads in island mode, and power the full LaGuardia College and Middle College High School demands in island mode. Train traction systems experience huge instantaneous spikes in electricity demand when trains accelerate. Amtrak's current traction monitoring system registers at an 8 second sampling rate and records a 15 MW peak. However, this sampling rate may not provide a sufficiently granular view of the traction system's peak requirements, and therefore the team is working with Amtrak to obtain higher resolution value to

better understand the real peak demand. During normal operation, the grid relies on high electrical inertia to absorb these spikes. Two strategies may enable operation of the traction system during emergency operations: (1) Formulate an optimized load to generation balance algorithm after obtaining high resolution dynamic input data (such as true electrical current demand during startup), and (2) develop emergency train service procedures, including identifying the specific rail lines to electrify in the event of an emergency in order to transport passengers to a suitable shelter location to receive emergency services outside of the city. This method would allow NYC-based electrification to support train movements far enough into New Jersey to deposit passengers and return into the City. The Project Team will work with Amtrak to develop the necessary emergency procedures necessary to ensure the microgrid's generation is sufficient to service the needs of the system in an emergency.

The proposed natural gas generators will operate continuously in grid-connected mode, reducing local dependence on grid-supplied power. The CHP unit will sell power to Con Ed under a long-term PPA and the natural gas units will sell power directly to Amtrak. The solar PV array and battery storage unit at the SSY-B footprint will supplement the 8 MW natural gas generator's output to meet critical loads. Penn Station will offtake 100% of the CHP's co-generated thermal energy.

2.2.4 Intentional Islanding

The microgrid will intentionally switch to island mode when doing so results in a more stable and reliable environment. Transitions to island mode will comply with New York State standardized interconnection requirements as well as local utility and building codes, which will ensure equipment and personnel safety throughout each phase of the switch.

Upon a command from the system operator, the MCS will automatically start any idle assets and synchronize DERs to grid power as necessary.⁴ Once the available power sources are synchronized with the grid (and each other), the system is ready to disconnect from the larger grid, and it will begin by opening the incoming utility line breakers. After completing the transition to island mode, the MCS must maintain system voltage and frequency between acceptable limits and adjust generator output to match aggregate load.

Due to the nature of the existing Con Ed lines and fully meshed network, the microgrid will not disconnect downstream Con Ed customers by switching to island mode. In other words, the network has the ability to re-route electricity to downstream loads, however, the design work in Phase II needs to ensure the mesh system will work around the automated switches isolating the two schools; this mesh coordination is only applicable at the two schools. Intentional islanding for power stability and participation in DR programs is possible, but it is unclear whether Con Ed will accept islanded operation as an eligible demand reduction.

⁴ The CHP and reciprocating generators should normally be online. The CHP will already be synchronized with the Con Ed grid, but the DERs at the SSY-B footprint may need to synchronize with each other before entering island mode.

2.2.5 Resynchronization to Con Ed Power

When operating in island mode, the microgrid will constantly monitor the status of the larger grid and will re-connect when conditions have stabilized. Signals from the MCS will prompt re-connection when monitored operational variables satisfy predetermined conditions. The MCS will be capable of both pre-programmed and manual re-connection using synchronization and protection equipment.

The proposed automated utility breakers at the point of common coupling (PCC) will connect the microgrid to the larger grid. The control system will trigger the opening or closing of these breakers at appropriate times during system transitions.

2.2.6 Standardized Interconnection

The microgrid design complies with New York Public Service Commission (NYPSC) interconnection standards. Table 2 outlines the most significant state interconnection standards that apply to this microgrid project. Customers that wish to connect DER projects to Con Ed's system must follow the same New York State Standard Interconnection Requirements (SIR) identified in Table 2. The NYPSC SIR applies to distributed generators with less than 2 MW capacity. Although the proposed natural gas generator at the Amtrak Sunnyside Yard A footprint is larger than 2 MW, generators that are close to 2 MW (approximately 2-4 MW) still usually follow NYPSC SIR. A recent proposal to modify the New York SIR to include generators up to 5 MW has not yet been approved. The proposed 3 MW reciprocating generator will likely need to follow the normal New York State SIR.

The 6 MW CHP unit and 8 MW reciprocating generator may need to follow the Federal Energy Regulatory Commission (FERC) Small Generator (2-20 MW) Interconnection Procedure and Small Generator Interconnection Agreement.⁵ The Small Generator Interconnection Procedure requires that interconnection be evaluated under a defined study process that includes a scoping meeting, a feasibility study, a system impact study, and a facilities study. The Small Generator Interconnection Agreement governs the responsibility, operation obligation, reactive power requirement, and metering rule and cost of applicable small generating facilities.

⁵ FERC guidelines can be found at: <http://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp>.

Table 2. New York State Interconnection Standards

Table outlines New York State interconnection standards by category (common, synchronous generators, induction generators, inverters, and metering) and a description of the standard.

Standard Category	Description
Common	<p>Generator-owner shall provide appropriate protection and control equipment, including a protective device that utilizes an automatic disconnect device to disconnect the generation in the event that the portion of the utility system that serves the generator is de-energized for any reason or for a fault in the generator-owner’s system</p> <p>The generator-owner’s protection and control scheme shall be designed to ensure that the generation remains in operation when the frequency and voltage of the utility system is within the limits specified by the required operating ranges</p> <p>The specific design of the protection, control, and grounding schemes will depend on the size and characteristics of the generator-owner’s generation, as well as the generator-owner’s load level, in addition to the characteristics of the particular portion of the utility’s system where the generator-owner is interconnecting</p> <p>The generator-owner shall have, as a minimum, an automatic disconnect device(s) sized to meet all applicable local, state, and federal codes and operated by over and under voltage and over and under frequency protection</p> <p>The required operating range for the generators shall be from 88% to 110% of nominal voltage magnitude</p> <p>The required operating range for the generators shall be from 59.3 Hz to 60.5 Hz</p>
Synchronous Generators	<p>Requires synchronizing facilities, including automatic synchronizing equipment or manual synchronizing with relay supervision, voltage regulator, and power factor control</p> <p>Sufficient reactive power capability shall be provided by the generator-owner to withstand normal voltage changes on the utility’s system</p> <p>Voltage regulator must be provided and be capable of maintaining the generator voltage under steady state conditions within plus or minus 1.5% of any set point and within an operating range of plus or minus 5% of the rated voltage of the generator</p> <p>Adopt one of the following grounding methods:</p> <ul style="list-style-type: none"> • Solid grounding • High- or low-resistance grounding • High- or low-reactance grounding • Ground fault neutralizer grounding
Induction Generators	<p>May be connected and brought up to synchronous speed if it can be demonstrated that the initial voltage drop measured at the PCC is acceptable based on current inrush limits</p>
Source: NYS Standardized Interconnection Requirements and Application Process, NYPSC	

2.2.7 24/7 Operation Capability

The project concept envisions the natural gas generators and CHP unit as the main generation source for the community microgrid. Existing natural gas infrastructure at Sunnyside Yard and Penn Station can support continuous operation of the generators, which should always provide enough electricity for the microgrid facilities.⁶ The battery storage unit at the SSY-B footprint can provide temporary backup power if the 8 MW reciprocating generator fails and must be re-started.

2.2.8 Two Way Communication with Local Utility

The new automation solution proposed in this report will serve as a protocol converter to send and receive all data available to the operator over Amtrak's WAN using industry standard protocols such as DNP3, OPC, Modbus, 61850, and ICCP (IEC 60870-6).

2.2.9 Voltage and Frequency Synchronism When Connected to the Grid

Microgrid controllers will automatically synchronize the frequency and voltage of all DER-generated power, which will include several rotating energy sources as well as inverter-based energy sources. Synchronization is key to maintaining a stable power network. The larger grid also requires constant synchronization of energy sources, but its comparatively higher electrical and mechanical inertia filters out most fast dynamics. In contrast, the microgrid will be sensitive to fluctuations in load or generator output. It is therefore crucial to constantly monitor and regulate generator output against aggregate load in real time.

2.2.10 Load Following and Frequency and Voltage Stability When Islanded

The microgrid's control scheme in island mode is quite similar to that of the larger transmission system. The system maintains frequency by controlling real power generation and regulates voltage by controlling reactive power availability. If generation matches the load plus the system losses, system frequency and voltage should stay within acceptable limits. Other factors, such as network topology and the distribution of generation and loads, can also affect the frequency and voltage stability. The Project Team will consider these factors and develop a microgrid design that accounts for them in the next phase of the NY Prize competition. The comparatively small size of the microgrid introduces new dynamics-related issues that will be carefully studied during the engineering design phase.

In island mode, the MCS will maintain control of the generating units to maintain voltage and frequency. In addition, the MCS will combine load shedding and generation control to maintain the demand supply balance.

2.2.11 Diverse Customer Mix

Connected facilities have varying impacts on power quality and stability based on load size and economic sector. The Amtrak-Long Island City microgrid will include Penn Station, Sunnyside

⁶ With the notable exception of the train traction system, as discussed throughout the document.

Yard, LaGuardia Community College, and Middle College High School. The approximate load breakdown by facility for the Sunnyside Yard microgrid is as follows:⁷

- Amtrak Sunnyside Yard – 63.2%
- Amtrak Penn Station – 21.4%
- LaGuardia Community College – 14.1%
- Middle College High School at LaGuardia – 1.3%

Amtrak’s Sunnyside Yard and Penn Station facilities together account for about 85% of microgrid energy consumption. Targeted energy efficiency upgrades at either facility could significantly reduce the microgrid’s average electricity demand, which would increase energy resilience in island mode. See Section 2.2.14 for more details on applicable Con Ed and NYSERDA energy efficiency programs.

2.2.12 Resiliency to Weather Conditions

The microgrid coverage area is exposed to the normal range of weather conditions that affects the Northeastern United States. Extreme weather events include, but are not limited to, torrential rain, snow, and wind that could cause falling objects and debris to disrupt electric service and damage equipment and lives. Sunnyside Yard has experienced significant interruption of service due to storm related and non-storm related events. This includes loss of power for a month because of Hurricane Sandy and a week in 2006 due to wind damage to a transmission line supplying the facility

By implementing line fault notifications and deploying other sensors, microgrid owners can ensure the network is as resilient as possible to storms and other unforeseen forces of nature. The CHP unit will be constructed inside the Amtrak service building next to Penn Station and will therefore be hardened from forces of nature. The two natural gas generators and the energy storage unit at Sunnyside Yard will be placed inside enclosures to keep them safe from extreme weather. If constructed overhead, the new medium-voltage distribution lines may be exposed to severe weather; however, burying these lines underground may represent an insurmountable capital cost. The Project Team will weigh the benefits and costs of overhead and underground line placement during the next phase of the NY Prize competition.

The microgrid’s information technology (IT) system is primarily based on fiber optics with several additional wireless communication components. Each distributed intelligent electronic device (IED) and DER will require a short length of physical wire to connect to the nearest network switch. Network switches will intentionally be placed near the IED or DER they serve, which makes disruption of a wired connection extremely unlikely. In the event an IED loses contact with the MCS, it is programmed to act on predetermined set points.

⁷ Based on each facility’s electricity consumption from 2014.

2.2.13 Black Start Capability

The proposed spinning generators will be equipped with black-start capabilities. If the Con Ed grid unexpectedly loses power, the MCS will initiate island mode by orchestrating the predefined black-start sequence. The CHP unit and natural gas generators will require an auxiliary source of direct current (DC) power to start multiple times in case of failure. They will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. After the 8 MW natural gas generator at the SSY-B footprint is on-line and providing a stable power supply, the MCS will synchronize output from the solar array and storage unit to bring them on-line.

2.2.14 Energy Efficiency Upgrades

EE is critical to the overall microgrid concept. The City of New York has developed an action plan to increase citywide EE which targets a 30 percent reduction in greenhouse gas emissions from energy use in buildings by 2025. The programs will collectively increase energy efficiency, decreasing the energy generation capacity necessary to supply overall load.⁸

LaGuardia Community College has completed various energy efficiency and conservation upgrades such as steam trap replacement, variable frequency drive installation on chillers and pumps, and boiler replacement. Sunnyside Yard and Penn Station have also taken action to increase energy efficiency. EE upgrades at Sunnyside Yard and Penn Station have included installing motion sensors on lighting systems, upgrading heating, ventilation, and air conditioning (HVAC) systems in several buildings, repairing compressor air leaks, and installing web based electricity, natural gas, and water monitoring systems.

At Penn Station, Amtrak is currently conducting an investment grade energy audit to survey all utility related services and equipment in Penn Station and associated assets to create a baseline, and develop Energy Conservation Measures (ECM) that are investment grade. The auditor will evaluate equipment that includes: air compressors & piping, HVAC equipment, pumps, motors, lighting, and tenant related equipment (refrigeration, waste heat, etc.). The auditor will work with Amtrak and NYSERDA to develop custom demonstration projects for ECMs that can use alternative/renewable/novel approaches and equipment. This could include battery storage, ice storage, geothermal, peak shaving, etc.

Existing Energy Efficiency Programs

The project will incorporate Con Ed EE programs to reduce load at existing facilities and will seek to qualify microgrid facilities for NYSERDA funded EE programs.

Applicable EE programs include:

- Con Ed Demand Management Incentives: Con Ed will provide incentives to eligible building owners and building managers for energy improvements that contribute to energy demand reduction of at least 50 kW during peak demand events. Types of projects that are eligible for the increased incentives include thermal storage, battery

⁸ NYC energy efficiency programs can be found at: <http://www.nyc.gov/html/builttolast/assets/downloads/pdf/OneCity.pdf>.

storage, chiller/HAVC/Building Management System (BMS)/control, lighting, DR enablement, and Non- Electric AC installing. Amtrak, LaGuardia Community College, and Middle College High School at LaGuardia may qualify for this program.

- Con Ed programs for Commercial and Industrial Facilities: Con Ed will pay up to 50% of the cost of an energy survey. These programs also offer equipment upgrade incentives and enhanced incentives for new EE technology. Amtrak, LaGuardia Community College, and Middle College High School at LaGuardia may qualify for this program.
- NYSERDA Commercial Existing Facilities Program: This program offers facilities two options for participation. Under the pre-qualified path, NYSERDA will compensate participating facilities up to \$60,000 for qualifying retrofits or EE upgrades (such as lighting; commercial refrigeration; HVAC; and gas equipment upgrades). Facilities can also apply for custom incentives under the performance-based path (if a facility wishes to participate in this path, it is crucial to involve NYSERDA early in the planning and development process). Amtrak, LaGuardia Community College, and Middle College High School at LaGuardia may qualify for this program.

2.2.15 Cyber Security

The microgrid management and control system network data will be fully encrypted when stored or transmitted. Network segmentation by function, network firewalls, and continuous monitoring of data activity will protect the microgrid from cyber intrusion and disruption. Access to the microgrid management and control center will be limited to authorized personnel. Activating and analyzing security logs may provide an additional level of security. The operating system and firewall will be configured to record certain suspicious events, such as failed login attempts.

Because the logical controllers, or IEDs, will be located at or near loads, the distributed equipment will take the IT system to the “edge” of the network, where it may be more vulnerable to hackers. A practical tool to prevent unauthorized access into the IT network is a program called Sticky media access control (MAC). Every network attached device has a media access control MAC interface that is unique to it and will never change. The Sticky MAC program monitors the unique address of the device and its designated network port and disables the port if the device is ever disconnected.

2.2.16 Use of Microgrid Logic Controllers

Microprocessor based IEDs serving as microgrid logic controllers are described below in Section 2.7.1. The role of the IEDs is to provide monitoring and control capabilities of the object being controlled. The Project Team believes this is a required capability for the proposed microgrid.

2.2.17 Smart Grid Technologies

The microgrid will offer a distributed network architecture allowing smart grid technologies to connect to the grid via multiple protocols including DNP3, OPC, Modbus, IEC 61850, ICCP (IEC 60870-6), and more as required. The Project Team believes this is a required capability for the proposed microgrid.

2.2.18 Smart Meters

Facilities in the microgrid coverage area do not have smart meters installed. Smart meters are not required for the proposed microgrid because the control sequence is performed at the feeder level.

2.2.19 Distribution Automation

The automation solution outlined in this study includes IEDs that are distributed at or near individual loads. Their role is to control the load and communicate monitored variables to the control system servers for processing, viewing, and data logging. IEDs can operate based on automated signals from the MCS or pre-programmed independent logic in case of a loss of communication with the MCS. The Project Team believes this is a required capability for the proposed microgrid.

2.2.20 Energy Storage

The SSY-B footprint includes one zinc air battery storage unit, rated at 1 MW/4 MWh. The battery will participate in Con Ed's Commercial System Relief Program from May through September and will shift peak loads at Amtrak facilities to manage time-of-use billing during the remainder of the year. Other possible uses for the battery include energy arbitrage and sale of ancillary services to New York Independent System Operator (NYISO); however, the Project Team determined demand response and time-of-use bill management to be the most lucrative strategies for deployment.

The Con Ed Demand Management incentive program for storage in the NYC area will finance around 60% of the capital cost of the battery storage unit.⁹ The only requirement associated with these incentives is that the battery be available for discharge during peak demand events.

2.2.21 Active Network Control System

The MCS will continuously monitor and control the microgrid in both grid-connected and island modes. Both monitoring and control will be decomposed into central (slow) and distributed (fast) components. A fast and reliable communication network is needed for such a hierarchical approach to be successful. All controllable components will communicate bi-directionally with the MCS via MODBUS, OPC, DNP3, TCP/IP, or other protocols as required. The communication infrastructure will be based on the site's existing fiber optics backbone partitioned using gigabit Ethernet switches owned by Amtrak.

2.2.22 Demand Response

As described above, Con Ed offers two primary DR programs to NYC residents: the CSRP and the Distribution Load Relief Program (DLRP). The programs are available from May through September, and both provide comparatively lucrative capacity payments to participants that can

⁹ Con Ed Demand Management energy storage incentives are due to expire in June 2016, but the Project Team expects they will be extended or replaced by a similar incentive program because Con Ed must still achieve considerable load reduction in the area.

guarantee load reduction.¹⁰ Moreover, by enrolling in three consecutive years upfront, customers can qualify for an additional three year incentive payment.

The battery will bid approximately 800 kW of capacity into Con Ed's Commercial System Relief Program. The MCS also has the capability to participate in DR programs by increasing generator output or curtailing flexible load on a signal from Con Ed. However, it is unlikely to do so because the microgrid generators are anticipated to run nearly at capacity in order to operate at peak economic efficiency, thus limiting the availability of excess capacity. It is unclear whether disconnecting from the larger grid and entering island mode will qualify the microgrid for participation in Con Ed DR programs. Because entering island mode would take both generation and load off the larger grid, the Project Team has assumed Con Ed will not accept island mode as acceptable load reduction for participation in DR programs.

2.2.23 Clean Power Sources Integration

The proposed energy sources—natural gas and solar energy—will provide the microgrid with reliable and relatively low-emission electricity. In the future it may be possible to expand the footprint or generation assets to include additional clean power sources. At that time, the Project Team will consider biomass and fuel cells.

2.2.24 Optimal Power Flow

The Project Team expects the CHP unit will sell power to Con Ed under a long-term PPA, while the generators at the SSY A and B footprints will sell power directly to facilities. The MCS will fully utilize the optimum output of generation sources at the SSY-B footprint at the lowest cost in a unique approach that includes fuel cost, maintenance, and energy cost as part of security constrained optimal power flow (SCOPF). The Penn Station and SSY-A footprints both host only one generator, so SCOPF will not be applicable.

2.2.25 Storage Optimization

The storage system will require intelligent controls to work in unison with the microgrid controls. The MCS will fully utilize and optimize the storage resource by managing the charge and discharge of the system. Possible uses for storage include reducing peak demand, participating in NYISO frequency regulation markets, shifting solar PV output to match aggregate load, and increasing system reliability by providing an energy bank.

2.2.26 PV Monitoring, Control, and Forecasting

The microgrid's PV inverter will usually operate at its maximum power point (MPP) because there is little associated operation and maintenance (O&M) cost. In some rare situations, the PV array might have to reduce its output for load following in island mode or to help frequency control. In such situations, the control is almost exclusively local with the output set point communicated by the central controller. As with other renewable energy sources, power output depends on weather and time of day.

¹⁰ The CSRP offers \$10/kW-month and the DLRP offers \$6/kW-month.

The microgrid power management system includes high resolution solar forecasting. Solar forecasting can increase the value of integrated PV and storage systems by intelligently deploying storage to smooth the natural spikes in the daily PV output curve.

2.2.27 Protection Coordination

Microgrid protection strategies can be quite complex depending on the network topology and distribution of load and generation. The existing protection scheme assumes bidirectional power flow of a certain magnitude in a fully redundant, mesh-type network serving this high density area. The microgrid introduces the possibility of unstable power flow in both grid-connected and island mode, which may complicate the necessary protection strategy. In later phases of this study, the microgrid designer will perform protection studies that account for power flow instability and low fault currents which can occur when the microgrid is operating in island mode.

2.2.28 Selling Energy and Ancillary Services

The Project Team expects the CHP unit will operate continuously, selling electricity to Con Ed at the utility's average local supply price throughout the year. Penn Station will purchase co-generated thermal energy from the CHP unit at a competitive local price. The natural gas generators at the SSY A and B footprints will sell electricity directly to connected facilities at a rate competitive with current purchase prices.

The microgrid's CHP unit and natural gas generators will be technically capable of participating in most ancillary service markets. Most lucrative NYISO ancillary service markets (such as the frequency regulation market) require participants to bid at least 1 MW of capacity. However, the microgrid's DERs will not reliably have 1 MW of capacity available to bid into these markets. Other ancillary service markets, such as spinning and non-spinning reserves, do not provide competitive payments to small scale generators such as the microgrid's 6 MW CHP unit or reciprocating generators. The Project Team has concluded the microgrid most likely will not participate in NYISO ancillary service markets unless the CHP unit or battery storage unit can be expanded.

Overbuilding the CHP unit could provide microgrid owners with interesting options. Penn Station has the capacity to purchase around 450% more steam from CHP unit, and microgrid owners could sell extra electricity capacity into the NYISO frequency regulation or installed capacity (ICAP) (installed capacity) energy markets. Expansive discussion of these programs is outside the scope of this feasibility study, but the Project Team will consider these options in Phase II of the NY Prize competition.

2.2.29 Data Logging Features

The microgrid control center includes a Historian Database to maintain real-time data logs. The Historian Database can also display historical trends in system conditions and process variables.

2.2.30 Leverage Private Capital

The microgrid project will seek to leverage private capital where possible in order to develop components of the microgrid. The Project Team is actively developing relationships with

investors and project developers that have expressed interest in NY Prize. As the project concept matures, the Project Team will continue to engage these groups to better understand how private capital can be leveraged for this specific project. The Project Team currently envisions continuous operation of all included generators and sale of electricity to Con Ed, Amtrak, and possibly the schools located in the SSY-B footprint. Investors will receive revenue from electricity and thermal energy sales and possibly from participation in ancillary service or DR programs. More detail is provided in Section 3.3.3.

2.2.31 Accounting for Needs and Constraints of Stakeholders

Developing the best possible value proposition for the community, utility, local industry, and other community stakeholders is at the center of this feasibility study. The Project Team has engaged with all involved parties to understand their specific needs and constraints. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.2.32 Demonstrate Tangible Community Benefit

The project's success and acceptance rely on its ability to provide benefits to the community. Active participation from the government, utility, and community groups is crucial to designing a microgrid that meets the community's needs. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

Amtrak currently uses a private electrical network that has multiple points of common coupling (PCC) with the main distribution system owned and run by Con Ed. Electricity. Energy from proposed generation assets will replace most of the energy delivered by Con Ed to Sunnyside Yard during grid-connected mode, offsetting the area's total demand. In island mode, proposed DERs will supply Sunnyside Yard's entire non-traction load, partial traction demand, two nearby schools, and both electric and thermal loads at Penn Station.

As described above, the microgrid design includes seven new and existing DERs distributed across three electrical footprints. This section will discuss the benefits of the proposed resources and how they will meet the microgrid's objectives in greater details.

2.3.1 Existing Generation Assets

The current design includes two existing 930 kW diesel generators at Amtrak's Penn Station service building (see Table 3 for details about these assets). These generators will only come online when electricity demand in Penn Station exceeds available capacity from the 6 MW CHP in island mode. Penn Station's electricity demand never exceeded 5.09 MW in 2014, so the Project Team expects limited operation of the existing diesel generators. However, the microgrid may expand in the future to include other facilities around Penn Station, which could drive the Penn Station footprint's peak electricity demand above 6 MW and thus require a higher level operation from the diesel generators.

If the microgrid expands to include facilities that possess backup generators, these backup generators can be connected to the microgrid. Each generator will require grid paralleling

switchgear and controllers to regulate and synchronize the generator’s output. The two existing 930 kW diesel generators and any future diesel backup generators added to the microgrid will only be activated in island mode when aggregate demand exceeds available generation from natural gas generators and renewable energy sources.

Table 3. Existing Distributed Energy Resource

Table describes the existing DERs to be incorporated into the microgrid, including their description, fuel source, capacity, and address.

Name	Description	Fuel Source	Capacity (kW)	Address
<i>Penn Station Footprint</i>				
DER1	Existing Generator at Penn Station	Diesel	930	266 W 31 st St
DER2	Existing Generator at Penn Station	Diesel	930	266 W 31 st St

2.3.2 Proposed Generation Assets

The microgrid design includes five new generation assets, listed in Table 4. Existing natural gas infrastructure at Penn Station and Sunnyside Yard has adequate volume and pressure to support continuous operation of the CHP unit and reciprocating generators, but natural gas lines will need to be extended to reach the proposed DERs.

The 8 MW reciprocating generator at the SSY-B Hz footprint will produce electricity at 60 Hz. In grid-connected mode, this electricity along with the electricity from Con Ed, will be converted to 25 Hz to support Amtrak’s train traction system. In island mode, some power from the 8 MW generator may flow through the converter to the traction system. Some electricity will also bypass the converter and will supply LaGuardia Community College and Middle College High School at 60 Hz.

The CHP unit at Penn Station will operate continuously in grid-connected mode, selling electricity to Con Ed under a long-term PPA (or alternatively sold via bilateral contracts to Amtrak and other users) and selling thermal energy to Penn Station. In island mode the CHP unit will follow Penn Station’s electrical load and will provide a corresponding amount of thermal energy.

The 3 MW reciprocating generator at the SSY-A footprint will supply electricity to Amtrak’s non-traction facilities in both grid-connected and island mode. It will be configured to follow these loads throughout the year.

All generators will be located on Amtrak’s land. The CHP unit will be located in the Amtrak service building across 31st Street from Penn Station.

Table 4. Proposed Generation Assets

Table shows the rating, fuel, and address for proposed generation assets.

Name	Description	Fuel Source	Capacity	Address
<i>Penn Station Footprint</i>				
DER3	Proposed CHP at Penn Station	Natural Gas	6 MW	266 W 31 st St
<i>SSY-A Footprint</i>				
DER4	Proposed at Sunnyside Yard – 60 Hz Substation	Natural Gas	3 MW	43 rd St
<i>SSY-B Footprint</i>				
DER5	Proposed at Sunnyside Yard – 25 Hz Substation	Natural Gas	8 MW	43 rd St
DER6	Proposed Solar PV Array at SSY	Sun Light	200 kW	43 rd St
DER7	Proposed Storage at SSY	Battery Storage	1 MW/4 MWh	43 rd St

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

Most of the electrical load at Penn Station is motor based with considerable reactive power demand. The proposed CHP unit should be able to accommodate the reactive power demand of the fan motors. If necessary, capacitors will be installed to provide appropriate reactive power. The CHP unit will have sufficient capacity to supply the entire load in island mode, which never exceeded 5.09 MW in 2014.

The Sunnyside Yard 25 Hz Traction Substation supplies an electrically isolated traction system with two 138 kilovolt (kV) Con Ed feeders. The peak demand in 2014 was 14.6 MW. However, this “peak” demand figure likely averages an instantaneous peak demand that was higher than 14.6 MW. The traction system normally relies on the large electrical and mechanical energy stored in Con Ed’s grid to absorb demand spikes during train engine starts. It is unlikely that any microgrid-sized DER could power the entire traction system in island mode, but the Project Team expects to devise a solution in Phase II of the NY Prize competition that will allow for operations of trains out of New York City at minimum in an emergency situation. The Project Team sized the proposed 8 MW reciprocating generator to provide maximum support to Con Ed in grid-connected mode (the 25 Hz substation has a maximum capacity of 8 MW).

The proposed 3 MW reciprocating generator at the SSY-A footprint is sized to supply non-traction electricity demand at Sunnyside Yard. This is also an isolated network and the proposed generator will be capable of supplying the load during grid-connected and island operations. The generator will be configured to follow non-traction load throughout the year.

The CHP unit will be constructed inside the Amtrak service building across from Penn Station, and the natural gas generators and storage unit will be constructed inside weather-proof enclosures. These structures should ensure that the generators are safe from extreme weather events. The natural gas pipeline is buried to protect it from severe weather.

The proposed CHP unit and natural gas generators will be capable of supplying reliable electricity by providing:

- Automatic load following capability – the generators will be able to respond to frequency fluctuations within cycles, allowing the microgrid to balance demand and supply in island mode.

- Black-start capability – the generators will have auxiliary power (batteries). At the SSY-B footprint, after the 8 MW reciprocating generator has established stable power flow, the main microgrid controller will synchronize the solar array and storage unit inverters to match the generator’s frequency and phase.
- Conformance with New York State Interconnection Standards.¹¹

The New York State Public Service Commission publishes Standardized Interconnection Requirements (SIR) for distributed generators smaller than 2 MW. Although the proposed natural gas generator at the SSY-A footprint is larger than 2 MW, generators that are close to 2 MW (approximately 2-4 MW) still usually follow NYPSC SIR. A recent proposal to modify the New York SIR to include generators up to 5 MW has not yet been approved. As a result, it is assumed the proposed 3 MW reciprocating generator unit will likely need to follow the normal New York State SIR.

The 8 MW reciprocating generator and 6 MW CHP unit will likely need to follow the Federal Energy Regulatory Commission (FERC) Small Generator (2-20 MW) Interconnection Procedure and Small Generator Interconnection Agreement.¹² The Small Generator Interconnection Procedure requires that interconnection be evaluated under defined study process that includes a scoping meeting, a feasibility study, a system impact study, and a facilities study. The Small Generator Interconnection Agreement governs the responsibility, operation obligation, reactive power requirement, and metering rule and cost of applicable small generating facilities.

2.4 Load Characterization (Sub Task 2.2)

The loads considered for inclusion in the microgrid consist of three distinct types differentiated by their use. The largest portion of the electricity demand goes to 25 Hz train traction systems. Because of its technical properties the traction system is supplied by two 138 kV high voltage lines. The rest of the demand is split between the operations demand (60 Hz facilities, including Penn Station, Amtrak’s non-traction facilities, and the schools) and thermal demand (steam at Penn Station). The Project Team sized proposed DERs to match electrical demand and allow for natural load growth at Amtrak and Sunnyside Yard’s facilities and train systems. The load characterizations below describe the electrical loads and thermal load served by the microgrid. Descriptions of the load sizes to be served by the microgrid along with redundancy opportunities to account for downtime are included below.

2.4.1 Electrical Load

The Project Team evaluated three Amtrak facilities and two local schools as the primary electrical loads for the Amtrak microgrid. Table 5 lists included facilities and Figures 1a and 1b provide their locations on a map.

¹¹ New York State Public Service Commission. Standardized Interconnection Requirements and Application Process for New Distributed Generators 2 MW or Less Connected in Parallel with Utility Distribution Systems (2014). Available from www.dps.ny.gov.

¹² FERC guidelines can be found at: <http://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp>.

Table 5. Prospective Microgrid Facilities and Train Traction Systems

Table lists the facilities and train traction systems included in the Sunnyside Yard proposed microgrid, including their classifications.

	Property	Address	Classification
<i>Penn Station Footprint</i>			
1	Amtrak’s Penn Station	266 W 31 st St	Federal
<i>SSY-A Footprint</i>			
2	Amtrak’s Sunnyside Yard Facility	43 rd St	Federal
<i>SSY-B Footprint</i>			
3	Amtrak’s Train Traction System at Sunnyside Yard	43 rd St	Federal
4	LaGuardia Community College	3110 Thomson Ave	School
5	Middle College High School at LaGuardia	3101 Thomson Ave	School

The microgrid’s DERs will be able to supply the microgrid’s entire non-traction load and partial traction loads in island mode. In grid-connected mode, the DERs will support the traction system and will relieve some of the congestion Con Ed experiences in the area. New generation and new community loads may be added incrementally to the microgrid in the future, which would require a concomitant extension of the microgrid’s communication and control infrastructure. However, governed by existing in-line electrical equipment ratings, the electrical infrastructure at the SSY-B footprint cannot support more than 8 MW of power. Future engineering studies will reveal a solution that would allow partial operation of the traction system in island mode or some combination of various generation assets in different locations to fully support the entire traction system in islanded mode.

After extensive consultation with Con Ed representatives, the Project Team has determined new distribution lines will be necessary to connect LaGuardia Community College and Middle College High School to the SSY-B footprint. Figures 1a and 1b provide an illustration of the proposed microgrid design and layout, including loads, existing electrical infrastructure, and proposed electrical infrastructure.

Figure 1a. Penn Station Equipment Layout

Figure shows the microgrid equipment layout, illustrating DERs, distribution lines, load points, and network switches for Penn Station.

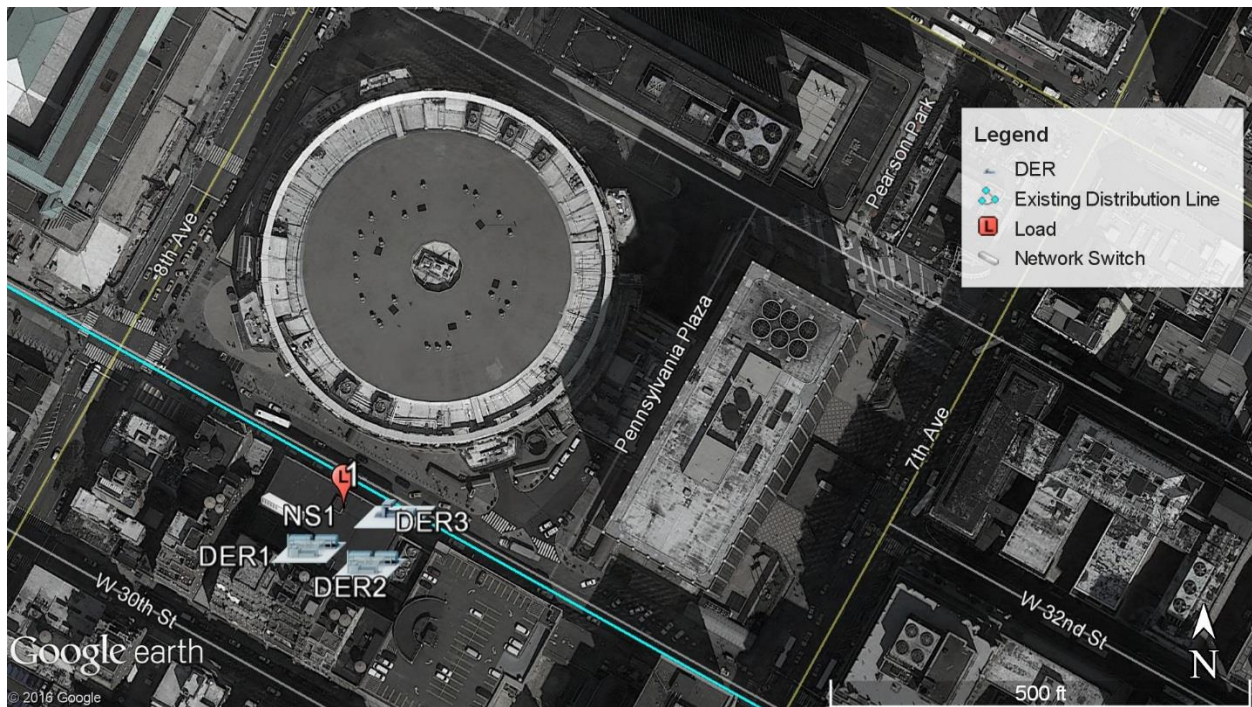
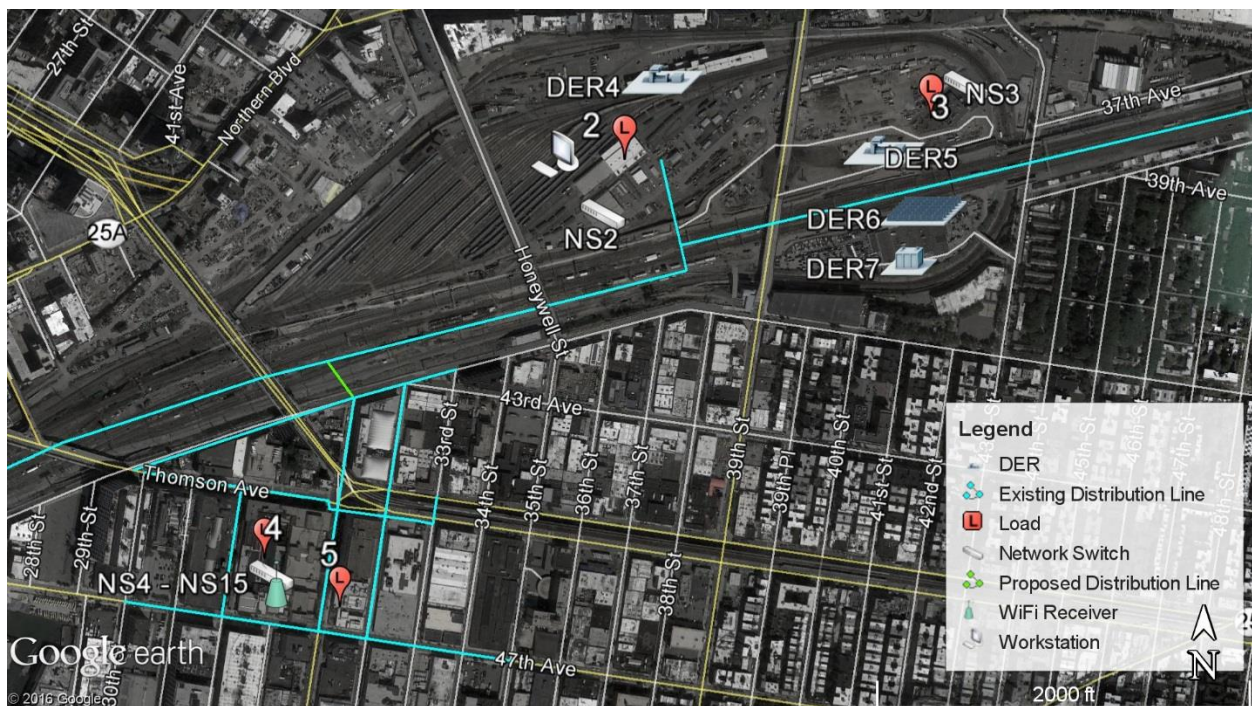


Figure 1b. Sunnyside Yard Equipment Layout

Figure shows the microgrid equipment layout, illustrating distributed energy resources, existing and proposed distribution lines, load points, servers and workstations, and network switches for Sunnyside Yard.



Con Ed provided the Project Team with twelve months of metering data, including hourly metering data where possible,¹³ for connected facilities (January through December 2014, summarized in Table 6). The Penn Station footprint’s aggregate peak load in 2014 was 5.088 MW, and the monthly average was 3.053 MW. The SSY-B footprint’s aggregate peak load in 2014 was 19.43 MW, and the monthly average was 9.929 MW. The SSY-A footprint’s aggregate peak load in 2014 was 2.86 MW, and the monthly average was 1.332 MW. The typical 24-hour profiles of the electrical loads for each facility can be found in the Appendix.

The Project Team did not have access to real-time power demand measurements and instead approximated power by averaging energy consumption over a period of time, usually 15 minutes or an hour. This averaging process flattens instantaneous real and reactive power peaks, which must be accounted for in the microgrid design process. The train traction system supplies electrical trains that draw large amounts of real and reactive power upon acceleration—the associated instantaneous spikes in power demand are flattened by the averaging process described above and are therefore not fully captured in Table 6.

The 8 MW reciprocating generator will be used to offset traction system demand during grid-connected operations. However, additional engineering analyses will need to be performed to determine exactly how the microgrid DER can power the traction system during islanded operation. The dynamic interactions between the traction system load and generation, especially PV inverters, should be carefully investigated in the next stage of the project.

Table 6. Sunnyside Yard’s 2014 Microgrid Load Points

Table shows the microgrid electric demand in kW, electric consumption in kilowatt hour (kWh), and thermal consumption in MMBTU.

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Figure 2 provides a typical aggregate hourly load profile for the three footprints of the proposed microgrid. The typical daily load patterns for loads in the Penn Station and SSY-A footprints are relatively flat. However, the SSY-B footprint’s typical load profile is more dynamic: load gradually increases from the night-time baseline around dawn, stays high throughout the day, and slowly decreases back to the night-time baseline from 16:00 to 20:00.

¹³ The team simulated hourly metering data for LaGuardia Community College, and Middle College High School at LaGuardia using their monthly data due to existing meter system malfunction.

Figure 2. Typical 24-Hour Cumulative Load Profile from 2014 Metering Data

Figure illustrates the typical 24-hour cumulative load profile. The figure represents the sum of individual facility typical 24-hour load profiles from 2014.¹⁴

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The electrical load at the Penn Station footprint includes tunnel lighting, chillers, and fans, which are electrical induction motors. Motors can draw high reactive power, resulting in a low power factor, for at least short periods of time during startups. The proposed CHP unit should be able to accommodate the reactive power demand of the fan motors. If necessary, capacitors will be installed to provide appropriate reactive power.

The proposed 6 MW CHP unit will operate continuously in both grid-connected and island mode throughout the year. It has sufficient electrical generation capacity to supply all of the Amtrak loads in the Penn Station footprint, where aggregate demand averaged 3.053 MW and never exceeded 5.088 MW in 2014.

The electrical load at the SSY-B footprint includes the large Amtrak traction system, LaGuardia Community College, and Middle College High School at LaGuardia. The train traction system has an average load of around 7.729 MW, but experiences instantaneous spikes of at least 15 MW when the trains accelerate. The electrical and mechanical energy stored in the large Con Ed grid can absorb the spikes caused by the train traction system, but the relatively small microgrid DERs do not have comparable inertia to overcome such disturbances. It is unlikely microgrid-sized generation assets will ever be able to power Amtrak's entire traction system in island mode, but the Project Team expects to develop a solution in the next phase of the NY Prize competition that will allow operation in an emergency. Some thoughts on how this might be achieved can be found in Section 2.7.4 Islanded Mode Control.

The 8 MW reciprocating generator at the SSY-B footprint was sized to provide maximum support to the train traction system in grid-connected mode. Under the current design, the 8 MW generator powers the traction system, LaGuardia Community College and Middle High School in island mode. Combined demand from LaGuardia Community College and Middle College High School averaged 2.199 MW and never exceeded 4.859 MW in 2014.¹⁵ Supported by a 200 kW PV array and a 1 MW battery unit, the 8 MW reciprocating generator should have the capacity to supply the loads with electricity in island mode.

The electrical load at the SSY-A footprint includes lighting, air condition, and other uses for buildings and non-traction facilities at Amtrak's Sunnyside Yard. The proposed 3 MW natural

¹⁴ As discussed throughout this section, the instantaneous peaks that the traction system experiences are flattened by hour long measuring intervals. See the Appendix for a properly scaled load profile for the traction system.

¹⁵ This number represents the highest aggregate monthly peak demand from 2014. Monthly peak demand was calculated by summing individual facilities' peak demand for the month. The final peak demand therefore assumes that facilities reached their individual monthly peak demands simultaneously, which is unlikely. The true peak demand was almost certainly less than 4.859 MW, but the Project Team was unable to obtain synchronized real-time load data for all included facilities.

gas generator will operate continuously in both grid-connected and island mode throughout the year. Aggregate demand from microgrid facilities averaged 1.32 MW and never exceeded 2.86 MW in 2014. The proposed 3 MW natural gas generator should therefore have adequate capacity to supply the microgrid facilities with electricity in island mode.

The Project Team expects some degree of natural load growth after construction of the microgrid. Because generators are sized to approximately match current facility demand, significant load growth could threaten the reliability of the microgrid's electricity supply in island mode. Microgrid facilities can mitigate this threat by investing in EE upgrades or intelligent building energy management systems (BEMS) that respond to commands from the main microgrid controller.

2.4.2 Thermal Consumption

Penn Station currently represents the only thermal load in the microgrid. Adding CHP capability to a natural gas generator greatly increases its efficiency. However, producing both thermal energy and electricity can complicate the generator's optimal operating strategy. DER operations can be optimized to follow electrical load, thermal load, or a combination of the two. The CHP unit at Penn Station will most likely be configured to follow electrical load in island mode, and will operate continuously in grid-connected mode, optimized for thermal load.¹⁶

Penn Station's annual thermal energy consumption is around 395,159 million British thermal units (MMBTUs) (shown in Table 6 above). The proposed CHP unit will produce approximately 63,360 MMBTUs of steam per year, which represents around 16% of Penn Station's annual thermal load on average. Steam demand at Penn Station varies significantly throughout the year—the proposed CHP unit will provide up to 60% of the facility's thermal energy in the summer months (see Figure 3). The Penn Station steam demand (load) is significantly higher than the proposed output of the CHP unit. Therefore, there is some opportunity to increase the size of the CHP unit for increased production and sale of steam should additional electricity generation capacity be required, creating a potential future option for expansion. The Project Team also evaluated thermal energy consumption at Amtrak's Sunnyside Yard, LaGuardia Community College, and Middle College High School at LaGuardia and found that none have continuous steam demand.

Figure 3. Penn Station Thermal Consumption

Figure shows Penn Station's thermal consumption (steam) for 2014 and approximate thermal output (steam) from continuous operation of the CHP unit (projected grid-connected operation strategy). Note: 1 MMBTU = 1,000,000 BTUs

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¹⁶ Assuming microgrid owners negotiate a long-term PPA with Con Ed.

2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1)

The existing distribution system infrastructure will be expanded and modified to accommodate microgrid operations. The microgrid will support two fundamental modes of operation: grid-connected (normal or grid paralleling) and island (emergency, or intentional) modes. During grid-connected operation, DERs will support microgrid loads and may have some capacity to feed excess power into the Con Ed grid. In island mode, DERs will maintain limited operation power to traction loads and will also power all non-traction systems.

The transition to island mode can be unintentional, essentially as a pre-programmed response to an unexpected outage on the larger grid, or intentional, to improve power reliability during a forecasted outage or provide economic benefits. The natural gas generators and battery storage unit will have black start capabilities to restart power after an unintentional switch to island mode, and will maintain adequate frequency and voltage across the system based on control signals from the MCS. Intentional islanding will not require black start capability as there will be no service interruption. The infrastructure and operations of the proposed microgrid are described below.

2.5.1 Grid Parallel Mode

The microgrid will most often operate in grid-connected mode. In this mode, the proposed DERs will operate continuously (refer to Table ES-2 for a complete list of microgrid DERs). The 6 MW CHP unit at Penn Station will sell electricity to the Con Ed grid, the 8 MW reciprocating generator will support Sunnyside Yard's 25 Hz traction system, and the 3 MW reciprocating generator will supply power to Sunnyside Yard's 60 Hz facilities. Output from the solar PV array and battery storage unit will be intermittent throughout the year. The battery unit may be used for support of the traction system, peak demand charge reduction, frequency regulation, or shifting solar production. Backup diesel generators will not come online in grid-connected mode.

The 8 MW reciprocating generator at the SSY-B footprint will provide power to the train traction system in grid-connected mode. The generator will produce power at 60 Hz, but will feed power to the Amtrak 25 Hz traction system through converters when serving the traction system in grid parallel mode.

If the main grid experiences unforeseen fluctuations in electricity demand or supply, it risks losing stability and possibly losing power. While operating in grid-connected mode, the microgrid may be able to provide spinning reserves or auxiliary power services. The fast ramping natural gas generators and battery storage unit can improve the main grid's frequency and voltage stability. A reliable communication channel between the utility and the microgrid control center should be established to make the microgrid operator aware of the larger grid's condition and vice versa, but contractual agreements between the utility and the microgrid operator will determine the extent of control the utility has over the assets.

2.5.2 Intentional Islanded Mode

The proposed energy management and control scheme will balance generation with microgrid demand and maintain adequate frequency, voltage, and power flow across the microgrid network in island mode. Island mode can be intentionally used during forecasted Con Ed grid outages or disturbances to maintain electricity supply for microgrid facilities—the system will manage the generation to match aggregate demand in real time. At the SSY-B footprint, the 8 MW reciprocating generator and 1 MW battery storage unit will provide flexible real-time response to changes in the traction system demand and the loads at LaGuardia Community College and Middle College High School. The proposed battery unit can also smooth the solar array's daily output by strategically charging and discharging throughout the day. Refer to the simplified one-line diagrams (Figure 4 to Figure 9) for detailed device representations showing both existing and proposed generation assets and their utility interconnection points.

2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)

This section describes the electrical and thermal infrastructure of the proposed microgrid. The infrastructure resiliency, the PCC, and the proposed utility infrastructure investment are also discussed below.

2.6.1 Electrical Infrastructure

Amtrak's existing electrical infrastructure at Sunnyside Yard and Penn Station will support Amtrak loads and will connect them to proposed generation assets. The specific network topology in the area is conducive to three separate microgrid footprints: the Penn Station footprint, the SSY-A footprint, and the SSY-B footprint. DERs at the SSY A and B footprints will be connected at the 60 and 25 Hz substations (electricity is delivered to both at 60 Hz; frequency converters are located at the 25 Hz substation).

Amtrak owns the electrical distribution system in the Penn Station footprint, which normally receives power from three Con Ed feeders at 13.2 kV. After power passes through the Con Ed meters, it is directed through Amtrak's Primary Power Distribution Switchboard (PPDS) where Amtrak distributes the incoming power to several substations that serve chillers, and tunnel fan plants. The PPDS is located inside the Amtrak service building across 31st Street from Penn Station, which is the proposed location for the CHP unit. The electrical one-line diagram for the PPDS is shown in Figure 4.

The two existing diesel generators are connected to the electrical line for chillers in Figure 5. There are also several automatic transfer switches (ATS) connected to the emergency distribution switchboard at the service building. These ATS's currently control backup power flow to loads at 7th Avenue vaults and 8th Avenue vaults in Penn Station. The proposed microgrid can leverage these existing connections to serve loads at the 7th and 8th Avenue vaults. These connections are shown in Figure 6.

Tables 7 and 8 describe the microgrid components and are referenced throughout the rest of the document.

Table 7. Sunnyside Yard’s Network Switch Description

Table outlines all fifteen IT network switches with their descriptions, status as existing or proposed, and approximate location.

Name	Description	Status	Address
NS1	Near Penn Station for communication	Proposed	266 W 31st St
NS2	Near DER4 for communication	Proposed	43 rd St
NS3	Near DER5, DER6, and DER7 for communication	Proposed	43 rd St
NS4 - NS15	Near LaGuardia Community College and Middle College High School at LaGuardia for communication with IED isolation switches on feeder	Proposed	Refer to Eqp. Layout

Table 8. Sunnyside Yard’s Server Description

Table describes the workstation and servers, their status as proposed, and their addresses. The Project Team has assumed that the servers will be placed in a safe, enclosed building on Amtrak’s Sunnyside Yard land. It is also possible these servers will be virtualized as an image on a rack-mounted server in a local data center. The placement of the microgrid servers and workstation may change as the ownership structure is decided.

Name	Description	Status	Address
Workstation	Operator/Engineer workstation	Proposed	43 rd St
Server1	Primary Energy Management System (EMS) and Supervisory Control and Data Acquisition (SCADA)	Proposed	43 rd St
Server2	Secondary EMS and SCADA	Proposed	43 rd St

All loads have their own transformers to step incoming power (13.2 kV) down to low voltage (480/277 V).

Figure 4. Penn Station PPDS One-Line Diagram

Figure displays a one-line diagram for Penn Station PPDS illustrating interconnections and lay-out.

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Figure 5. Penn Station Chiller Plant One-Line Diagram

Figure displays a one-line diagram for Penn Station chiller plant illustrating interconnections and lay-out.

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Figure 6. Penn Station Service Building Emergency Switchboard One-Line Diagram

Figure displays a one-line diagram for Penn Station Service Building Emergency Switchboard illustrating interconnections and lay-out.

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Amtrak owns the electrical distribution system for traction and non-traction proprietary loads in the SSY A and B footprints. However, there is currently no distribution system that can connect the proposed DERs to LaGuardia Community College and Middle College High School. New medium-voltage distribution lines will be necessary to connect the schools to the existing Amtrak network. Since the existing Con Ed distribution system is fully meshed (redundant) and quite complex in this high density area, more detailed studies will need to be performed in Phase II of the NY Prize competition.

The traction system at the SSY-B footprint receives power from two Con Ed feeders isolated from the rest of the Sunnyside network (refer to Figure 7 for more details). The feeders supply four frequency converters that convert incoming power to 25 Hz. The traction system uses 25 Hz power because higher torques are attainable at lower frequencies. As discussed throughout this document, a strong power network with large-scale generation and electrical inertia is necessary to power the entire traction system. In island mode, the proposed 8 MW reciprocating generator cannot cope with transients caused by electrical train engines at start up, but the Project Team is exploring alternatives that may allow limited operation of the traction system to at least enable trains to get from SSY to the New Jersey border, above ground, past the tunnel. The current design proposes sending power from the 8 MW generator to the traction system in grid-connected mode and to the schools in island mode. In grid-connected mode, power from the reciprocating generator will flow through the existing frequency converters to supply the traction system. The electrical infrastructure and connection for these system are shown in Figure 7 and Figure 8.

The SSY-A footprint includes Amtrak's non-traction facilities. These facilities include the commissary, storage room, block house, and other support and maintenance structures. The proposed 3 MW natural gas generator will be connected to the existing 13.8 kV bus via pad mounted equipment (PME) and will supply the SSY-A footprint's loads in both grid-connected and island mode. The electrical infrastructure and connection for these system are shown in Figure 9.

Figure 7. Amtrak Sunnyside Yard Train Traction Electrical System One-Line Diagram

Figure displays a one-line diagram for Amtrak Sunnyside Yard Train 25 Hz Traction Electrical System illustrating interconnections and lay-out.

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Figure 8. High School and College Distribution System One-Line Diagram

Figure displays a one-line diagram for electrical distribution system of LaGuardia Community College, and Middle College High School at LaGuardia illustrating interconnections and lay-out.

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Figure 9. Amtrak Sunnyside Yard 60 Hz Substation One-Line Diagram

Figure displays a one-line diagram for Amtrak Sunnyside Yard 60 Hz Substation illustrating interconnections and lay-out.

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2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The proposed components and interconnection points for the Amtrak-Long Island City community microgrid are listed in Table 9. The PCC between the main grid and the Penn Station footprint will be located at the three utility breakers behind Con Ed meters in Figure 4. The PCC between the main grid and the SSY-B footprint will be located at the two utility breakers behind Con Ed meters in Figure 7. The PCC between the main grid and the SSY-A footprint will be located at the utility breakers behind the step down transformers in Figure 9. All of these utility breakers will be upgraded to respond to signals from the MCS.

The microgrid will rely on automated switches across Amtrak's distribution system to segment loads, which is required for precise microgrid control and reliability. This segmentation is critical to provide voltage and frequency control within the millisecond response intervals required for maintaining a stable microgrid and serving multiple loads using distributed generators. The microgrid also includes multiple automated switches to isolate LaGuardia Community College and Middle College High School from Con Ed's distribution system. All the switches controlled by MCS, either existing or proposed are described in Table 10.

Table 9. List of Components

Table lists all the distribution devices/components included in the microgrid design.

Device	Quantity	Purpose/Functionality
Microgrid Control System Protocol Converter (Siemens SICAM PAS or equivalent) and centralized generation synchronizer (EasyGen Woodward or equivalent)	1 Primary 1 Back-up	Protocol Converter responsible for operating the Microgrid’s field devices via protocol IEC-61850, MG sequence of operations, etc. The centralized synchronizer coordinates voltage and frequency from multiple generation sources and synchronizes their outputs
Automated Circuit Breaker/Switches (Siemens 7SC80 relay or equivalent)	41	New switches/breakers with relays/controllers. Existing breakers can be upgraded for remote control/monitoring. These components will isolate microgrid from utility grid, or downstream loads
Generation Controls	5	OEM Generation controllers serve as the primary resource for coordinating generator ramp up/ramp down based on external commands and reaction to Microgrid load changes which work with a centralized generation synchronizer
PV Inverter Controller (OEM Fronius or equivalent)	1	Controls PV output and sends live solar/power output data to SCADA and EMS for forecasting/decision making input
Storage Inverter Controller	1	Controls battery storage input/output and sends live power data to SCADA and EMS for forecasting. Receives charge/discharge commands from SCADA Microgrid control
Network Switch (RuggedCom or equivalent)	15	Located at IEDs and controllers for network connection, allowing remote monitoring and control

Table 10. List of Automated Switches

Table lists all the distribution automated switches and its functionality in the microgrid design.

Switch Number	Existing/ Proposed	Functionality
<i>Penn Station Footprint</i>		
SW1, SW3, and SW5	Existing	Utility Breakers (PCC) for Penn Station Footprint
SW2, SW4, and SW6	Existing	Transformers Protection Switches
SW7	Proposed	CHP Generator Control Switch
SW8 to SW26	Existing	Load Segment Control Switch
SW27 and SW28	Existing	Diesel Generators Control Switch
<i>SSY-B Footprint</i>		
SW29	Proposed	Storage Unit Control Switch
SW30	Proposed	Solar PV Array Control Switch
SW31 and SW32	Existing	Utility Breakers (PCC) for SSY-B Footprint
SW33	Proposed	Load Segment Control Switch for Connection to Two Schools
SW34	Proposed	Natural Gas Generator Control Switch
SW35	Existing	Load Segment Control Switch for Train Traction System
SW39 to SW50	Proposed	Distribution Switches for microgrid Isolation
<i>SSY-A Footprint</i>		
SW36 and SW37	Existing	Utility Breakers (PCC) for SSY-A Footprint

SW38	Proposed	Natural Gas Generator Control Switch
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All microgrid devices will require a reliable source of DC power. Each device (or cluster of devices) will have a primary and backup power supply source. During normal operation, a 120 volt alternating current (VAC) power source will power an alternating current (AC)/DC converter to power the microgrid devices and maintain the charge of the DC battery banks. The device current draw (amperage used by each device) should not exceed 60% of the available power supply. When the normal AC voltage source is unavailable, the battery bank can provide DC power to devices for at least one week.

2.6.3 Basic Protection Mechanism within the Microgrid Boundary

The power protection system monitors grid variables, including voltage, current, and frequency, and takes necessary actions (such as de-energizing a circuit line) to maintain these variables at appropriate levels. Currently, protection schemes are based on the assumption that power flows are bidirectional. At a later design stage, protection studies accounting for the key characteristics of island mode will have to be performed, which include bidirectional power flow stability and very low fault current detection.

The current design includes controls that can prevent back-feeding of power to the larger Con Ed grid. However, the microgrid is capable of exporting energy back to Con Ed.

2.6.4 Thermal Infrastructure

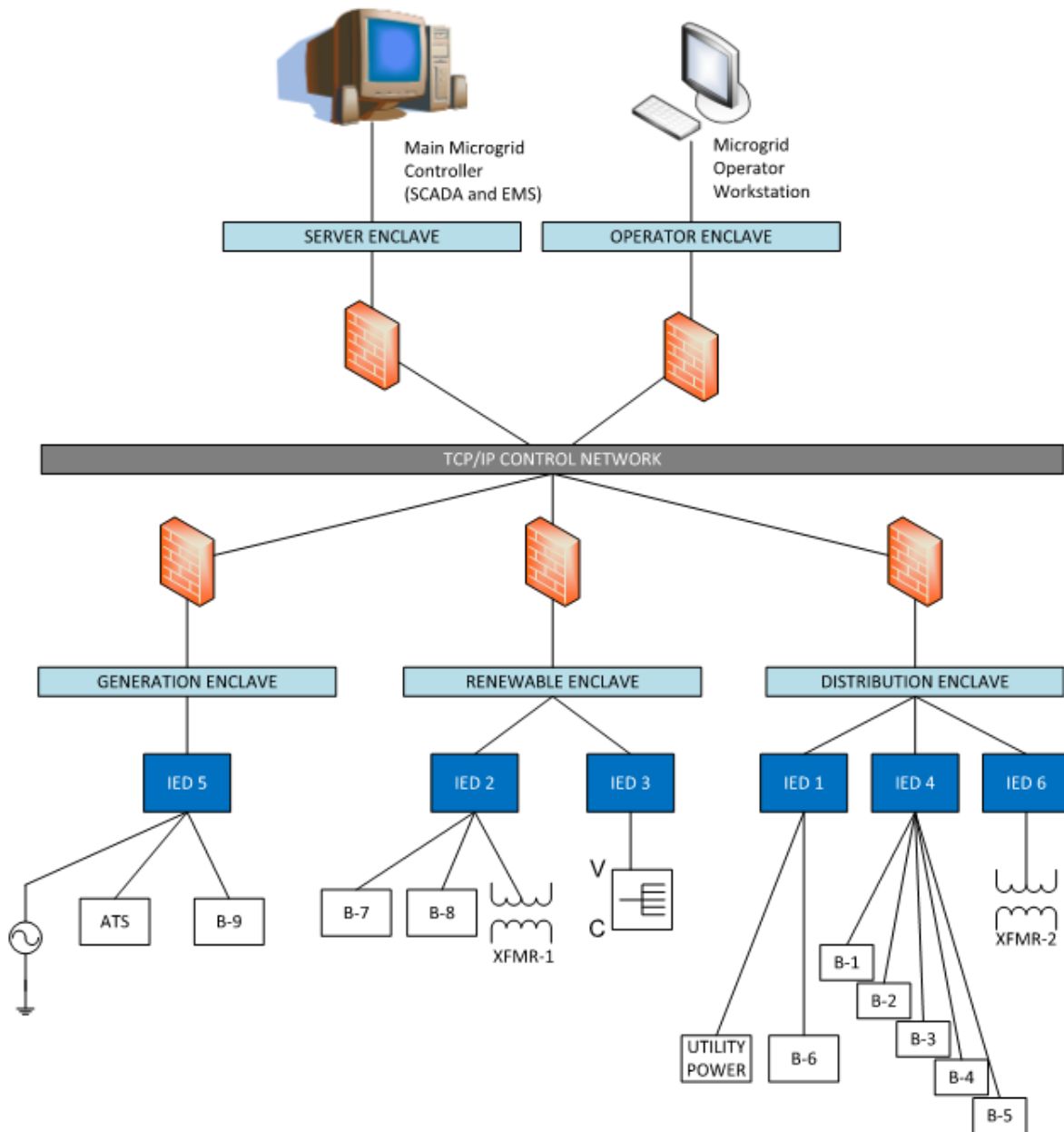
The proposed CHP unit and natural gas generators will require steady supplies of natural gas to operate continuously. Existing natural gas lines will provide adequate volume and pressure—50,000 cubic feet per hour at 3 pounds per square inch gauge (psig)—but will need to be extended to reach the proposed DERs. The CHP at Penn Station will require an extension of around 500 feet from the existing natural gas line on 7th Avenue. The existing gas line on 37th Street and Skillman Avenue will need to be extended by around 1,600 feet to reach the proposed 3 MW and 8 MW reciprocating generators.

2.7 Microgrid and Building Control Characterization (Sub Task 2.5)

This section provides a more detailed description of the microgrid's modes of operation. The microgrid control system will include an EMS and a SCADA based control center (see Figure 10), hereafter collectively referred to as the main microgrid controller. Distributed IEDs will communicate with the main microgrid controller over Amtrak's Transmission Control Protocol/Internet Protocol (TCP/IP) network. In grid-parallel mode, the microgrid will synchronize frequency and voltage magnitude with the larger grid and will have the potential to export excess electricity to Con Ed. When controllers detect an outage or emergency disturbance on the larger grid, the microgrid will switch to island mode. In these situations, the microgrid will disconnect from the larger grid and proceed with the programmed black-start sequence (described in Section 2.7.7) to start power flow through included lines and devices. When power returns after an outage, the main microgrid controller will manage re-synchronization to the Con Ed grid (described in Section 2.7.8).

Figure 10. Diagram of Representative Microgrid Control System Hierarchy

The following network diagram illustrates a conceptual microgrid control network with a generator, breakers, transformers, an ATS, IEDs (which could be actuators, Meters, Accumulators, or programmable logic controller (PLCs)), a renewable energy source, and the Main Microgrid Controller with SCADA and Energy Management System (EMS) server and client workstation node.



2.7.1 Microgrid Supporting Computer Hardware, Software and Control Components

The following is a preliminary list of hardware components needed for the Sunnyside Yard microgrid:

- Energy sources – The microgrid requires DERs in order to supply electricity to connected facilities. To some degree, flexible loads that can be reduced during peak demand events may also be considered as energy sources.
- Microgrid Control System – The MCS is composed of an energy management system (EMS) and SCADA based control center. The MCS is responsible for logging relevant data, regulating generator output, curtailing flexible loads (where possible), and managing transitions between modes of operation.
- Distribution system breakers, switches and controls – Distributed equipment is crucial to forming a microgrid from a non-contiguous set of loads.
- Utility breakers and controls – These controls interface between the Amtrak electric grid and the Con Ed medium voltage feeders at Penn Station and the high voltage feeders into Sunnyside Yard.
- New electric distribution lines – New medium-voltage distribution lines will be necessary to pick up LaGuardia Community College and Middle College High School at LaGuardia.
- Generator and storage controls/relays – These components will be installed at each generator and storage unit/inverter. They will control generator output based on signals from the MCS.

The proposed system uses a Service Oriented Architecture (SOA) software platform that will serve as the messaging and integration platform for the monitoring and control of distributed equipment. The SOA system supports almost any power device or control system from any major vendor and therefore ensures communication networkability and interoperability between competing vendor systems. The computer hardware and software required for a fully automated operational microgrid design are as follows:

- SOA software platform – The SOA platform facilitates the monitoring and control of included power devices and control systems.
- Two Redundant Array of Independent Disks (RAID) 5 servers (including 1 primary, 1 backup) for the MCS – The MCS will include an EMS and a SCADA based control center, and will optimize the operation of the microgrid. This includes determining which critical loads will be supplied, integrating PV output into the energy portfolio (including high resolution solar forecasting), and controlling the charge/discharge of energy storage units. The system combines information on power quality, utilization, and capacity in real time, which allows the community and control algorithms to balance electricity supply with microgrid demand.
- Historian database server – Historian database collects and logs data from various devices on the network.

- Applications server (one or more) – Depending on the software and hardware vendors’ preference, application servers may be used for numerous purposes. Common uses for an application server include, but are not limited to, backup and recovery, antivirus, security updates, databases, a web server, or used as some other software depending on how the SCADA and EMS vendors configure their platform.
- Operator workstations for SCADA and EMS – Workstation computers, sometimes called thin-clients, allow operators to view real-time data and control the microgrid from the SCADA control room or a remote location. Users must have proper access rights and permissions to operate workstation computers.
- Intelligent Electronic Device distribution switches: Automated circuit breaker/switch (Siemens 7SC80 relay or equivalent) – The microprocessor based logic controllers in the field (also referred to as IEDs) are programmed to act on predetermined set points. They can also be manually overridden by the MCS or a human operator. The control system host servers continuously poll these logic controllers for data using discrete or analog signals. Resulting data is processed by the IEDs connected to control elements.
- Pad Mount Equipment (PME) (Siemens 7SJ85 multi breaker control relay or equivalent) – The PME, which includes switches and fuses, can be updated remotely via MCS or automatically change state by sensing variables and acting on predetermined set points.
- PV and Storage Inverter Controller (Original equipment manufacturer Fronius or equivalent) – This component will control PV and storage unit output and send data to the MCS for forecasting.

Use of the listed hardware, software, and resources must be synchronized to maintain stable and reliable operation.

2.7.2 Grid Parallel Mode Control

When the microgrid operates in grid-connected mode, every generator will synchronize its voltage (magnitude and phase) and frequency with the voltage (magnitude and phase) and frequency of the electrically closest main grid point. After initial synchronization, the generator voltage phase will drift away from the main grid’s voltage phase, which will allow the flow of active and reactive power. The generator’s voltage magnitude and frequency will be maintained as close as possible to the main grid’s voltage magnitude and frequency. During grid parallel mode, generation assets will follow the Institute of Electrical and Electronics Engineers (IEEE) 1547 standard for interconnecting distributed resources with electric power systems. The IEEE 1547 and other DER interconnection standards required by utilities are applicable to synchronous, asynchronous, and inverter-based generation.

A utility might have additional technical and economic requirements if the microgrid plans to export energy or provide ancillary services to the distribution grid. Because of the complex, fully meshed Con Ed’s distribution system, back feeding into the Con Ed grid will require more detailed studies in the next stage of the NY Prize competition.

The proposed CHP unit and natural gas generators are capable of providing ancillary services to Con Ed's grid to enhance the reliability of the system. They can provide reactive power and frequency response services on demand, but providing reactive power support may diminish each rotating generator's ability to generate real power.

2.7.3 Energy Management in Grid Parallel Mode

The proposed microgrid will integrate software and hardware systems to ensure reliability and effective performance. Optimization of microgrid performance involves three distinct phases: measurement and decision, scheduling and optimization, and finally execution and real time optimization.

Data logging features will allow the main microgrid controller to measure historical performance and track significant trends. Human operators can use this data to prioritize loads, manage generator output, and schedule maintenance for generators and microgrid components. The microgrid executive dashboard will collect and filter information on the current operating strategy as well as performance metrics for SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), and CAIDI (Customer Average Interruption Duration Index), all adjusted to reflect the high sampling frequency of the system. Other performance metrics include power interruptions (defined as 50% variance of predicted voltage to measured voltage for 10 minutes or longer), voltage violation (defined as variance of actual voltage to predicted voltage for 5 minutes), and frequency violations (defined as variation to predicted frequency of more than 0.2 Hz for more than 10 minutes). The executive dashboard will calculate daily, weekly, and monthly rolling totals for all of these metrics.

After analyzing historical trends and monitoring real-time data, the main microgrid controller will optimize operation of the microgrid by managing generator output and flexible loads. In grid-connected mode the MCS will prioritize the deployment of renewable generation and will aim to offset electrical demand charges whenever possible.

2.7.4 Islanded Mode Control

The transition to island mode can be either unintentional or intentional.

Unintentional Island Mode

The main microgrid controller is programmed to respond to an unplanned outage at the level of the distribution or transmission system, known as unintentional island mode. An outage at the distribution system level can occur within or outside the microgrid footprint, and the microgrid islanding scheme must be able to handle either situation. MCS relays at the PCC will recognize low voltage or other contingencies, and the appropriate switches will open automatically disconnecting the microgrid from the larger grid. Any existing on-line generation will be isolated and ramped down via generation breakers. All microgrid loads and distribution switches will then be switched open via designated circuit breakers and relays to prepare for local generation startup. Using the spinning generators' black start capabilities, the MCS will commence island mode operation. The CHP unit and natural gas generators will ramp up to 60 Hz and prepare to

supply each of the microgrid loads in sequence. The MCS will manage generator output in each footprint to meet electricity demand in real time.

After the generator has established stable power flow, the microgrid control system will synchronize the frequency, voltage amplitude, and phase of the PV and battery inverters with the natural gas generator's output.

The SSY-A footprint only contains one DER, so there is no need for synchronization after a black start. The diesel generators at the Penn Station footprint will rarely come online, but if their capacity is required they will be synchronized to the CHP unit.

Intentional Island Mode

Unlike the unintentional transition to island mode, the intentional transition is seamless and closed—it does not require a black start. The microgrid will intentionally switch to island mode if:

- The Con Ed grid has an expected outage that could potentially affect transmission power to Sunnyside Yard and Penn Station.
- The Con Ed grid needs to perform network maintenance work, thereby isolating loads in the Sunnyside Yard or Penn Station area.

The intentional transition to island mode begins when the MCS receives the command to prepare for islanding. The main microgrid controller will automatically start and parallel the generation assets. Once the available power sources are synchronized, the system is considered ready to implement islanded operation. The Penn Station and SSY-A footprints will open the incoming utility line breakers. The SSY-B footprint will close the train traction switches and lines to LaGuardia Community College and Middle College High School, and finally open the incoming utility line breakers.

Once in islanded mode, the MCS must maintain the voltage and frequency between acceptable limits and perform load following. The proposed energy management and control scheme will balance generation with microgrid demand and maintain adequate frequency, voltage, and power delivery across the microgrid network. The MCS will manage the generation from the synchronous generators, solar arrays and storage unit to match aggregate demand in real time. Refer to the simplified one-line diagrams from Figure 4 to Figure 9 for a detailed device representation showing both existing and proposed generation assets and their utility interconnection points.

Traction Power in Island Mode

As mentioned throughout the study, powering the traction system in islanded mode will take extra design consideration and engineering efforts in the audit and design phase (NY Prize Phase II). During normal operation power flows to Amtrak's distribution system through multiple connections to the main grid. At Sunnyside Yard, a 138 kV substation supplies the traction system through a 25 Hz AC/DC-DC/AC converter. The microgrid design proposes an 8 MW

natural gas generator at this substation. If the proposed generator is to replace the power supplied by this substation, two main issues should be addressed during future detailed engineering design.

First, electric trains require large amounts of electrical power during startups. Under normal operating conditions, the Con Ed macrogrid (referred to as the main grid, hereafter) can power the traction system during these instantaneous demand spikes even though the substation transformers are not rated to handle them continuously. In island mode, with only the limited generation capacity of the microgrid available, the islanded microgrid will not be able to reliably handle the demand spikes under standard operations. It may be possible, however, to provide sufficient limited power to slowly start the trains sequentially in the event of an outage.

Second, the traction system has multiple points of common coupling (PCC) with the main grid. If there is a wide-area system failure (PJM, NYISO, NEISO rolling blackout), the 8 MW natural gas generator at Sunnyside Yard would suddenly experience much higher demand than it was designed to support, unless fitted with the proper grid controls. In the Phase II engineering design, control requirements will be assessed so the system is properly isolated from other traction demands outside of the Sunnyside Yard/Penn Station New York City footprint.

In light of these issues, we are exploring two strategies, which will be further developed in NY Prize Phase II, that may enable operation of the traction system during emergency operations: (1) Formulating an optimized load-to-generation balance algorithm after obtaining high resolution dynamic input data (such as true electrical current demand during startup), which will optimize the acceleration/deceleration of trains in the footprint during emergency service, and (2) developing emergency train service operating procedures, including identifying the specific rail lines to electrify in the event of an emergency in order to transport passengers to a suitable shelter location to receive emergency services outside of the city. These methods will allow the Penn Station/Sunnyside yard microgrid to support train movements sufficient to evacuate passengers outside New York City and return to continue evacuation. Our preliminary analysis indicate that both approaches will have to be successfully implemented to fully support emergency traction power operations, but both will provide some incremental value if deployed independently.

The first approach is to use a load dispatch algorithm to optimize train load demand in a reduced generation scenario (grid outage). Under normal operating conditions, the traction system supports a base load from moving trains in addition to demand spikes from accelerating trains. In an islanded scenario, our approach would use real time communications and a sophisticated control algorithm to reduce loads by allowing moving trains to coast for specific periods to allow for acceleration of stopped trains (albeit, at lower rates of acceleration than normal). In this way the base load would decrease, increasing the generator's capacity available to support another train's acceleration from a cold stop. This approach would require real time communication and monitoring of each trains' status (position, speed and acceleration, i.e. stopped, moving under

power, or coasting) coupled with an advanced controls systems to implement the advanced control algorithms.

The second approach requires using the existing automated breakers at the substation to disconnect downstream traction loads, which represent an unnecessary demand on the proposed generator's limited resources. This approach, which can be implemented at little cost, would allow the microgrid to serve trains in Sunnyside Yard and the tunnels between NYC and New Jersey. The proposed 8 MW generator does not have sufficient capacity to power the entire traction system, so if the Con Ed grid loses power, sections of the traction system must be disconnected. Amtrak already has remotely controlled circuit breakers at the Hackensack Substation, just outside of New York City in New Jersey that can isolate this part of the system, removing its electric load from the microgrid. Opening these breakers would enable a formation of a microgrid at Sunnyside Yard whose electric demand approximately matches the capacity of the proposed generator. This method enables trains to reliably exit the tunnels between New York City and New Jersey. There, if available, trains could also switch to power being generated by the Public Service Electric and Gas Company (PSEG) after exiting the tunnels. We are also exploring similar options to move trains north to Sunnyside Yard, where, depending upon the extent of the outage, they may be able to transfer back to main grid power. If trains are equipped with onboard diesel engines, they may use these engines after exiting the tunnels. However, dual-mode trains make up a very small percentage of Amtrak's fleet. Building additional DERs at various downstream PCCs could allow the microgrid to power the remaining sections of the traction system in the future.

2.7.5 Path to Resolving Traction Challenges

Although powering the traction system in island mode will require further studies and extensive collection of data, the Project Team believes it is technically feasible to provide sufficient power to provide an emergency evacuation plan. Partitioning the traction system into sections will reduce overall load on the proposed generator, and advanced load and generation algorithms may flatten the instantaneous peaks associated with acceleration.

Obtaining high resolution dynamic input data is crucial to finalizing a workable solution. Since the existing SCADA system at Amtrak only samples data every 8 seconds, the Project Team is working with Amtrak engineers to procure an analog meter that more accurately captures these system variables with higher resolution. The next step is to fully understand the train's electrical specifications. After this, the generator overcurrent capability should be compared with normal train engine startup currents. The train engine startup current levels and durations also depend on the mechanical load, so the Project Team will measure startup current level and duration under different mechanical loads if the data is not available from the manufacturer. After collecting the necessary data above, the Project Team will develop a load-to-generation algorithm that balances base load with instantaneous demand spikes from acceleration. As long as the dedicated natural gas generator is running, this solution will allow trains to operate in a grid outage for any desired amount of time.

In addition to the load-to-generation optimization process the Project Team will also work with Con Ed, Amtrak and PSEG to assess the best route to move trains out of the City and what breakers and lines will be leveraged to do so and what upgrades will be required to allow for the microgrid to power the trains to their destination. Power flow studies may also need to be conducted to better understand the impacts of testing the system on a “blue sky day” and where power generation from other utilities or DERs may need to be provided to evacuate residents to a safe location. Finally, it will be Project Team, in partnership with the State of New York and New York City, will work to incorporate a technically viable solution into the emergency evacuation and preparedness strategies of the region.

2.7.6 Energy Management in Islanded Mode

After completing the transition to island mode, the main microgrid controller will perform a series of operational tests to ensure the microgrid is operating as expected and that power flow is stable and reliable. The MCS will gather data on power flow, short circuit, voltage stability, and power system optimization using an N+1 (N components plus at least one independent backup component) contingency strategy to determine whether additional load can be added. The N+1 strategy ensures that extra generation is always online to handle the loss of the largest spinning generator and assumes the running generator with the highest capacity could go off line unexpectedly at any time. The N+1 strategy does not apply to the SSY-A footprint because it only includes one DER. It should be noted that low-priority loads may be disconnected in order to maintain the N+1 power assurance.

The microgrid must also be capable of handling any contingencies that may occur within the islanded system. These contingencies include:

- Generators that do not start.
- Generators that trip off unexpectedly during microgrid operation.
- Switchgear that fails to operate.
- Switchgear that fails to report status.
- Loss of power from the CHP unit or natural gas generators.
- Loss of power from the solar arrays.

The MCS will optimize the microgrid’s operation by managing generation assets and prioritizing critical loads according to operational requirements. Proposed DERs will provide stable, sustainable, and reliable power. The MCS will continuously balance generation and load in real-time, monitoring relevant variables (i.e., system frequency and voltage) and adjusting generator output as necessary. At the SSY-B footprint the main microgrid controller will first deploy energy from renewable generation assets and adjust the natural gas generator’s output to match remaining electricity demand. The microgrid design relies on a 1 MW/4 MWh battery storage unit to compensate for changing output from the solar arrays in island mode. The battery will smooth rapid fluctuations in output and, along with the natural gas generator, will provide a reliable supply of energy when sunlight is not available or when there is a large demand spike.

The proposed battery storage unit can be used for multiple purposes:

- Long-term storage: Long-term backup, to be used in conjunction with solar PV arrays to maintain power in a long-term outage.
- Ancillary services: Frequency regulation (enhances stability by providing an immediate response to a change in system frequency), spin/non-spin reserves (providing capacity to the NYISO), and voltage support (ensure reliable and continuous electricity flow across the grid).
- Shifting solar output: Storing excess generation from the solar PV arrays for a few hours, usually to offset higher priced periods (e.g., shifting excess solar generation from 1-3 PM to 4-6 PM when grids tend to peak).
- Energy arbitrage: Similar to shifting solar output, but instead of storing excess generation from the solar arrays, the battery units will purchase wholesale electricity from the NYISO when the Location Based Marginal Price (LBMP) is low and sell it back to the NYISO when the LBMP is high.
- Black starts: The units can start power flow through the microgrid in the event of an unplanned larger grid outage.

2.7.7 Black Start

The proposed CHP unit, natural gas generators, battery storage unit, and existing diesel generators will be equipped with black start capabilities. If the Con Ed grid at Sunnyside Yard or Penn Station unexpectedly loses power, the main microgrid controller will initiate island mode by orchestrating the predefined black start sequence (see below). The microgrid then begins the unintentional transition to island mode. A DC auxiliary support system is an essential part of the spinning generators' black start capabilities. The battery system must have enough power to start the generator multiple times in case it fails to start the first time.

When the larger grid unexpectedly loses power, the main microgrid controller orchestrates the black start sequence as follows:

1. PCC breaker opens.
2. All active generation is disconnected (including the battery storage).
3. The main microgrid controller waits a pre-set amount of time (approximately 30 seconds) in case Con Ed power comes back.
4. The main microgrid controller disconnects the entire current load (after estimating aggregate electricity demand).
5. The microgrid generators are synchronized with each other (one will usually provide reference voltage and frequency).
6. The main microgrid controller reconnects the microgrid loads based on the available generation and a predetermined load priority order.

The MCS will manage any contingencies that arise during the black-start operation (e.g., breakers do not respond to trip commands and the microgrid does not properly disconnect from

the larger grid). Lower priority loads will be energized only if sufficient capacity can be guaranteed. If the main generators do not start as expected during a utility outage, the MCS is equipped with contingency algorithms to appropriately manage the situation. If possible, the main microgrid controller will still isolate the microgrid, but only critical loads will be satisfied.

The MCS will allow operators to designate certain generators as unavailable for participation in the microgrid (e.g., if they require maintenance) so the generator dispatch and load shedding algorithms can accommodate a reduced available capacity.

2.7.8 Resynchronization to Con Ed Power

When power is restored to the larger grid, the main microgrid controller will coordinate a safe and orderly re-connection. The system will first wait a predefined, configurable time period to ensure that power has been reliably restored and then will commence resynchronization with the Con Ed power supply. As a final check, the system operator will either receive an automated notification or directly contact Con Ed to confirm that power flow on the larger grid is on-line and stable.

While operating in island mode, the system will constantly monitor the status of the utility feeder at the PCC and determine when nominal frequency and voltage have been restored. When power is restored, the main microgrid controller will temporarily disconnect the solar array and battery storage unit at the SSY-B footprint. This will allow the natural gas generator to match microgrid load and maintain microgrid frequency without complications from unpredictable PV power dips or spikes. Before the microgrid system starts paralleling with the utility, it will balance local generation and load so as not to exceed either minimum or maximum export limits or time durations set forth in the utility interconnection agreement. The main microgrid controller will then synchronize output from the natural gas generator with the utility service through the utility circuit breaker and close the incoming line. When microgrid power flow has been synchronized to the larger grid, the main microgrid controller will bring the solar array and battery storage unit back on-line.

The resynchronization sequences at the SSY-A and Penn Station footprints will follow a similar procedure. Without solar PV arrays or other secondary DERs, these footprints will simply balance generation with load, synchronize their respective primary generators with the utility service, and close the incoming breaker.

2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6)

The existing IT and telecommunication infrastructure at Sunnyside Yard is best suited for taking advantage of Amtrak's existing microgrid communication system. The communication system and network switches (which have local backup batteries) will communicate with both wired and wireless components that are electrically served by the microgrid in islanded mode. During the intermittent stage, or black start sequence mode, the headend IT network equipment and base station for the IT network communications system will be powered by their backup batteries.

The microgrid design will require minimal additional hardware (i.e., the network switches, WiMax Base Station, WiMax subscriber units, servers, and computers required to manage a microgrid) to seamlessly integrate with the IT system.

2.8.1 Existing IT & Telecommunications Infrastructure

Amtrak already takes advantage of its existing fiber optic backbone ring and existing Ethernet switches for reliable Internet and Local Area Network (LAN) activities, making convergence quite feasible. The wireless components of the control system, which work on open architecture protocols, use a TCP/IP Ethernet-enabled component that controls each of the uniquely addressed modules to wirelessly communicate via a standard, non-licensed radio frequency mesh 900 megahertz (MHz) industrial scientific and medical (ISM) band signal network.

Amtrak already has IT infrastructure in place for monitoring and control of the traction system in real time. The monitored data is not logged and the SCADA system is outdated but it will be upgraded in the near future. Historical data will be crucial for microgrid real time operations and optimization.

Amtrak's electrical distribution system is a rather large network not really suitable for wireless communication. The only location where wireless technology will be used is for the IED isolation switches on the feeders serving the College and High School. Everywhere else, existing fiber optics will be used in conjunction with Ethernet data-grade cables. Since it assumed Amtrak's existing fiber optics system will be used, a Virtual Private Network (VPN) over the internet or using a private fiber optics network is not required, although it could be an option in the future if the design team decides to not use Amtrak-owned fiber. Either way, fiber optics will be the preferred mode of data transmission since it is reliable, secure, and fast.

The proposed microgrid consists of two locations that will be monitored and controlled hierarchically, locally (fast control) and remotely (slow control). The supporting IT infrastructure will tie together and coordinate the monitoring and control at these two time scales. While the local controls will be responsible for real time device control the remote controller will optimize and schedule operations of the devices on a slower time scale.

2.8.2 IT Infrastructure and Microgrid Integration

While the IT infrastructure is reliable and available for the expansion of the proposed automated microgrid system, additional microgrid hardware and software is needed. There are seven main components required for any microgrid system to successfully integrate with an IT/telecommunication infrastructure: host servers, application servers, operator workstations, network switches, network-attached logic controllers, data transmission systems (either fiber or Ethernet cables), and the vendor agnostic SOA software that facilitates the monitoring and control of virtually any power device or control system. All of these critical parts work together and serve a specific role.

2.8.3 Network Resiliency

Cyber security falls into the two primary stages (1) design and planning, and (2) continuous operations. Cyber security is especially important for the microgrid control system as it utilizes TCP/IP protocols for compatibility amongst the distribution system. This convergence has also introduced vulnerabilities to the MCS because the MCS vendors have historically lagged behind in implementing security patches rolled out by the Operating System security teams.

For the planning stage, design considerations address cyber security by assigning roles to network-attached components on Amtrak’s WAN thereby controlling data flow and access permissions over the integrated MCS and overarching IT architecture.¹⁷ For example, the design utilizes a network segmentation scheme by function (separate segments/enclaves for servers, operators, generation, and distribution), in addition to network firewalls, for clean and continuous monitoring and control of data flow. The firewall routes noncritical traffic such as unrelated corporate printers and other drivers, email, and all other non-essential internet services (which could be backdoors for hackers into the MCS) to a dedicated “demilitarized zone” usually consisting of a single security hardened server.

Because the logic controllers will be located at or near loads in the neighboring Con Ed area, the distributed equipment will take the IT system to the “edge” of Amtrak’s network, where it is potentially more vulnerable to hackers. Sticky media access control (MAC) is an inexpensive and practical program that can help prevent unauthorized access and protect the Amtrak IT network. Every network attached device has a unique, unchanging MAC interface. The Sticky MAC program is configured to monitor the unique address of the device and its designated network port. If the device disconnects, the program disables the port and thus prevents an unauthorized device that may have malicious code from entering the IT system.¹⁸

Physical security measures, such as electronic badge access or cipher combination hardware locksets, should also be considered. The Project Team recommends implementing physical security at the perimeter of the control center building in Sunnyside Yard and network communication closets where the switches reside.

The data transmitted throughout the proposed Amtrak microgrid will be encrypted, but several additional intrusion protection measures can easily be implemented. One simple and inexpensive method is to disable any of the 65,535 TCP ports not used to make the microgrid system work (depending on final configuration, only a few TCP ports will need to be active). More TCP ports will need to be active when the available enterprise-level monitoring and control access will be utilized.

Activating and analyzing security logs is also important. As a rule, the operating system and firewall can be configured so certain events (e.g., failed login attempts) are recorded. The

¹⁷ Assumes the microgrid will utilize enterprise-level remote monitoring and control.

¹⁸ Sticky MAC is a common, widely effective IT security countermeasure. The Project Team does not foresee any difficulties integrating Sticky MAC into microgrid operations.

security portion (software that resides on the control system servers) will be configured so only operators and engineers with specific login credentials can access and control the microgrid.

In the event of a loss of communication with the IT system, the microgrid will continue to operate. The programmed logic code for the network attached controllers is stored locally in each module, giving the controllers the ability to operate as standalone computers in the event of a disruption between the IT system and microgrid.

Cyber Security will also be considered during the operations stage to maintain against ongoing threats. The Team considers the safety and availability of the microgrid to be the most critical aspects of the microgrid. Testing and/or simulation of the system responses to software updates is important because it allows the owner or operator to identify any anomalies which the software updates might introduce to the overall system before full deployment in the field. Further considerations will be assessed during the next phase of the Prize initiative.

2.9 Microgrid Capability and Technical Design and Characterization Conclusions

The Amtrak microgrid objectives are to provide reliable, economical and clean power to identified Amtrak and community electrical and thermal loads in both grid-connected and island configurations. To achieve these goals, the new distributed energy resources will have to be supported by existing and new monitoring and control hardware and software using state-of-the-art IT technology.

In conclusion, the project is technically feasible. However, three significant items remain in order for Sunnyside Yard's community microgrid to become a reality. First, the connection from Amtrak distribution system to Con Ed distribution system for picking up LaGuardia Community College and Middle College High School at LaGuardia may become more difficult and complicated. This is because of the fully meshed electrical distribution system Con Ed used. The team will work close with Con Ed to propose the most economical and practical solution for this connection to pick up two schools without interfering the original protection system in next phase of the project.

Second, DERs may be built and owned by a third party and possibly expanded incrementally over time to supply adjacent community facilities. The microgrid owners must obtain access to the generators on Amtrak's property for maintenance and service. The Project Team is currently working with Amtrak to ensure access. Because Amtrak is a major stakeholder in the microgrid project and has significant incentive to support project completion, the Project Team expects this challenge to be resolved by the time of construction.

Third, due to the physical characteristics of the train traction system, the Project Team is still determining the best way to maintain its power supply during islanded operations in the SSY-B footprint. At a minimum, until further studies are performed, the Team has outlined two strategies to enable trains to carry passengers out of New York City.

3. Assessment of Microgrid's Commercial and Financial Feasibility (Task 3)

The conclusions in this document are predicated on several fundamental assumptions, as outlined in the Executive Summary. SPV shareholders will finance the entire capital expense of the project. The proposed microgrid may not participate in ancillary service markets or DR programs given its size and placement on the feeder with downstream loads. However, cash flows from normal operation as proposed in this feasibility study will recover initial investment costs and provide positive returns to investors.

3.1 Commercial Viability – Customers (Sub Task 3.1)

The preliminary microgrid design includes five facilities distributed across three footprints (see Figure ES-1 for a list of included facilities). Amtrak, Penn Station, LaGuardia Community College, and Middle College High School will be the microgrid's direct customers. Private investors will own proposed DERs and microgrid infrastructure through an SPV. The proposed DERs will produce revenues and savings from electricity sales, thermal energy sales, and deployment of battery storage for DR and TOU bill management. Penn Station will purchase 100% of the cogenerated steam from the CHP unit throughout the year.

Included Amtrak facilities provide critical services (as defined by NYSEERDA) to the community during emergency situations. The project will affect several groups of stakeholders in the Long Island City and New York City communities that are not physically connected to the microgrid, including the regional stakeholders served by Long Island Rail Road (LIRR), New Jersey Transit (NJT), and Amtrak. The benefits and challenges to microgrid stakeholders are discussed further in this section.

3.1.1 Microgrid Customers

The proposed microgrid includes three critical facilities and two schools (see Table 11 for a list of direct microgrid customers). Penn Station, LaGuardia Community College, and Middle College High School will continue to purchase electricity from Con Ed throughout the vast majority of the year. Amtrak facilities in Sunnyside Yard at the SSY A and B footprints will purchase electricity directly from the SPV in grid-connected mode. When there is an outage on the larger Con Ed system, the microgrid will switch to island mode and microgrid customers will purchase electricity directly from the SPV. The transition to islanded operation may be intentional or unintentional.

Although facilities outside the microgrid's footprint will not receive electricity from the microgrid's generation assets during emergency outages, local citizens will benefit from the availability of transportation and shelter. In their day-to-day operations, each of the microgrid facilities serves the larger community. By maintaining critical services during emergency outages, these facilities increase their value to the community.

Table 11 (below) identifies each of the direct microgrid customers. The full group of stakeholders that will benefit from the microgrid is discussed in Section 3.2.3.

Table 11. Microgrid Customers

Facilities that will be connected to the microgrid. Amtrak will purchase electricity directly from the microgrid for non-traction loads at Sunnyside Yard in both grid-connected and island mode, while other facilities will only purchase electricity directly from the microgrid in island mode. Penn Station will purchase steam from the SPV in both grid-connected and island mode.

Property	Address	Classification	Critical Service	Back-up Generation	Direct Purchases from Microgrid (electricity)
Penn Station	266 W 31 st St	Private	Yes	Yes	Island mode only
Amtrak’s Sunnyside Yard Facility	43 rd St	Private	Yes	No	Both grid-connected and island mode
Amtrak’s Train Traction System at Sunnyside Yard	43 rd St	Private	Yes	No	Island mode only ¹⁹
LaGuardia Community College	3110 Thomson Ave	School	No	No	Island mode only
Middle College High School at LaGuardia	3101 Thomson Ave	School	No	No	Island mode only

3.1.2 Benefits and Costs to Other Stakeholders

Stakeholders in the Long Island City microgrid extend beyond connected facilities to include SPV investors, Con Ed, and residents of Long Island City, New York City, and the tristate area.

The majority of benefits and costs to stakeholders fall into these following categories:

- Supply of power during emergency outages
- Electricity generation in grid-connected mode
- Thermal energy generation in grid-connected mode
- Cash flows to owners
- Upfront capital investment and land requirements

Details of each will be discussed in turn below.

Supply of power during emergency outages: The microgrid will supply power to three critical Amtrak facilities as well as two schools. The critical facilities can provide transportation and shelter to the New York City area in the event of a long-term grid outage.

Electricity generation in grid-connected mode: The new 6 MW CHP and 200 kW solar array will operate continuously in grid-connected mode, selling electricity to Con Ed under a custom long-term PPA. The reciprocating generators at the SSY A and B footprints will follow Amtrak

¹⁹ The current proposal does not include any operation of the traction system during island mode. However, the Project Team is exploring solutions that would allow partial operation of this system in island mode. If such a solution is devised in Phase 2 of the NY Prize competition, Amtrak will purchase electricity for the traction system directly from the SPV in island mode.

traction and non-traction loads in grid-connected mode. Continuous energy generation will reduce load for the larger Con Ed system in a critical congestion corridor during both peak demand events and normal periods of operation, stabilizing electricity prices in the area and possibly deferring the utility's future transmission capacity investments. Amtrak will purchase electricity directly from the 3 MW and 8 MW reciprocating generators at 90% of the local industrial rate.

Thermal energy generation in grid-connected mode: The CHP unit will provide process steam to Penn Station throughout the year. Cogenerated thermal energy will provide around 16% of the facility's average annual steam demand. Penn Station will benefit from reduced operation and maintenance costs associated with existing boilers.

Cash flows to DER owners: Cash flows will derive from electricity sales to Con Ed and to connected facilities, thermal energy sales to Amtrak, demand response payments from Con Ed, and savings from intelligent deployment of battery resources. The microgrid project will generate consistently positive operating cash flows, which will recover investment costs and produce positive returns. The Federal investment tax credit (ITC), NY Sun Program, and Con Ed Demand Management incentive program for electricity storage all increase the project's value. Additional subsidies from NY Prize would make the proposed microgrid an even more attractive investment.

Upfront capital investment and land requirements: The primary costs will be purchasing and installing necessary microgrid equipment and proposed generation assets. Amtrak has land available for proposed DERs.

3.1.3 Purchasing Relationship

In grid-connected mode, the SPV will sell electricity from the proposed CHP unit and 200 kW solar array to Con Ed under a long-term PPA.²⁰ The 3 MW and 8 MW reciprocating generators will follow traction and non-traction loads at Sunnyside Yard, selling electricity directly to Amtrak. The SPV will bid 800 kW of capacity from the battery storage unit into the Con Ed CSRP from May through September, the months during which Con Ed DR programs are active. Amtrak will use the battery storage unit for TOU bill management for the remainder of the year, transmitting savings to SPV owners. Penn Station, LaGuardia Community College, and Middle College High School will maintain their current electricity-purchaser relationship with Con Ed during grid-connected mode. Traction and non-traction facilities at Sunnyside Yard will obtain most of their electricity directly from microgrid DERs in grid-connected mode and will be billed directly by the SPV.

In island mode the facilities will be physically disconnected from the larger grid and directly supplied by the proposed generation assets. Sufficient power will be supplied to the train traction system to support limited train movements and LCC and MCHS will be request to curtail non-

²⁰ The proposed solar array will not qualify for net metering because it will be owned by the SPV, which does not own a metered facility in the area.

critical loads. Microgrid software will monitor electricity usage at Penn Station, Amtrak non-traction loads, LaGuardia Community College, and Middle College High School. Facilities will remit payment to the SPV as appropriate. Con Ed will not be involved in island mode sales or operations, as the design makes minimal use of the utility’s infrastructure in the area. Islanded operation contracts will be established during development and construction, and will address both the order in which islanded facilities are brought back on-line following an island event and the associated cost for participating in the microgrid. See Figures 11 and 12 below for the purchasing relationships.

Figure 11. Normal Operation Purchasing Relationship

Value streams and purchasing relationships between the various entities during grid-connected operation.

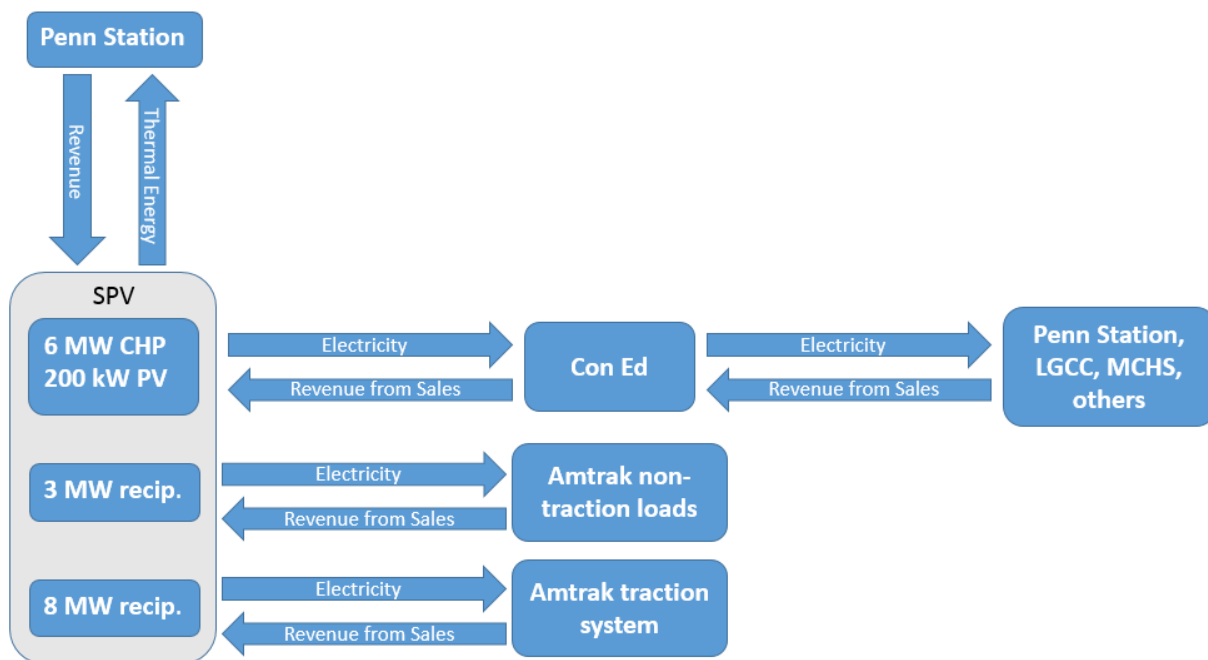
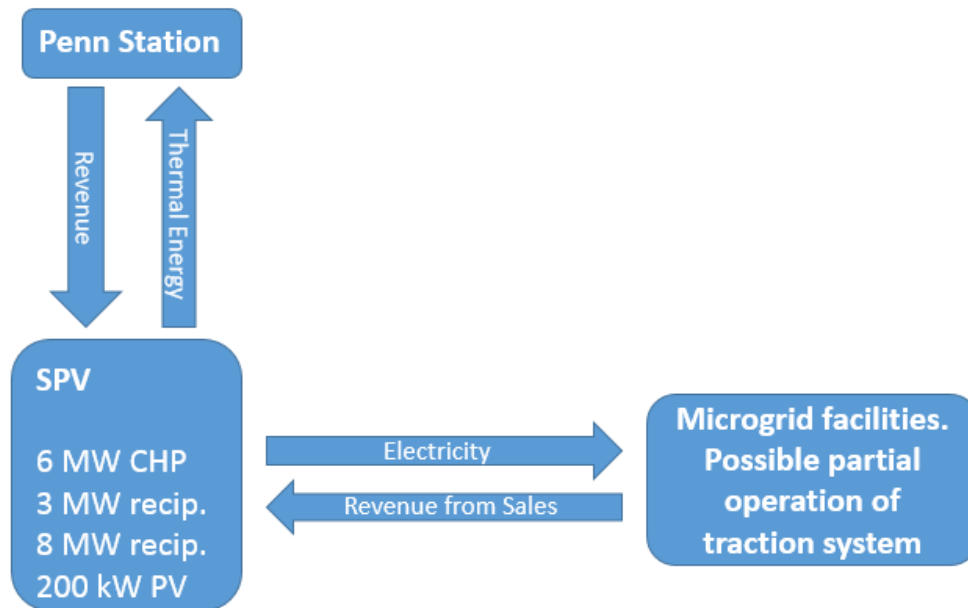


Figure 12. Islanded Operation Purchasing Relationship

Value streams and purchasing relationships between the various entities during islanded operation.



3.1.4 Solicitation and Registration

The microgrid design team will work with representatives from Amtrak, the schools, and Long Island City to formalize agreements with the identified microgrid customers. This outreach will include informal discussions and, ultimately, signed agreements of participation in the microgrid and any fee structure determined by the NYPSC. Formal registration with the microgrid will be managed by programming the logic controllers to include or exclude facilities from islanded services based on their agreements with the utility. The Project Team views registration as an operational feature and not a legal requirement.

3.1.5 Energy Commodities

In grid-connected mode the CHP unit and solar array will sell electricity to Con Ed. The utility will distribute this electricity as dictated by system needs. The 3 MW and 8 MW reciprocating generators will sell electricity directly to Amtrak at 90% of the local industrial rate. The 3 MW generator will follow Amtrak’s non-traction loads at Sunnyside Yard, while the 8 MW generator will support Amtrak’s traction system.

In island mode the microgrid’s DERs will sell electricity directly to connected facilities. The CHP unit will sell electricity directly to Penn Station and the 3 MW reciprocating generator will sell electricity directly to Amtrak at Sunnyside Yard, providing electricity for non-traction loads. The 8 MW reciprocating generator, 200 kW solar PV array, and battery storage will support the traction system and will send electricity directly to LaGuardia Community College and Middle College High School over new medium-voltage distribution lines.

Penn Station will purchase co-generated steam from the CHP unit throughout the year. However, because the CHP unit will be configured to follow Penn Station's electrical load in island mode, there will be less steam available for purchase when there is an emergency outage.

The volume of electricity purchased from the CHP in grid-connected mode will depend on the generator's output as dictated by the microgrid controllers, system demand, and agreements between the SPV and Con Ed. It will likely operate at nearly full load throughout the year in order to maintain a steady supply of thermal energy to Amtrak. The CHP will not participate in NYISO ancillary service markets because most lucrative markets require at least 1 MW of available capacity, which represents around 17% of the CHP unit's nameplate capacity. The requisite fast changes in output would also make the CHP unit's thermal output unpredictable, which would discourage Amtrak from purchasing co-generated thermal energy. Ancillary service markets that do not have minimum capacity requirements (such as spinning and non-spinning reserves) rarely offer competitive payments. As such, ancillary services sales from the CHP system are unlikely.

The SPV will bid 800 kW of capacity from the proposed battery into the Con Ed CSR. This demand response program runs from May through September, and provides payments for both capacity and actual load reduced during an event. Further, if participants can guarantee participation for at least three years, the battery is eligible for an additional capacity payment. The Project Team determined that 800 kW was a safe level to bid into the program, as participants are expected to reduce load for at least four hours, and the battery's total energy capacity is 4 MWh. The battery will be deployed for TOU bill management and peak demand charge reduction at Amtrak's 60 Hz Sunnyside Yard facilities during the remainder of the year.

The microgrid will not enter island mode for economic reasons because doing so would interfere with Con Ed infrastructure during normal operation. Participation in DR programs by islanding the microgrid will therefore be impossible.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to SPV shareholders, direct participants, Con Ed, New York City citizens, and the larger State of New York. The proposed DERs will produce reliable, relatively low-emission electricity in both normal and islanded operation. SPV members will receive stable cash flows from operation of the proposed energy generation resources for the life of the project. The benefits, costs, and total value of the microgrid project are discussed in detail below.

3.2.1 Business Model

Table 12 below provides an overview of the microgrid project, including an analysis of project strengths, weaknesses, opportunities, and threats (SWOT).

Table 12. Microgrid SWOT Analysis

Strengths, weaknesses, opportunities, and threats (SWOT) associated with the microgrid.

Strengths	Weaknesses
<ul style="list-style-type: none"> • Allows for the use of existing Amtrak transmission and distribution infrastructure, thereby reducing the potential cost burden of constructing new lines and feeders • Co-generated thermal energy will provide an additional revenue stream to the SPV and replace an existing boiler (or multiple boilers) at Penn Station • Single ownership model ties benefits and costs into a single value stream • Ensures that vital transportation services in New York City remain accessible during emergencies • Normal operation proposed in this document will recover investment costs and provide positive returns to investors 	<ul style="list-style-type: none"> • Single ownership structure risks regulatory treatment as an electric corporation • Distributed footprints increase the risk of disruption to the information technology and microgrid communication systems • Existing natural gas lines must be extended to reach proposed generators • Project requires new medium voltage electric distribution lines to connect the Amtrak distribution system to LaGuardia Community College and Middle College High School
Opportunities	Threats
<ul style="list-style-type: none"> • Encourages teamwork between local government and private investors • Demonstrates the feasibility of reducing load on the larger grid with distributed energy resources • Provides a proof point for making transportation systems more resilient. There are many opportunities to develop similar projects across the United States • Local generation reduces the amount of electricity that must be imported from the Con Ed grid. This project may decrease Con Ed’s future infrastructure investments • Capturing additional subsidies such as NY Prize Phase III funding could make the microgrid a highly attractive investment 	<ul style="list-style-type: none"> • Changes in regulatory requirements could impact the proposed business model and stakeholder goals. • If natural gas prices increase, it will significantly raise the microgrid’s marginal cost of producing electricity, which may prompt a re-negotiation of electricity prices for microgrid facilities

Although there are several valuable strengths and opportunities associated with the single ownership model, there are also weaknesses and threats that must be addressed and, if possible, mitigated.

- **Financial** – SPV members will seek a long-term PPA, or some other form of long-term purchase agreement, with Con Ed and Amtrak to guarantee steady future revenue streams from the CHP, reciprocating generators, and solar array. As long as the agreements reliably guarantee fair compensation for generator output over the project lifespan, SPV members must be content with flexible compensation rates and a low amount of risk. Second, if natural gas prices increase in the future, the microgrid’s marginal cost of producing electricity may rise. This would drive the SPV to request a higher price for DER-generated electricity from Con Ed and Amtrak.

- **Regulatory** – Utilities in New York State cannot own generation assets unless they demonstrate why full vertical integration provides value to their customers. The State of New York wishes to avoid situations in which a single entity monopolizes energy generation and distribution resources. Utilities may not purchase DERs, and microgrid investors that purchase distribution infrastructure may be considered utilities. Because most microgrid infrastructure and DERs are located on Amtrak property, the microgrid should not qualify as a utility.
- **Traction System** – By powering one train at a time, the microgrid will be able to partially serve the traction system during islanded operation. Other options include expanding battery storage to keep more energy in reserve and increase the SSY-B footprint's peak output capacity. Additional technical solutions are being actively explored and will be addressed in depth in Phase II.

3.2.2 Replicability and Scalability

The microgrid is being designed with industry standard equipment and software that can be applied to diverse existing infrastructure. The transit specific features of the proposal will limit future replication to electrified transit systems, however these are numerous along the eastern seaboard to include Amtrak's NEC, NYC MTA, New Jersey Transit, LIRR, Metro North Railroad, PATH, and rail systems in Philadelphia, Baltimore, Washington DC, and Boston.

Technical Replicability. The proposed microgrid technology does not present a barrier to project replicability. The primary components of the microgrid, including the proposed generation assets, switches, SCADA, and the EMS, are widely available and could be repeated in any given location. All interconnections with the Con Ed grid are industry standard. Natural gas infrastructure is an essential component of the project's replicability; without a steady natural gas supply, other communities would have to sacrifice the reliability (by relying on solar and/or wind power) or emissions efficiency (by using diesel or fuel oil) that make this project feasible. However, the impact that the proposed microgrid will have on the local community is less replicable because the project targets unique existing transportation infrastructure.

Organizational Replicability. Private ownership of both DERs and microgrid infrastructure could create regulatory challenges. The Project Team does not expect regulatory issues to significantly impact the microgrid because the project provides substantial value to New York City and New York State. In most situations it would be preferable to propose private DER ownership coupled with utility ownership of distribution and control infrastructure, as it would bring private capital into the energy arena and would provide a platform for utilities to realize revenue from distributed energy resource projects.

The proposed generation assets qualify for significant incentive payments—the NY Sun program will offset around 30% of the solar array's capital cost, the Federal ITC will offset an additional 30% of the solar array's capital cost, and the Con Ed Demand Management electricity storage incentive program will offset around 60% of the battery storage unit's capital cost. These incentives are important to the project's commercial viability even though the SPV can sell

electricity at relatively high prices and still remain competitive with the expensive electricity in New York City. Termination or expiration of any of these incentive programs could hinder the replicability of this design, especially in areas where DERs will be forced to sell energy at a lower price.

Scalability. The proposed microgrid is scalable to the extent that Con Ed will allow use of existing infrastructure. Alternatively, the SPV could build new distribution lines to reach new facilities. Adding new facilities may also require expanded generation capacity; however, if the 8 MW reciprocating generator only supports LaGuardia Community College and Middle College High School in island mode, it will have up to 3 MW of extra capacity available for adding loads.

Expanding the microgrid to adjacent Con Ed feeders would require new lines, new switches and breakers, and additional power flow studies to ensure safe operation of the microgrid.

Incongruent line voltages could further increase the electrical complexity of linking multiple feeders.

3.2.3 Benefits, Costs and Value

The microgrid will provide widely distributed benefits, both direct and indirect, to a multitude of stakeholders. The SPV will receive stable cash flows for the lifetime of the project, New York City will benefit from a more resilient transportation system, and the community and utility will benefit from a more resilient electric system. These costs and benefits are described in Tables 13 through 18. Moreover, the local community will not bear any of the project's costs. This proposal involves a wide group of stakeholders and provides value to all involved parties. SPV investors will receive positive returns and Con Ed will benefit from expanded distributed energy resources in a key congested area.

Tables 13 through 18 below provide an overview of the benefits and costs to members of the SPV, direct microgrid customers, Con Ed, citizens of Long Island City and surrounding municipalities, and the State of New York.

Table 13. Benefits, Costs, and Value Proposition to SPV

SPV shareholders will receive stable cash flows for the lifetime of the project.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
SPV	<ul style="list-style-type: none"> - Investors will receive annual cash flows from electricity sales, thermal energy sales, demand response payments, savings from TOU bill management, and microgrid connection or participation fees - Federal ITC and NY Sun incentive together recover around 60% of solar array’s cost in the project’s first year - Con Ed Demand Management storage incentives recover around 60% of the battery’s capital cost in the project’s first year - NY Prize Phase III funding would recover an additional \$5 MM of capital costs 	<ul style="list-style-type: none"> - Initial capital outlay for generation assets - Forecasted installed capital costs for generation assets total around \$27.6 MM - Ongoing operation and maintenance of DERs - Financing costs associated with initial capital outlay will persist for many years 	<ul style="list-style-type: none"> - Low risk returns assured through long-term purchase contracts make the proposed DERs an attractive investment - High electricity prices in NYC allow SPV owners to realize a competitive operating profit from proposed DERs - With existing subsidies and projected cash flows from normal operation, SPV shareholders will receive a positive return on investment - Although available state and federal incentives improve the project’s commercial viability, it does not rely on them

Table 14. Benefits, Costs, and Value Proposition to Con Ed

Con Ed will receive non-cash benefits from the microgrid without bearing any capital or operating costs.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Con Ed	<ul style="list-style-type: none"> - The utility will continue to sell electricity to direct customers - The utility may realize cost savings on decreased line congestion - Local generation reduces the amount of power that must be imported from the larger grid - Battery storage unit will be discharged during peak demand events to provide load relief - Improved reliability provided to customers within the microgrid’s footprint 	<ul style="list-style-type: none"> - Con Ed’s electrical infrastructure around LaGuardia Community College and Middle College High School will be used in island mode 	<ul style="list-style-type: none"> - Improved grid resiliency by integrating local generation assets with local distribution networks - Con Ed will have a new supply of electricity valued at their average supply charge but will marginally reduce their transmission and distribution costs in the immediate area

Table 15. Benefits, Costs, and Value Proposition to Long Island City

Long Island City will become a leader in achieving NY REV goals by providing a local market for DER-generated electricity and catalyzing investment in DERs. New York City residents will have a more resilient transportation service in emergencies.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Long Island City	<ul style="list-style-type: none"> - The microgrid will provide a resilient and redundant energy supply to critical transportation services that are available to citizens of the City and surrounding communities (including NYC) - Meet NY Reforming the Energy Vision goals by encouraging DER construction and improving energy resiliency - Expand local renewable energy generation 	<ul style="list-style-type: none"> - Potential noise disturbances from operation of generators 	<ul style="list-style-type: none"> - Critical and important services will maintain power during outages, allowing Amtrak to continue operations and schools to serve as shelters - The microgrid project will serve as a catalyst for customers becoming more engaged in energy opportunities and will inspire residential investment in DERs, such as solar PV and battery storage, as citizens see benefits associated with avoiding peak demand hours, producing enough electricity to be independent from the larger grid, and selling electricity in a local market - Generating electricity with the new solar PV array and efficient natural gas generators will offset emissions from potential diesel backup generation

Table 16. Benefits, Costs, and Value Proposition to Connected Facilities

Connected facilities will benefit from a more resilient energy supply and may choose to invest in small DERs of their own.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Connected Facilities	<ul style="list-style-type: none"> - Resilient and redundant energy supply to operations - Access to a local market for distributed energy resources makes investments in small DERs more attractive to connected facilities - Thermal energy from the CHP unit will reduce the need for existing boilers at Penn Station - Amtrak facilities at Sunnyside Yard will gain a less expensive source of electricity during normal operation 	<ul style="list-style-type: none"> - Slightly higher electricity prices during island mode 	<ul style="list-style-type: none"> - Maintain operations during emergency outages and provide valuable critical services to the community - Local market for excess energy makes investments in small DERs (such as solar panels) profitable for connected facilities - Amtrak will reduce operation and maintenance costs associated with generating thermal energy and purchasing electricity

Table 17. Benefits, Costs, and Value Proposition to the Larger Community

The larger community will have access to critical transportation services and may have some ability to reconnect power (if the microgrid expands connections in the future) during grid outages.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Community at Large	<ul style="list-style-type: none"> - Access to critical transportation services during grid outages - Access to shelter at LCC and MCHS during grid outages 	<ul style="list-style-type: none"> - Because the larger community will not be connected to the microgrid, this stakeholder group will not bear any costs 	<ul style="list-style-type: none"> - Potential for connection to the microgrid if the footprint of the microgrid is expanded. As proposed, the generators may consistently out-produce connected critical loads in outage situations - Future expansion of the microgrid could bring more facilities into the design— however, the community may need to install advanced metering infrastructure (AMI) meters for this to be feasible

Table 18. Benefits, Costs, and Value Proposition to New York State

The microgrid provides a tangible example of a community working towards a significant NY REV goal: to expand the privately-owned DER industry and propagate smart grid technologies.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
New York State	<ul style="list-style-type: none"> - Efficient natural gas-fired generators will offset high-emission peaking assets and local diesel standby generators during peak demand events - Cash flows will provide tangible evidence of microgrid project’s commercial viability - Indirect benefits (such as outages averted) will demonstrate the benefits of microgrids paired with DERs to citizens across the state and reduce load on the larger grid - Each microgrid accelerates NY state’s transition from old macrogrid technology to newer, smaller technologies - Meet NY Reforming the Energy Vision goals by encouraging DER construction and improving energy resiliency 	<ul style="list-style-type: none"> - Depending on financing plans, growth of microgrid popularity, and increased use of natural gas-fired generators, the state may need to develop additional plans for expanding natural gas infrastructure 	<ul style="list-style-type: none"> - Successful construction and operation of a community microgrid will demonstrate the tangible value of microgrid projects - Indirect benefits associated with microgrids will encourage and inspire citizens to strive for DER in their own communities

3.2.4 Demonstration of State Policy

The proposed microgrid represents a major step towards achieving New York State energy goals; it will provide a local platform for excess energy generation throughout the year, help the community adapt to climate change, and expand renewable energy generation. The proposed microgrid supports the New York State Energy Plan by providing a power distribution platform for locally-owned DERs.

By coordinating proposed distribution infrastructure and DERs as a local distributed system platform (DSP), the microgrid will act as a distributed resource and will provide local grid stabilization through injections and withdrawals of power. As more distributed resources are added throughout Long Island City and Amtrak territory, the microgrid can be tuned to provide continual support for these assets (e.g., by providing ancillary services) and will diversify and enhance its portfolio of revenue streams. Eventually, as more microgrids arise in New York State, the proposed microgrid can integrate seamlessly into a larger “grid of grids” to promote energy markets, trading, and enhanced consumer choice for preferred power source.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

The Project Team includes Con Ed, the Long Island City government, Booz Allen Hamilton, Siemens AG, and Power Analytics. It may expand to include financiers as the project develops. Details on the Project Team can be found in this section.

3.3.1 Stakeholder Engagement

The Project Team has been engaged in constant communication with local stakeholders from the outset. Booz Allen and its partners have also communicated with each of the proposed facilities to gauge electric and steam demand and discuss other aspects of the project development. Over multiple meetings with the Project Team, representatives from Amtrak and Con Ed have provided essential data and discussed how the microgrid’s DERs and infrastructure will integrate with existing facilities.

3.3.2 Project Team

The microgrid project is a collaboration between the public sector and the private sector, led by Booz Allen Hamilton with significant support from Power Analytics, Amtrak, Verde Advisory, Viridity Energy, and Con Ed. Each of the private sector partners is well qualified in the energy and project management space. The community has strong interest in improving its energy reliability and expanding its clean energy generation capacity. Tables 19 and 20 provide details on the Project Team.

Table 19. Project Team

Background on Booz Allen Hamilton, Power Analytics, Con Ed, Viridity Energy, and Verde Advisory

Booz Allen Hamilton	Headquarters: McLean, VA	Annual Revenue: \$5.5 B	Employees: 22,700
History and Product Portfolio: Booz Allen was founded in 1914 and in the ten decades since its founding, Booz Allen has assisted a broad spectrum of government, industry, and not-for-profit clients including the American Red Cross, all branches of the Department of Defense, the Chrysler Corporation, NASA, and the Internal Revenue Service. Booz Allen’s energy business includes helping clients analyze and understand their energy use and develop energy strategies, recommending technology solutions to achieve their energy goals, and executing both self- and 3 rd party funded projects including energy efficiency, renewable energy, and smart grids.			
Power Analytics	Headquarters: San Diego, CA	Annual Revenue: \$10-15 MM	Employees: 50
History and Product Portfolio: Founded 25 years ago, Power Analytics is a privately-held small business that develops and supports electrical power system design, simulation, and analytics software. The Company’s worldwide operations include sales, distribution, and support offices located throughout North America, South America, Europe, Asia, and Africa and Australia.			
Consolidated Edison, Inc.	Headquarters: New York, NY	Annual Revenue: \$13 B	Employees: 14,500
History and Product Portfolio: For more than 180 years, Consolidated Edison has served the world’s most dynamic and demanding marketplace—metropolitan New York. Con Ed provides electric service to approximately 3.3 million customers and gas service to approximately 1.1 million customers in New York City and Westchester County. The company also provides steam service in certain parts of Manhattan. Con Ed receives yearly operating revenues of approximately \$13 BN and owns assets totaling approximately \$44 BN.			
Viridity Energy	Headquarters: Philadelphia, PA	Annual Revenue: Not disclosed	Employees: Not disclosed
History and Product Portfolio: Founded in 2008, Viridity Energy develops software that allows businesses and large facilities to use infrastructure and EE upgrades to generate revenue from wholesale electricity markets. The company has also succeeded in capturing energy generated by train braking systems, and diverting the saved energy back into the power grid.			
Verde Advisory	Headquarters: Chicago, IL	Annual Revenue: Not disclosed	Employees: Not disclosed
History and Product Portfolio: Verde Advisory is a boutique advisory firm that specializes in energy and infrastructure. The firm serves active energy funds and helps clients navigate challenges in energy transmission, distribution, and customer relationships.			

Table 20. Project Team Roles and Responsibilities

Table outlines roles, responsibilities, and expectations for each member of the Project Team during development, construction, and operation of the microgrid.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Con Ed	Con Ed will work with the Project Team to develop the concept and provide input.	Con Ed will oversee connections with existing infrastructure to ensure that the project does not violate interconnection standards or compromise their lines.	Con Ed will have limited responsibilities during the operation phase; they have indicated no interest in owning or operating DERs or microgrid infrastructure.
Long Island City	The City will serve as the main conduit to representatives of the schools.	As the liaison, the City will coordinate with all local and state parties as needed.	As the liaison, the City will coordinate with all local, regional, and state parties as required.
Amtrak	Amtrak will work with Project Team to develop the concept and provide input on proprietary infrastructure, electrical loads, and DER placement.	Amtrak must make land available for construction of DERs and must allow modification of proprietary electrical infrastructure.	Amtrak’s proprietary lines form the main backbone of the microgrid. Amtrak and the SPV will develop an agreement delineating operating responsibilities and appropriate islanding circumstances.
Booz Allen	BAH is responsible for the delivery of the Feasibility Study and its component parts. This includes serving as the central clearinghouse of data, design, and proposal development as well as the key POC for NYSERDA on this task.	BAH will serve in an advisory and organizational role, working in a similar prime contractor capacity to provide overall design, costing, and construction management services.	BAH would serve in an outside, advisory capacity upon completion of the microgrid and during its operation.
Power Analytics	Power Analytics is the partner for energy software solutions. The PA team, in conjunction with Siemens and Booz Allen, is responsible for the design of the SCADA and system software components and controls.	Power Analytics may lead the installation of control and energy management software following hardware installation and in concert with Siemens.	Provide IT systems support; may play an active role in system management through the EnergyNet software platform.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Suppliers	There are no suppliers required during this development phase; however, project partners and suppliers Siemens and Power Analytics are closely involved in feasibility and design portions of the project. BAH is in touch with additional suppliers of hardware and software including Duke Energy, Enel Green Power, Anbaric Transmission, Bloom, and Energize.	Siemens or another engineering and technology firm will be the hardware supplier, including switches and other physical controls. Power Analytics or another software company will be the EMS and SCADA provider, responsible for software and server components.	The installer of the hardware and software will continue to provide maintenance and advisory services as required to ensure proper and efficient functioning of their components. The software provider will work in cooperation with Con Ed to assess the best approach to daily operations of the software system.
Financiers/Investors	The SPV will be created during the project development phase. Investors for DERs may include any of the entities mentioned in the rows above.	Debt and equity investors will supply the cash required to complete the construction and installation of generation assets and microgrid controls.	SPV owners will realize revenues from the sale of electricity and thermal energy. Further, SPV owners will have responsibility for switching to island mode and regulating voltage and frequency across the microgrid’s loads in both grid-connected and island mode.
Legal/Regulatory Advisors	Regulatory advice is housed within Booz Allen. Further counsel will be retained as necessary to create the SPV and arrange financing.	Legal and regulatory will be a combination of Booz Allen, the City, Con Ed, and any outside counsel required.	Legal and regulatory will be the responsibility of the City, the utility, and any investors in the SPV

3.3.3 Financial Strength

The principal shareholders in the microgrid project will be private investors through the SPV. However, Con Ed and Amtrak will be important players.

Con Ed is one of the oldest utilities in the United States. For more than 180 years it has served one of the world’s most dynamic and demanding marketplaces in metropolitan New York. Con Ed provides electric service to approximately 3.3 million customers and gas service to approximately 1.1 million customers in New York City and Westchester County. The utility receives yearly operating revenues of approximately \$13 billion.

Amtrak, or the National Railroad Passenger Corporation, is a partially government-funded American railroad service. Headquartered in Washington, DC, Amtrak serves over 500 destinations across the contiguous United States and Canada, including the busy Northeast Regional and Acela Express lines. Amtrak owns Penn Station, which serves approximately 1,200 trains and more than 600,000 rail passengers on an average weekday, and is the busiest passenger transportation facility in North America.²¹ At the end of fiscal year 2014, Amtrak

²¹ Betts, Mary Beth (1995). “Pennsylvania Station”; Robert Sciamino (2013). “How to squeeze 1,200 trains a day into America’s busiest transit hub.”

owned assets worth approximately \$12.5 billion. The corporation receives yearly revenues in excess of \$3 billion but consistently has higher operating costs than revenues. The federal government subsidizes Amtrak and has a vested interest in keeping the rail service operational. Given the relatively reliable return on investment for solar PV arrays, efficient CHP units, and reciprocating generators, the microgrid project should attract attention from outside investors. The microgrid will produce positive returns for investors which may be amplified by NY Prize Phase III funding.

3.4 Commercial Viability – Creating and Delivering Value (Sub Task 3.4)

The specific technologies included in the microgrid design will enable rapid and efficient transitions between grid-connected and island mode based on signals from a SCADA control center. The proven efficacy of proposed microgrid components enhances the replicability and scalability of the design. This section will discuss the technical components of the microgrid and why they were chosen.

3.4.1 Microgrid Technologies

The specific technologies included in the microgrid design were chosen to meet the goals of providing reliable and efficient power in both grid-connected and island mode, achieving automatic load following, and developing black start capability.

A solar PV array and natural gas-fired reciprocating generators were chosen as generator technologies to reduce GHG emissions and enhance the reliability of the power supply. The CHP unit and natural gas generators will be capable of automatic load following (responding to load fluctuations within cycles, allowing the microgrid to maintain system voltage and frequency) and black starts. These generators will also reduce the need for diesel generation in emergency outage situations.

The new solar PV unit will provide a renewable component to the microgrid generation mix and is a more appropriate addition than an expanded natural gas unit. It will provide emission-free electricity during daylight hours and move the community and the state closer to the renewable generation goals set forth in state goals and the Renewable Portfolio Standard. However, PV generation will face the same problems in Sunnyside Yard that it does elsewhere in the northeastern United States: variable weather conditions and long periods of darkness in the winter.

The proposed battery storage unit uses an emerging zinc-air cell technology. Because it is so new, this technology has not accumulated much operational data. However, one manufacturer, Eos Energy Storage, projects that the battery will last 5,000 cycles at greater than 75% efficiency per discharge, and plans to sell the batteries at \$160/kWh.²² The batteries' uses include, but are not limited to, peak shaving, long term energy storage, frequency regulation, and demand response. The battery will require inverters to synchronize its DC output with the AC electricity

²² Eos Aurora: <http://www.eosenergystorage.com/products/>.

flowing through the larger grid and intelligent controls to synchronize with the microgrid control system.

The proposed microgrid includes numerous components that have been previously used and validated. Solar PV and natural gas generators, with and without CHP capability, are both widely used technologies, with more than 6 gigawatts of solar PV installed in 2015 in the United States. In NY State alone, there are more than 400 installed reciprocating CHP units with aggregate nameplate generating capacity that exceeds 295 MW.²³ The switch components are all industry standard and are widely used in utilities worldwide, and the IEDs, which are robust and safe via embedded electrical protections, are similarly standard across the industry. Team partner Power Analytics has similarly successful implementations of its Paladin software in microgrid environments, including the 42 MW, University of California, San Diego microgrid project that serves 45,000 persons.²⁴

3.4.2 Operation

SPV investors will receive all project-derived revenues, but will also be responsible for ongoing operation and maintenance costs. The SPV may receive some advice from Con Ed regarding the logistics of day-to-day operation. Regular maintenance and checks of equipment will be conducted based on manufacturer or installer recommendations and will ensure the proper function of all grid elements.

Decisions regarding the proper level of generation from local assets, load following, N+1 assurance, and other similar issues will be addressed automatically in real-time by the logic controllers and the MCS. The decision algorithms will be programmed upon installation with input from Amtrak and the SPV, with the ability to alter or revise them if operations dictate that to be the appropriate action. Interactions with the Con Ed power grid will be automatically governed by the microgrid controllers.

This analysis assumes Con Ed will purchase electricity from the CHP unit and solar PV array and distribute it across the grid during normal operation. Penn Station and the schools will continue to be billed for electricity via the regular Con Ed billing mechanism and cycle. However, Amtrak loads at Sunnyside Yard will receive electricity directly from the proposed reciprocating generators and will be billed by the SPV. In island mode, all connected facilities will purchase electricity directly from the SPV. Penn Station will purchase thermal energy from the CHP unit throughout the year.

Additional fees may be imposed upon microgrid participants as a percentage of their electricity cost. However, given the extremely limited amount of time forecasted in island operation and the commensurately limited time the customers will need to rely on the microgrid, the fee will be extremely marginal.

²³ US DOE, <https://doe.icfwebsiteservices.com/chpdb/state/NY>.

²⁴ <http://www.poweranalytics.com/company/pdf/M-12-GE-PPT-X-001-03%202012%20UCSD%20Virtual%20summit.pdf>.

3.4.3 Barriers to Completion

The barriers to constructing and operating the microgrid are primarily financial. Assuming the SPV will sell electricity and thermal energy to Con Ed and Amtrak, the microgrid will produce positive operating cash flows from year to year. These cash flows will recover initial investment costs after subsidies and provide positive returns to investors. The NY Sun program, Federal ITC, and Con Ed Demand Management storage incentive will together offset around 2% of total project cost. The project may still be commercially viable without these programs, but any grants that reduce the high initial capital expenditure will be valuable. Although the project will produce positive returns, the return on investment may not be competitive with equities or other high yield investments. However, if the project receives NY Prize Phase III funding, it will be a more attractive and competitive investment.

3.4.4 Permitting

The microgrid may require certain permits and permissions depending on the ultimate design choices.²⁵ The SPV will need to provide timely written notice to the New York State Department of Transportation (NYSDOT) if any of the proposed construction affects state rights-of-way, and will most likely need to apply for project specific permits. The SPV will need to comply with all applicable laws, rules, and regulations regarding construction, maintenance, and operation.²⁶ Further, the SPV may need to apply for a street works permit if any microgrid-related construction falls into the following categories: street opening, building operations/construction activity, sidewalk construction, and canopies.²⁷

The project is in an Environmental Protection Agency (EPA) Criteria Pollutant Non-Attainment zones for 8-hour ozone. The CHP unit and natural gas generators will require air quality permits pursuant to the Clean Air Act and to any non-attainment zone permitting restrictions.

3.5 Financial Viability (Sub Task 3.5)

The distributed energy resource assets included in the microgrid design will primarily produce revenue streams from electricity sales to Con Ed, electricity sales to Amtrak at Sunnyside Yard, and thermal energy sales to Penn Station. These assets will require significant initial capital outlay as well as annual operation and maintenance costs. The microgrid project qualifies for the NY Sun incentive, Federal ITC, and Con Ed Demand Management storage incentive, which will partially offset the initial investment costs. Private investors will use a mix of debt and equity to finance their shares. This section will discuss the revenues, costs, and financing options associated with the microgrid project in more detail.

²⁵ New York City permitting information can be found at: <http://www.nyc.gov/html/dot/html/infrastructure/permits.shtml>.

²⁶ NYSDOT laws, rules, and regulations can be found at: <https://www.dot.ny.gov/divisions/operating/oom/transportation-systems/traffic-operations-section/highway-permits/utility-permits>.

²⁷ The New York City Street Works Manual can be found at: <http://streetworksmanual.nyc>.

3.5.1 Revenue, Cost, and Profitability

The microgrid has a number of savings and revenue streams, as outlined in Table 21. The revenues will sum to approximately \$10 million per year, while fuel, operation, and maintenance will cost around \$7.2 million per year. Yearly cash flows should consistently recover operating costs and provide positive returns to investors. However, the investment may not be competitive with equities or other high-yield vehicles. NY Prize Phase III funding would make the microgrid a more attractive and competitive investment.

Table 21. Savings and Revenues

Expected yearly revenues and savings directly associated with operation of the microgrid and its DERs.

Description of Savings and Revenues	Savings or Revenue	Relative Magnitude	Fixed or variable
Electricity sales from CHP unit ²⁸	Revenue	\$3.6 MM	Variable
Electricity sales from solar PV array	Revenue	\$20,000	Variable
Electricity sales from 3 MW reciprocating generator ²⁹	Revenue	\$1.1 MM	Variable
Electricity sales from 8 MW reciprocating generator ³⁰	Revenue	\$4.7 MM	Variable
Revenue from CSRP capacity payments and deployment ³¹	Revenue	\$95,000	Fixed and Variable
Savings from TOU bill management ³²	Savings	\$50,000	Variable
Thermal energy sales from CHP unit	Revenue	\$380,000	Variable
Total Yearly Revenue and Savings		\$10 MM	Variable

²⁸ The Booz Allen Team calculated Con Ed’s supply charge for electricity to be approximately \$0.081/kWh in zone J. This is the assumed price for grid-connected sales from the CHP unit and solar array.

²⁹ Based on annual electricity consumption of approximately 11,675 MWh by non-traction loads and a sales price of \$0.0954/kWh (90% of the local industrial rate).

³⁰ Based on a capacity factor of 70% (generator will not be able to supply many of the traction system’s instantaneous peaks) and a sales price of \$0.0954/kWh (90% of the local industrial rate).

³¹ Capacity payments based on a bid of 800 kW at \$10/kW-month for CSRP participation and \$10/kW-month for the 3 year incentive. Additionally, Con Ed pays participants \$1/kWh reduced. The Project Team assumed 20 hours of program activation based on the 2013 record.

³² Based on 1 MW available for TOU bill management, a 50% capacity factor (method adapted from Sandia National Laboratories, “Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide”), 7 months of deployment per year, and a value of \$180/kW-year (Sandia National Labs through the Rocky Mountain Institute, “The Economics of Battery Energy Storage”).

Table 22. Capital, Design, and Operating Costs

Expected costs from construction, design, and operation of the microgrid. Operating costs are expressed as yearly totals.

Description of Costs	Type of Expense	Relative Magnitude	Fixed or Variable
6 MW CHP unit	Capital	\$12 MM	Fixed
3 MW reciprocating generator	Capital	\$3.9 MM	Fixed
8 MW reciprocating generator	Capital	\$10.4 MM	Fixed
200 kW solar PV array	Capital	\$480,000	Fixed
Zinc air battery	Capital	\$830,000	Fixed
Distributed Equipment	Capital	\$890,000	Fixed
Microgrid Control System	Capital	\$450,000	Fixed
IT costs (wireless and cables)	Capital	\$90,000	Fixed
New electric lines	Capital	\$15,000	Fixed
Extension of natural gas lines	Capital	\$2.28 MM	Fixed
Total Capital Expenditures		\$31.3 MM	Fixed
Design considerations and simulation analysis	Planning and Design	\$750,000	Fixed
Project valuation and investment planning	Planning and Design	\$100,000	Fixed
Assessment of regulatory, legal, and financial viability	Planning and Design	\$75,000	Fixed
Development of contractual relationships	Planning and Design	\$75,000	Fixed
Total Planning and Design		\$1 MM	Fixed
Fuel for CHP and reciprocating generators	Operating	\$5.6 MM	Variable
Maintenance for CHP and reciprocating generators	Operating	\$1.5 MM	Variable
Solar PV maintenance	Operating	\$4,000	Fixed
Battery maintenance	Operating	\$25,000	Fixed
Microgrid control system O&M	Operating	\$70,000	Fixed
Total Operating Expenses		\$7.2 MM	Variable

The proposed microgrid will qualify for three existing incentive programs: the NY Sun program, the Federal solar ITC, and the Con Ed Demand Management storage incentive. Together these incentive programs provide around \$770,000 in the project's first year, or 2% of total project capital expenditures. Other possible sources of incentive payments include NYSERDA Phase III NY Prize funding (up to \$5 million). See Table 23 for details on the available incentive programs.

Table 23. Available Incentive Programs

State and utility incentive programs that were included in the commercial/financial feasibility analysis and whether the incentive is required or preferred for the microgrid project to be feasible

Incentive Program	Value	Required or Preferred
NYSERDA NY Prize Phase III	\$5,000,000	Preferred
NY Sun	\$145,000	Preferred
Federal Solar ITC	\$145,000	Preferred
Con Ed Demand Management storage incentive	\$480,000	Preferred

3.5.2 Financing Structure

The development phase is characterized by the negotiation and execution of the construction financing and debt structure and agreements with any equity partners. Awards from Phase II of the NY Prize Community Microgrid Competition will supply most of the funding for project design and development and are essential as this Phase does not generate any revenue for cost-recovery purposes, with the Project Team providing capital for any costs that exceed available NYSERDA funding. This is based on the Phase II cost structure as described in NYSERDA RFP-3044. Amtrak and the Project Team will provide cash support or needed in-kind services consisting primarily of system expertise and support. Development will conclude with formal contract relationships between the utility and the customers of the microgrid, available and relevant rate and tariff information from the NYPSC, and firm financing for the construction of the project (described below).

The SPV, formerly established in Phase II, will leverage funds from private investors to complete the construction phase. Phase III NY Prize funding, which would provide up to \$5 million to the SPV for microgrid and DER equipment and installation, could make the microgrid a more attractive investment.

The Project Team has confirmed that Amtrak will grant the physical space to site the DERs at no cost. The SPV will maintain ownership of all generation assets and control infrastructure.

3.6 Legal Viability (Sub Task 3.6)

Like any infrastructure project that involves development of public and private land, the microgrid will require legal and regulatory agreements for ownership, access, zoning, permitting, and regulation/oversight. This section considers the various legal aspects of the microgrid project and discusses the likelihood of each becoming an obstacle to the project's success.

3.6.1 Ownership and Access

Legal considerations will include access limitations, franchising, zoning, and permitting. Private investors will own and operate DERs and microgrid control infrastructure. Microgrid equipment, including generation, will primarily be installed on Amtrak's land. However, the new lines that

connect the Con Ed electric system to the Amtrak electric lines may require permits. Access to the proposed data network and physical access to assets and infrastructure will not represent a significant barrier to project completion.

3.6.2 Regulatory Considerations

State and Utility Regulation

The new DERs will be regulated under relevant State code, however the process for constructing small distributed energy resources in New York is well established. The microgrid will comply with all rules governing the interconnection of generation assets to the grid, and given Con Ed's participation in the project, the Project Team does not envision any onerous requirements.

Local Regulation

All entities that require the use of public ways (i.e., for transmission or distribution facilities) must be granted permission by the presiding municipal authority in the form of a franchise or some lesser consent, depending on the scope of the usage. Nearly all of the proposed microgrid infrastructure and generation will be constructed on Amtrak's land, exempting the SPV from most associated permitting. However, the new distribution lines may require permits as discussed in Section 3.4.4. Local zoning codes may require permits for the modification of property, and this may apply to the accessory addition of distributed energy resources. As the generators will be constructed on Amtrak's land, the Project Team does not anticipate major problems in obtaining necessary zoning permits.

Air Quality

Natural gas generators may be subject to a variety of federal permits and emission standards depending on the type of engine, the heat or electrical output of the system, how much electricity is delivered to the grid versus used onsite, and the date of construction. The specific details associated with the proposed CHP unit and natural gas generators will determine the applicability of the regulations below. CAA regulations applicable to Reciprocating Internal Combustion Engine systems will apply. These regulations include:

- National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines (RICE): 40 CFR part 63 subpart ZZZZ
- New Source Performance Standards for Stationary Spark Ignition (SI) ICE: 40 CFR part 60 subpart JJJJ (natural gas generators)

Per EPA guidance, these regulations apply to all engine sizes, regardless of the end use of the power generated. However, further review and analysis must be conducted when details of the type and size of the generation system are confirmed.

New York state has enacted amendments to Environmental Conservation Law Articles 19 (Air Pollution Control) and 70 (Uniform Procedures) as well as New York State Department of Environmental Conservation (NYS DEC) amended regulations 6NYCRR Parts, per the 1990 Amendments to the Clean Air Act. With this demonstration of authority, NYS DEC received

delegation of the Title V operating permit program from the EPA. Title V Permits are required for all facilities with air emissions greater than major stationary source thresholds. New York's air pollution control permitting program combines the federal air operating permitting program with long-standing features of the state program. The primary rules for applications are found in 6NYCRR:

- [200](#) (General Provisions),
- [201](#) (Permits and Certificates),
- [621](#) (Uniform Procedures) and
- [231](#) (New Source Review in Non-attainment Areas and Ozone Transport Regions).

Final application of these rules will depend on the size and technology of the selected CHP unit.

3.7 Project Commercial and Financial Viability Conclusions

The microgrid project will include three critical facilities, a college, and a high school. A single SPV will own and operate DERs and microgrid infrastructure. Its design includes five new DERs to be located at Penn Station and Sunnyside Yard: a 6 MW natural gas CHP unit, a 3 MW natural gas reciprocating generator, an 8 MW natural gas reciprocating generator, a 1 MW/4 MWh battery, and a 200 kW solar photovoltaic array. The SPV will provide the capital required to purchase and install these DERs and will receive revenues from electricity and thermal energy sales throughout the lifespan of the project. Investors in the SPV will contribute funds to the daily operation and maintenance of the DERs, and will leverage advice from Siemens and Con Ed to keep the microgrid components and control infrastructure running smoothly.

The Project Team forecasts yearly revenues of approximately \$10 million and yearly operation and maintenance costs of approximately \$7.2 million. The proposed microgrid will provide positive returns to investors, but may require NY Prize Phase III funding to be competitive with equities and other high yield vehicles. These estimates and value propositions are predicated on several assumptions, as outlined in the Executive Summary.

The microgrid will not enter island mode to participate in DR programs, as doing so would interfere with Con Ed infrastructure during otherwise normal operation. However, the microgrid's generation assets will effectively contribute to load reduction in Long Island City and Manhattan through normal operation, and the battery storage unit will bid 800 kW of capacity into Con Ed's CSRP.

In addition to revenues from electricity and thermal energy sales, the microgrid will provide indirect financial and non-financial benefits to local citizens, SPV shareholders, Con Ed, and the larger New York City community. Improved resilience of transportation services enhances the local population's safety and quality of life during emergency outages, and local energy generation reduces the strain on the larger energy transmission and distribution infrastructure. Future expansion of the microgrid could provide electric service to additional facilities in Long Island City or Manhattan.

Permitting and regulatory challenges should be reasonably straightforward. The primary regulatory consideration will be the Clean Air Act permitting of the new CHP unit and natural gas generators. The SPV may also need to apply for zoning permits and rights-of-way permits for the proposed DERs and new distribution lines.

4. Cost Benefit Analysis

Section 4 Cost Benefit Analysis is made up of seven sections in addition to the introduction:

- **Section 4.1** analyzes the *facilities connected to the microgrid* and their energy needs.
- **Section 4.2** discusses the *attributes of existing and proposed DERs*, including factors such as nameplate capacity and expected annual energy production.
- **Section 4.3** analyzes *potential ancillary services sales and the value of deferring transmission capacity investments*.
- **Section 4.4** reviews the *overall costs* associated with construction and installation of the microgrid as well as the fuel, operation, and maintenance costs required over the lifetime of the microgrid.
- **Sections 4.5 and 4.6** discuss the *community benefits* of maintaining power during a grid-wide outage and outline the costs associated with operating the microgrid in island mode.
- **Section 4.7** presents the Industrial Economics (IEc) *benefit-cost analysis report and associated Project Team commentary*.

4.1 Facility and Customer Description (Sub Task 4.1)

The proposed microgrid will include three facilities from various rate classes and economic sectors. NYSERDA designates three primary rate classes based on type of facility and annual electricity consumption: residential, small commercial (less than 50 MWh per year), and large commercial (greater than 50 MWh per year). See Table 24 for basic statistics on each facility's energy usage. All five of the proposed microgrid facilities belong to the large commercial rate class requiring approximately 125,584 MWh of electricity per year. Additionally the average aggregate demand in 2014 was 14.31 MW and rose as high as 27.38 MW.

There are two kinds of facilities in the microgrid including private and educational in the proposed Sunnyside Yard microgrid footprint. The education facilities, LaGuardia Community College and Middle College High School at LaGuardia, comprise more than 15.3% of the microgrid's total annual electricity usage. The private facilities, the Sunnyside Yard loads and Penn Station, make up 84.7% of electricity usage. The combination of existing and proposed generation assets included in the microgrid design will be capable of meeting 100% of average aggregate facility energy usage during a major power outage, but may approach their generation limits if several large facilities simultaneously reach peak energy use. In these situations, the backup generators will need to come online to supply additional electricity. For information on each facility's average daily operation during a major power outage, see Table 24.

Table 24. Facility and Customer Detail Benefit³³

Table provides details about each facility and customer served by the microgrid, including average annual electricity usage, 2014 peak electricity demand, and hours of electricity required during a major power outage.

REDACTED PER NDA WITH CON ED

³³ Load data was provided to Booz Allen by Con Ed.

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates new and existing DERs, including one proposed CHP system, two proposed natural gas generators, one proposed solar PV array, one proposed battery storage unit and two existing diesel generators. The proposed CHP unit, natural gas generators and solar PV array will produce an average of 13.28 MW of electricity throughout the year³⁴ (including projected capacity factors), and the existing backup generators will provide up to 1.86 MW of backup generation capacity during emergencies.

The CHP has a nameplate capacity of 6 MW and will operate nearly continuously. Assuming a capacity factor of 85%, the CHP will produce approximately 44,676 MWh of electricity over the course of the year. If a major power outage occurs, the CHP will produce an average of 122.4 MWh of electricity per day. The CHP system will use around 11.5 Mcf (1000 ft³) of natural gas per MWh generated, which amounts to a fuel cost of around \$63/MWh to operate.³⁵

The 60 Hz substation natural gas generator has a nameplate capacity of 3 MW and will operate nearly continuously. Assuming a capacity factor of 42.5%, the natural gas generator will produce approximately 11,680 MWh of electricity over the course of the year. Although the natural gas generator has the ability to generate 22,338 MWh of electricity at an 85% capacity factor, it will follow Amtrak's non-traction loads at Sunnyside Yard generating only what is demanded. If a major power outage occurs, the natural gas generator will produce an average of 32 MWh of electricity per day. The natural gas generator will use around 9.5 Mcf (1000 ft³) of natural gas per MWh generated, which amounts to a fuel cost of around \$51.5/MWh to operate.³⁶

The 25 Hz substation natural gas generator has a nameplate capacity of 8 MW and will operate nearly continuously. Assuming a capacity factor of 70%, the natural gas generator will produce approximately 49,056 MWh of electricity over the course of the year. Although the natural gas generator has the ability to generate 59,568 MWh of electricity of electricity at an 85% capacity factor, it will follow Amtrak's traction loads generating only what is demanded resulting in a capacity factor closer to 70%. If a major power outage occurs, the natural gas generator will produce an average of 163.2 MWh of electricity per day. The natural gas generator will use around 11.5 Mcf (1000 ft³) of natural gas per MWh generated, which amounts to a fuel cost of around \$63/MWh to operate.³⁷

Limited by weather conditions and natural day-night cycles, the 0.2 MW solar PV array is expected to produce 245.28 MWh per year. Because many outages are caused by severe weather events, solar panels cannot be relied upon to provide energy during emergency outages without

³⁴ NG generator capacity factor: 85% (EPA estimate for 10 MW generator, <http://www3.epa.gov/chp/documents/faq.pdf>)
Solar array capacity factor: 14% (NREL PV Watts Calculator).

³⁵ Price of natural gas: \$5.74 per Mcf (average CHGE supply price from 2013-2015).

³⁶ Price of natural gas: \$5.74 per Mcf (average CHGE supply price from 2013-2015).

³⁷ Price of natural gas: \$5.74 per Mcf (average CHGE supply price from 2013-2015).

supplementary battery storage. However, on average the solar array will produce 0.672 MWh of electricity per day. Maintenance costs for the solar array will be around \$4,000 per year,³⁸ which means the marginal cost of producing solar electricity will be about \$34/MWh.³⁹

The existing diesel backup generators will only be used in emergency situations when the microgrid requires a black start or when the proposed generation is not producing sufficient electricity to meet aggregate demand or goes offline for maintenance. The diesel generators have a combined nameplate capacity of 1.86 MW. The Booz Allen team forecasts around 2.67 hours of larger grid outage based on Con Ed's CAIDI from 2013,⁴⁰ and therefore predicts annual output from the backup generators will be insignificant. The backup diesel generators require around 132 gallons of fuel per hour of operation.⁴¹ In the event of a major power outage, the generators could produce up to 44.64 MWh/day.⁴² See Table 25 for a detailed list of all proposed and existing DERs in the Amtrak microgrid footprint.

³⁸ Annual fixed O&M cost: \$20/kW per year (NREL, http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html).

³⁹ Capital cost: \$440,000 (Siemens Solar PV estimate), Variable cost: 30 years of production at a cost of \$20/kW per year (Siemens lifecycle estimate, NREL), Discount rate: 7% (industry standard discount rate; NREL <http://www.nrel.gov/docs/fy13osti/58315.pdf>).

⁴⁰ Grid outage data from DPS 2013 Electric Reliability Performance Report (Con Ed average CAIDI).

⁴¹ Backup Diesel Generator fuel consumption rate – Cummins Power Generation estimate.

⁴² The Booz Allen team forecasts a 100% level of operation from the backup generator based on historical loads and expected generator output. In 2014, the average load in Sunnyside Yard was 14.31 MW. The CHP system, natural gas generators and solar array can provide an average of 13.28 MW of generation. Load is expected to exceed the proposed generation's maximum output for approximately 100% of time spent in island mode. Solar output is unreliable, but it should provide significant support on the most irradiated days of the year when peak demand is highest.

Table 35. Distributed Energy Resources

Table lists DERs incorporated in the microgrid, including their energy/fuel source, nameplate capacity, estimated average annual production under normal operating conditions, average daily production in the event of a major power outage, and fuel consumption per MWh generated (for fuel-based DERs). “Normal operating conditions” assumes approximately 2.67 effective hours of operation per year for the diesel backup generator.

Distributed Energy Resource Name	Location	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Expected Daily Production During Major Power Outage (MWh)	Potential Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
							System fuel	Units of MMBTUs
DER1 - Backup Generator at Penn Station	Penn Station	Diesel	0.930	2.48	22.32	22.32	71 Gallons	9.86 MMBTUs
DER2 - Backup Generator at Penn Station	Penn Station	Diesel	0.930	2.48	22.32	22.32	71 Gallons	9.86 MMBTUs
DER3 - Proposed CHP at Penn Station	Penn Station	Natural Gas	6	44,676	122.4	144	11.2 Mcf	11.5 MMBTUs
DER4 - Proposed Natural Gas Generator at Sunnyside Yard – 60 Hz Substation	Sunnyside Yard	Natural Gas	3	11,680	32	72	9.26 Mcf	9.5 MMBTUs
DER5 - Proposed Natural Gas Generator at Sunnyside Yard – 25 Hz Substation	Sunnyside Yard	Natural Gas	8	49,056	134.4	192	11.2 Mcf	11.5 MMBTUs
DER6 - Proposed Solar PV Array at Sunnyside Yard - 25 Hz Substation	Sunnyside Yard	Sunlight	0.20	245.28	0.672	1.6	N/A	N/A
DER7 - Proposed Battery Storage at Sunnyside Yard - 25 Hz Substation	Sunnyside Yard	N/A	1 MW / 4 MWh	4.0	4.0	4.0	N/A	N/A

4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3)

4.3.1 Peak Load Support

The microgrid’s proposed generation assets will operate nearly continuously throughout the year, providing a constant level of load support. Although continuous operation will limit the CHP and natural gas generators’ ramp-up capability during peak demand events, it will also maximize revenue for owner of the microgrid. See Table 26 for the maximum generation capacities of the proposed and existing DERs.

The proposed solar array will be at its most productive on days with peak solar irradiance when peak demand events are common, thus providing peak load support when it is most needed. The solar array will provide around 0.028 MW of load support on average over the course of a year. However, their generation depends on weather conditions and time of day, therefore solar array is not a reliable source of peak load support.

The proposed battery unit will also be able to provide peak load support. The battery unit will have the ability to provide up to 1 MW of load support for 4 hours at full charge.

Table 26. Distributed Energy Resource Peak Load Support

Table shows the available capacity and impact of the expected provision of peak load support from each DER. Existing generation was not included because it is not expected to generate electricity outside of emergency island mode situations (existing diesel and natural gas generators).

Distributed Energy Resource Name	Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER3 - Proposed CHP at Penn Station	Penn Station	Maximum of 6	No
DER4 - Proposed Natural Gas Generator at Sunnyside Yard – 60 Hz Substation	Sunnyside Yard	Maximum of 3	No
DER5 - Proposed Natural Gas Generator at Sunnyside Yard – 25 Hz Substation	Sunnyside Yard	Maximum of 8	No
DER6 - Proposed Solar PV Array at Sunnyside Yard - 25 Hz Substation	Sunnyside Yard	Maximum of 0.2	No
DER7 - Proposed Battery Storage at Sunnyside Yard - 25 Hz Substation	Sunnyside Yard	Maximum of 1 MW for 4 hours	No

4.3.2 Deferral of Transmission/Distribution Requirements

The majority of Con Ed's congestion in the Brooklyn-Queens area is south of the Yard, therefore according to Con Ed, the 13.28 MW of average local generation produced by the DERs will only marginally defer the need to invest in new or upgraded power lines. Although these power lines will last up to one hundred years if well maintained,⁴³ they can only transmit a limited amount of power. As demand for electricity in Mamaroneck increases, the lines might need to be supplemented to handle additional load.

The same is true for distribution capacity investments on a local, feeder-by-feeder basis. However, constructing DERs could actually increase the distribution capacity investment cost in certain cases (e.g., if the assets are placed in remote locations and thus expensive to connect to the local grid). Although the Sunnyside Yard area has available electric capacity, approximately 280 feet of new distribution lines will be need to be built to properly connect the educational facilities to the Amtrak 25 Hz Substation footprint generator and will require a significant investment.

4.3.3 Ancillary Services

The proposed zinc air batteries in the Sunnyside microgrid will participate in ancillary services markets. The zinc air battery unit will bid 1 MW of capacity into the NYISO frequency regulation market throughout the year. By continuously discharging or charging according to signals from the NYISO, the batteries will produce revenues for owners and improve power stability on the larger grid.

4.3.4 Development of a Combined Heat and Power System

Penn Station will be a steady and reliable customer for all of the steam generated by the CHP system. At normal levels of operation, the CHP unit will produce approximately 5,280 MMBTUs of steam per month. This will meet approximately 16% of the Penn Station's average monthly thermal energy demand, which is around 32,930 MMBTUs.⁴⁴ By purchasing steam from the CHP unit, Penn Station will replace around 63,360 MMBTUs of natural gas with co-generated steam every year.

4.3.5 Environmental Regulation for Emission

The microgrid's generation assets will drive a net 16,143 MTCO₂e (metric tons CO₂ equivalent) increase in GHG emissions as compared to the New York State energy asset mix. The proposed generation assets will produce around 105,658 MWh of electricity per year. The proposed CHP unit and natural gas generators will emit approximately 57,855 MTCO₂e per year,⁴⁵ while the solar array will emit none. The current New York State energy asset mix would emit

⁴³ Professor John Kassakian, MIT: <http://engineering.mit.edu/ask/how-do-electricity-transmission-lines-withstand-lifetime-exposure-elements>.

⁴⁴ Data supplied by the Con Ed.

⁴⁵ CHP Emissions Rate: 0.51 MTCO₂e/MWh (assuming 117 lb CO₂e per MMBTU; EIA, <http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11>).

approximately 38,349 MTCO_{2e} to produce the same amount of electricity⁴⁶ and natural gas-fired boilers would emit around 3,363 MTCO_{2e} to produce the same amount of thermal energy.⁴⁷ The microgrid's generation assets will therefore result in a net increase in emissions by 16,143 MTCO_{2e}.

The microgrid's generation assets will not need to purchase emissions permits to operate and will not exceed current New York State emissions limits for generators of their size. The New York State overall emissions limit was 64.3 MMTCO_{2e} in 2014, and will begin decreasing in the near future. The state sells an "allowance" for each ton of CO_{2e} emitted in excess of the limit at allowance auctions, but does not require assets under 25 MW to purchase allowances. The CHP unit is defined as a "small boiler" by NYS DEC limits (fuel input of 10-25 MMBTU/hour). The NYS DEC is currently developing output-based emissions limits for distributed energy resource assets. These limits on SO₂, NO_x, and particulate matter (to be captured in 6 NYCRR Part 222) should be published in late 2015 or early 2016. The main source of emissions regulations for small boilers is currently the EPA 40 CFR part 60, subpart JJJJJ—however, this law does not include gas-fired boilers.

The CHP will require an operating permit in addition to other construction permits. The costs of obtaining this permit will be in line with the cost of a construction permit and not comparable to the price of emissions allowances. The existing generators are already permitted and therefore will not incur any significant emissions costs.

Table 27 catalogs the CO₂, SO₂, NO_x, and Particulate Matter (PM) for the CHP, natural gas and diesel generators.

⁴⁶ Assuming an asset mix of 15% coal, 31% natural gas, 6% oil, 17% hydro, 29% nuclear, 1 % wind, 1% sustainably managed biomass, and 1% "other fuel". This adds up to around 0.36 MTCO_{2e}/MWh. Info from EPA (http://www3.epa.gov/statelocalclimate/documents/pdf/background_paper_3-31-2011.pdf).

⁴⁷ Average emissions rate for natural gas boilers: 0.053 MTCO_{2e}/MMBTU. Info from EIA (117 lb CO₂ per MMBTU; <http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11>).

Table 27. Emission Rates

Table shows the emission rates for each DER per MWh and per year. Notice the rates vary drastically for each emissions type (CO₂, SO₂, NO_x).

Distributed Energy Resource Name	Location	Emissions Type	Emissions Per MWh (Metric Tons/MWh)
DER1 & DER2 Backup Generator at Penn Station	Penn Station	CO ₂	0.7196 ⁴⁸
		SO ₂	0.1911 ⁴⁹
		NO _x	2.9074
		PM	0.2046
DER3 - Proposed CHP at Penn Station	Penn Station	CO ₂	0.553
		SO ₂	0.0000067 ⁵⁰
		NO _x	0.00055 ⁵¹
DER4 & DER5 - Proposed Natural Gas Generator at Sunnyside Yard	Sunnyside Yard	CO ₂	0.553
		SO ₂	0.0000067
		NO _x	0.00055

4.4 Project Costs (Sub Task 4.4)

4.4.1 Project Capital Cost

The microgrid design requires the following new pieces of distributed equipment across the microgrid:

- A control system to provide one point of control for operating the microgrid and synthesizing real-time electricity data from the connected facilities.
- Intelligent electronic devices to interface with the 13.2 kV distribution feeder.
- Automated breakers installed throughout the microgrid footprint to allow the microgrid to isolate and maintain power to the microgrid connected facilities.
- Grid-paralleling switchgear to synchronize each generator’s output to the system’s frequency.

The total installed capital cost of the distributed equipment and IT gear is estimated to be \$1.3 million. The Project Team estimates the \$12 million for the 6 MW CHP unit, \$10.4 million for the 8 MW natural gas generator, \$3.9 million for the 3 MW natural gas generator, \$480,000 for the 0.2 MW solar PV array and \$832,000 for the 1 MW battery unit.⁵² The cost of overhead

⁴⁸ Diesel Generator Emissions rate: 0.72 MTCO₂e/MWh (assuming 161 lb CO₂e per MMBTU; EIA, <http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11>).

⁴⁹ Michigan Department of Environmental Quality; Environmental Science and Services Division. “Potential to Emit, Diesel Fired Generator Calculation Worksheet.”

⁵⁰ CHP calculator, EPA.

⁵¹ EPA, <http://www3.epa.gov/chp/documents/faq.pdf>.

⁵² CHP Capital Cost: \$1,800/kW (Siemens CHP estimate), Natural Gas Generator Capital Cost: \$1,300/kW (Siemens Natural Gas Generator estimate).

powerline installation will be \$17,000 or \$151,000 if the powerlines are installed underground.⁵³ The cost of natural gas line installation at Penn Station will be \$1 million and the cost of natural gas line installation at Sunnyside Yard will be \$1.28 million.⁵⁴ This brings the total installed capital cost to approximately \$31.25 million if the powerlines are installed overhead, not including interconnection fees and site surveys. If the powerlines are installed underground the total installed capital cost will be \$31.37 million. Additionally the estimated capital cost does not account for any financial incentives or tax credits that may lower the overall cost of the microgrid. See Tables 28 and 29 below for estimated installed costs for each microgrid component.

Table 28 details capital cost of the microgrid components; it includes equipment such as the microgrid control system and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid.

The Project Team estimates nearly every piece of microgrid equipment has a useful lifespan of 20 years. The only component with a shorter lifespan will be the microgrid control system (Siemens SICAM PAS or equivalent), which will be replaced by more advanced software after seven to eight years.

Table 28. Distributed Equipment Capital Cost

Estimated costs and lifespan of the distributed equipment associated with the microgrid.

Distributed Equipment Capital Costs				
Capital Component	Quantity	Installed Cost (\$ (+/- 30%))	Component Lifespan (Years)	Purpose/Functionality
Microgrid Control System	1 Primary	\$50,000	7 - 8 years	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
(Siemens SICAM PAS or equivalent)	1 Back-up			
Microgrid Control Center (Siemens MGMS or equivalent)	1	\$300,000	20	Provides data trending, forecasting, and advanced control of generation, loads and AMI/SCADA interface, interface to NYISO for potential economic dispatch.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay)	18 New 41 Upgraded	\$655,000	20	New breaker/switch at distribution load feeders to enable IED interface with and control by the microgrid
Generation Controls (OEM CAT, Cummins, etc.)	5	\$20,000	20	OEM generation controllers serve as the primary resource for coordinating generator ramp

Solar PV Capital Cost: \$2,400/kw (Siemens Solar PV estimate)

Battery Unit Cost: \$208/kw (vendor estimate)

⁵³ Cost estimate provided by Travers Dennis - Con Ed.

⁵⁴ Cost estimate provided by James Skillman- Con Ed.

Distributed Equipment Capital Costs				
Capital Component	Quantity	Installed Cost (\$ +/- 30%)	Component Lifespan (Years)	Purpose/Functionality
(Load Sharing via Basler, etc.)				up/ramp down based on external commands. Basler distributed network controllers allow primary generator to establish Microgrid frequency and supply initial load, while also managing load sharing between all spinning generators and paralleling sequence.
PV Inverter Controller (OEM Fronius or equivalent)	1	\$4,000	20	Controls PV output and sends data to SCADA and EMS for forecasting.
WiMax Base Station	1	\$8,000	20	Located near microgrid control cabinet. Communicates wirelessly with WiMax subscriber units for remote control and monitoring of breakers and switches. Should be installed at high location.
WiMax Subscriber Units	15	\$30,000	20	Each subscriber unit can communicate back to the WiMax base station for SCADA monitoring and control or remote relay to relay GOOSE messaging.
WiMax configuration and testing	1	\$23,000	-	The configuration and testing of the WiMax hardware
Installation Costs	-	\$205,000	-	Installation of capital components in the microgrid

Table 29. Capital Cost of Proposed Generation Units

Table displays the estimated costs and lifespan of the equipment associated with the generation units of the microgrid.

Proposed Generation Units				
Capital Component	Quantity	Installed Cost (\$) (+/- 30%)	Component Lifespan (Years)	Purpose/Functionality
6 MW CHP System	1	\$12,000,000	20	Generation of electricity
8 MW Natural Gas Turbine	1	\$10,400,000	20	Generation of electricity
3 MW Natural Gas Turbine	1	\$3,900,000	20	Generation of electricity
0.2 MW PV System	1	\$480,000	30	Generation of electricity
1 MW Battery Unit	1	\$832,000	20	Storage of electricity

The microgrid IT infrastructure will also require Cat-5e Ethernet cables for communication between distribution switches, generation switchgear, PV inverters, and network switches. The design uses Cat-5e cabling, including RJ-45 connectors at \$0.61 per cable.⁵⁵ The total installation cost of cabling is approximately \$5.65 per foot for Cat-5e cables.⁵⁶ The Project Team will use the existing cabling infrastructure to install the communications cables, thereby avoiding the high costs of trenching the proposed lines. The estimated total cost for the microgrid IT infrastructure is around \$30,000.⁵⁷

In addition to the microgrid IT infrastructure, the microgrid will need new distribution lines in order to connect the educational facilities to the Amtrak 25 Hz Substation footprint generator. The Project Team has determined the approximate cost of building these new distribution lines is \$17,000 for an overhead installation and \$151,000 for an underground installation.⁵⁸ The Booz Allen team as also determined that additional natural gas lines need to be installed at both Penn Station and Sunnyside Yard. The approximate cost of the new natural gas lines at Penn Station is \$1 million and \$1.28 million for the new lines at Sunnyside Yard.⁵⁹

4.4.2 Initial Planning and Design Cost

The initial planning and design of the microgrid includes four preparation activities and total to approximately \$1 million.

1. The first set of activities are the design considerations and simulation analysis which will cost approximately \$750,000 to complete.

⁵⁵ Commercially available RJ-45 connectors, \$0.30 per connector.

⁵⁶ Installation costs for Cat5e: \$5.45/ft Component cost for Cat5e: \$0.14/ft (commercially available).

⁵⁷ The Project Team estimated ~4,000 feet of Cat5e.

⁵⁸ The Project Team has determined that approximately 280 feet of new line is required at the cost of \$60/ft for overhead installation and \$540/ft for underground installation according to Travers Dennis at Con Ed.

⁵⁹ The Project Team has determined that approximately 500 feet of new natural gas line is required in Penn Station at the cost of \$2000/ft and an additional 1600 feet of trenched natural gas line is needed at Sunnyside Yard at the cost of \$800/ft according to James Skillman at Con Ed.

2. The second activity focuses on the financial aspects of the project including project valuation and investment planning which will cost approximately \$100,000.
3. The third activity focuses on the legal aspects of the project including an assessment of regulatory issues and legal viability which will cost approximately \$75,000.
4. The fourth activity focuses on the development of contractual relationships with key partners will cost approximately \$75,000.

A breakout of the initial planning and design costs are illustrated in Table 30 below.

Table 30. Initial Planning and Design Cost

Table displays estimates and descriptions for engineering, legal, and financing costs involved in initial planning and design of the microgrid.

Initial Planning and Design Costs (\$) ⁶⁰	Cost Components
\$750,000	Design considerations and simulation analysis
\$100,000	Project valuation and investment planning
\$75,000	Assessment of regulatory, legal, and financial viability
\$75,000	Development of contractual relationships
\$1,000,000	Total Planning and Design Costs

4.4.3 Operations and Maintenance Cost

The proposed DERs will incur fixed operation and maintenance costs, including fixed annual service contracts.

Annual service for the proposed CHP and natural gas generators will cost approximately \$1.48 million.⁶¹ The microgrid owner will also incur \$12,600/year in total costs for annual fixed system service agreements for the solar PV array and backup generators.⁶²

The DERs will also incur variable O&M costs that fluctuate based on output. These include fuel and maintenance costs outside of scheduled annual servicing. First, the CHP and natural gas generators will require capital for fuel, consumable chemicals, and other operating expenses. The average price of natural gas for the microgrid will be \$5.74/Mcf, which translates to an average fuel cost of \$51.5/MWh for the 3 MW natural gas generator and \$63/MWh for the 6 MW CHP system and 8 MW natural gas generator.

The diesel fuel usage of the backup diesel generators is difficult to predict because they will be used only during some emergency outage situations. The average price of diesel fuel in New

⁶⁰ Estimates developed by Booz Allen Project Team and independent consultant.

⁶¹ CHP O&M Estimate: \$0.014/kw (Siemens estimate).

⁶² \$1,000 for solar PV array (\$20/kW per year), \$4.60/kW-year for backup diesel generators (Electric Power Research Institute, "Costs of Utility Distributed Generators, 1-10 MW") and \$1,500 for natural gas generator (Pete Torres, Prime Power; yearly service for small scale natural gas generator).

York State from 2013-2015 was \$3.91 per gallon, which translates to an average fuel cost of approximately \$0.28/kWh (assuming an output of 14.1 kWh/gallon). The high price of diesel fuel, along with increased GHG emissions, discourages extended use of the diesel generators.

The solar PV array will not require fuel to operate, and it should not require service outside of the normally scheduled downtime. Normally scheduled downtime should cost approximately \$20/kW per year.⁶³

The microgrid owner will also incur \$25,000 per year in total costs for annual fixed system service agreements for the battery unit.

Annual service for all non-DER microgrid components will cost approximately \$70,000 per year.⁶⁴ Table 31 outlines all fixed operations and maintenance (O&M) costs associated with normal operation of the DERs.

Table 31. Fixed Operating and Maintenance Cost

Table displays estimated values and descriptions of the fixed O&M costs associated with operating and maintaining the microgrid’s DERs.

Fixed O&M Costs (\$/year)	Cost Components
~ \$4,000	Solar PV System Service Agreements – Annual costs of maintenance and servicing of unit
~ \$625,500	CHP System Service Agreement – Annual costs of maintenance and servicing of unit
~ \$8,600	Backup Diesel Generator Service Agreements – Annual costs of maintenance and servicing of unit
~ \$850,500	Natural Gas Generator Service Agreements – Annual costs of maintenance and servicing of unit
\$25,000	Battery System Service Agreement – Annual costs of maintenance and servicing of units
\$70,000	Non-DER Microgrid Components Service Agreement - Annual costs of maintenance and servicing of components

4.4.4 Distributed Energy Resource Replenishing Fuel Time

The both the CHP and natural gas units will have a continuous supply of fuel unless the pipeline is damaged or destroyed, therefore the CHP and natural gas units will be able to operate continuously. There is effectively no maximum operating duration for the CHP and natural gas units in island mode. DERs such as diesel generators have limited tank sizes and have clear maximum operating times in island mode.

At full operation, the diesel generators will require a total of 132 gallons of diesel fuel per hour. Both generators have a 1,600 gallon fuel tank that gives them an operating period of 24 hours at full load.

⁶³ NREL (projects \$0/kWh variable maintenance costs): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.

⁶⁴ O&M for non-DER microgrid components: \$70,000/year (Siemens).

The solar PV array does not require fuel for operation, but its output depends on weather and time of day.

The battery unit does not require fuel for operation, but is limited by a maximum output of 1 MW for a total of 4 hours. Table 32 shows the fuel consumption and operating times for all of the microgrid DERs.

Table 32. Maximum Fuel Operating Time for Distributed Energy Resource

Table displays the potential maximum operating times in Islanded Mode for each DER. The corresponding fuel consumption for each DER is also detailed.

Distributed Energy Resource	Location	Energy Source	Maximum Operating Time in Islanded Mode without Replenishing Fuel (hours)	Fuel Consumption During this Period	
				Quantity	Unit
DER1 - Backup Generator at Penn Station	Penn Station	Diesel	1	1600	Gallon
DER2 - Backup Generator at Penn Station	Penn Station	Diesel	1	1600	Gallon
DER3 - Proposed CHP at Penn Station	Penn Station	Natural Gas	N/A	N/A	MMBTUs
DER4 - Proposed Natural Gas Generator at Sunnyside Yard – 60 Hz Substation	Sunnyside Yard	Natural Gas	N/A	N/A	MMBTUs
DER5 - Proposed Natural Gas Generator at Sunnyside Yard – 25 Hz Substation	Sunnyside Yard	Natural Gas	N/A	N/A	MMBTUs
DER6 - Proposed Solar PV Array at Sunnyside Yard - 25 Hz Substation	Sunnyside Yard	Sunlight	N/A	N/A	N/A
DER7 - Proposed Battery Storage at Sunnyside Yard - 25 Hz Substation	Sunnyside Yard	N/A	N/A	N/A	N/A

4.5 Costs to Maintain Service during a Power Outage (Sub Task 4.5)

4.5.1 Backup Generation Cost during a Power Outage

All microgrid generation assets will serve as backup generation in the event of an extended power outage. The CHP and natural gas generators will be the most reliable and productive of the DERs, providing a maximum of 17 MW to the microgrid at any given time. Because the CHP and natural gas generators will use natural gas via pipeline as fuel, disruptions to its fuel source are unlikely. The CHP and natural gas generators can generate a maximum of 346.8

MWh per day, using approximately 4,432 Mcf (4,548 MMBTU) of natural gas. The CHP will not require startup or connection costs in order to run during island mode and should not incur any daily variable costs other than fuel.

The solar array will be available for backup generation during a power outage, but its production is too inconsistent for it to qualify as a true backup generator. Extreme weather is responsible for many emergency outages in New York State, and such weather will greatly reduce the output of the solar panels. However, when high state-wide electricity demand on the most irradiated days of summer causes outages, the solar panels will be at their most productive and could provide up to 0.2 MW of load support to the proposed microgrid.

The battery unit will be able to provide backup load support to the microgrid in the case of a grid wide outage. The battery unit can provide up to 1 MW for 4 hours at full charge.

The backup generators will only come online when the natural gas unit and solar array do not provide sufficient power to the islanded microgrid. Because the CHP and natural gas generators can produce 17 MW of power at full capacity and the microgrid's loads had an average power demand of 14.31 MW during 2014, the CHP, natural gas generators and solar array should be capable of satisfying the microgrid's power demand in all situations. However, the backup generators will be necessary throughout the total outage time to cover peak demand beyond the CHP unit and natural gas generators' capacity. At full operation during expected outages the combined 1.86 MW of generation would produce an average of 4.96 MWh per day. At full capacity, the backup generators can produce up to 44.64 MWh. The backup generators will require around 3,200 gallons of diesel at full capacity. One-time startup costs or daily non-fuel maintenance costs for either of the diesel generators are not anticipated. Table 33 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

Table 33. Cost of Generation during a Power Outage

Table lists each generation unit and its respective energy source. Additionally, nameplate capacity, expected power outage operating capacity, and daily average production of power (in MWh) is detailed. Lastly quantity and units of daily fuel and operating costs (both one-time and ongoing) are described.

Location	Distributed Energy Resource	Energy Source	Nameplate Capacity (MW)	Expected Operating Capacity (%)	Avg. Daily Production During Power Outage (MWh/ Day)	Fuel Consumption per Day		One-Time Operating Costs (\$)	Ongoing Operating Costs per day – Fuel and variable O&M
						Quantity	Unit		
Penn Station	DER1 - Backup Generator at Penn Station	Diesel	0.930	100%	22.32	1585	Gallons	N/A	\$5,575
Penn Station	DER2 - Backup Generator at Penn Station	Diesel	0.930	100%	22.32	1585	Gallons	N/A	\$5,575
Penn Station	DER3 - Proposed CHP at Penn Station	Natural Gas	6	100%	144	1,614	Mcf	N/A	\$10,980
Sunnyside Yard	DER4 - Proposed Natural Gas Generator at Sunnyside Yard – 60 Hz Substation	Natural Gas	3	100%	72	666.6	Mcf	N/A	\$4,685
Sunnyside Yard	DER5 - Proposed Natural Gas Generator at Sunnyside Yard – 25 Hz Substation	Natural Gas	8	100%	192	2,152	Mcf	N/A	\$14,640
Sunnyside Yard	DER6 - Proposed Solar PV Array at Sunnyside Yard - 25 Hz Substation	Sunlight	0.20	14%	0.672	N/A	N/A	N/A	\$11
Sunnyside Yard	DER7 - Proposed Battery Storage at Sunnyside Yard - 25 Hz Substation	N/A	1 MW / 4 MWh	100%	4.0	N/A	N/A	N/A	\$68.50

4.5.2 Cost to Maintain Service during a Power Outage

There are no costs associated with switching the microgrid to island mode during a power outage other than the operational costs already accounted for Table 33. Please refer to Table 33 for one-time and ongoing costs of microgrid generation per day. The proposed microgrid has the capacity to support all the connected facilities, which means even those facilities with backup generators will not have to rely on or pay for on-site backup power. Facilities not connected to the microgrid will experience power outages and may need emergency services depending on the severity of the emergency event. Any other cost incurred during a wide spread power outage will be related to the emergency power (i.e. portable generators) rather than electricity generation costs.

4.6 Services Supported by the Microgrid (Sub Task 4.6)

All of the facilities to be connected to the microgrid are privately owned buildings that serve smaller populations for most of the year, but provide critical services to the entire population during emergency situations such as Penn Station. For estimates of the population served by each critical facility, see Table 34.

Backup power supplied by the microgrid should provide 100% of each facility's electricity demand during outage situations. However, if backup power from the microgrid is not available, the critical services provided by these facilities will be severely hampered. Some critical services do not require electricity (e.g. driving a police car to the scene of a crime), while others are completely dependent on a stable power supply (e.g. Penn Station and the Amtrak propulsion system). Based on the portfolio of services that each facility provides and the electricity dependency of each service, Table 34 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 34. Critical Services Supported

Table details critical services supported by the microgrid during an outage. The table also shows the percentage of services lost for each facility when backup power is not available during an outage.

Facility Name	Population Served by This Facility	Percentage Loss in Service During a Power Outage ⁶⁵	
		When Backup Power is Available	When Backup Power is Not Available
Penn Station (PS footprint)	~ 650,000 ⁶⁶	0%	100%
Amtrak’s Sunnyside Yard Facility (60 Hz footprint)	~ 28,000 ⁶⁷	0%	100%
Amtrak’s Train Traction System at Sunnyside Yard (25 Hz footprint)	~ 28,000	0%	100%
LaGuardia Community College	~ 20,000 ⁶⁸	0%	75%
Middle College High School at LaGuardia	~ 550 ⁶⁹	0%	90%

4.7 Industrial Economics Benefit-Cost Analysis Report

As follows is a direct cost-benefit analysis deliverable from Industrial Economics. IEc was hired by NYSERDA to conduct a benefit-cost analysis of each feasibility study. The benefit-cost analysis of the proposed Amtrak-Long Island City microgrid was delivered to the Project Team on March 29, 2016.

4.7.1 Project Overview

As part of NYSERDA’s NY Prize community microgrid competition, Sunnyside Yard has proposed development of a microgrid that would serve five facilities within Queens, including:

- Amtrak’s Penn Station Service Building
- Amtrak’s Sunnyside Yard and Facility
- The Sunnyside Train Traction Propulsion System
- LaGuardia Community College

⁶⁵ Booz Allen estimated % loss based on energy demands and services provided for Emergency Services, Municipal Services, Health Services, and Education Services based on previous research by NIH and CDC (<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1497795/>; <http://www.ncbi.nlm.nih.gov/pubmed/15898487>; <http://emergency.cdc.gov/disasters/poweroutage/needtoknow.asp>).

⁶⁶ <http://takingnote.blogs.nytimes.com/2013/03/28/transplanting-madison-square-garden/> and http://www.nj.com/news/index.ssf/2013/11/how_to_squeeze_1200_trains_a_day_into_americas_busiest_transit_hub.html.

⁶⁷ <https://www.amtrak.com/pdf/factsheets/NEWYORK15.pdf>.

⁶⁸ Approximately 19,550 students (9,100 part-time) and 450 faculty and staff <http://www.usnews.com/education/community-colleges/cuny-laguardia-community-college-CC02184>.

⁶⁹ Approximately 500 students and 50 faculty and staff <http://www.mchslic.com/>.

- Middle College High School at LaGuardia

This project is designed to be a large scale resilience project for Amtrak and the New York Subway, to provide power to Penn Station and electrify railways in case of emergencies. The microgrid would be powered by five new distributed energy resources: a 6.0 MW natural gas-fired CHP unit; two natural gas turbines (3.0 MW and 8.0 MW each); a 0.2 MW photovoltaic array; and one battery unit with an output of 1.0 MW and 4.0 MWh of storage capacity. The 6.0 MW natural gas-fired combined heat and power unit would be installed at Penn Station; the remaining four distributed energy resources would be located at Sunnyside Yard. In addition, the microgrid would incorporate two currently installed backup diesel generators at Penn Station with individual capacities of 0.93 MW. Sunnyside Yard anticipates that the natural gas units and photovoltaic system would produce electricity for the grid during periods of normal operation. In contrast, the diesel generators and battery unit would produce power only during an outage, when the microgrid would operate in islanded mode. The system as designed would have sufficient generating capacity to meet average demand for electricity from the five facilities during a major outage. The project’s consultants also indicate that the system would be capable of providing black start support to the grid.

To assist with completion of the project’s NY Prize Phase I 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.

4.7.2 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 benefit cost analysis (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.⁷⁰ 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 1.⁷¹

⁷⁰ 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 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 using a three percent discount rate, to value CO₂ emissions. As the NYPSC notes, "The SCC is distinguishable from other measures because it operates over a very long time frame, justifying use of a low discount rate specific to its long term effects." The model also uses EPA's temporal projections of social damage values for SO₂, 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.]

⁷¹ The New York State Department of Public Service (DPS) requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions. The reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. In estimating the reliability benefits of a microgrid, the BCA employs metrics that exclude outages caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

4.7.3 Results

Table 35 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 4.9 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

Table 35. BCA Results (Assuming 7 Percent Discount Rate)

Economic Measure	Expected Duration of Major Power Outages	
	Scenario 1: 0 Days/Year	Scenario 2: 4.9 Days/Year
Net Benefits - Present Value	-\$28,400,000	\$413,000
Benefit-Cost Ratio	0.9	1.0
Internal Rate of Return	-4.2%	6.8%

Scenario 1

Figure 13 and Table 36 present the detailed results of the Scenario 1 analysis.

**Figure 13. Present Value Results, Scenario 1
(No Major Power Outages; 7 Percent Discount Rate)**

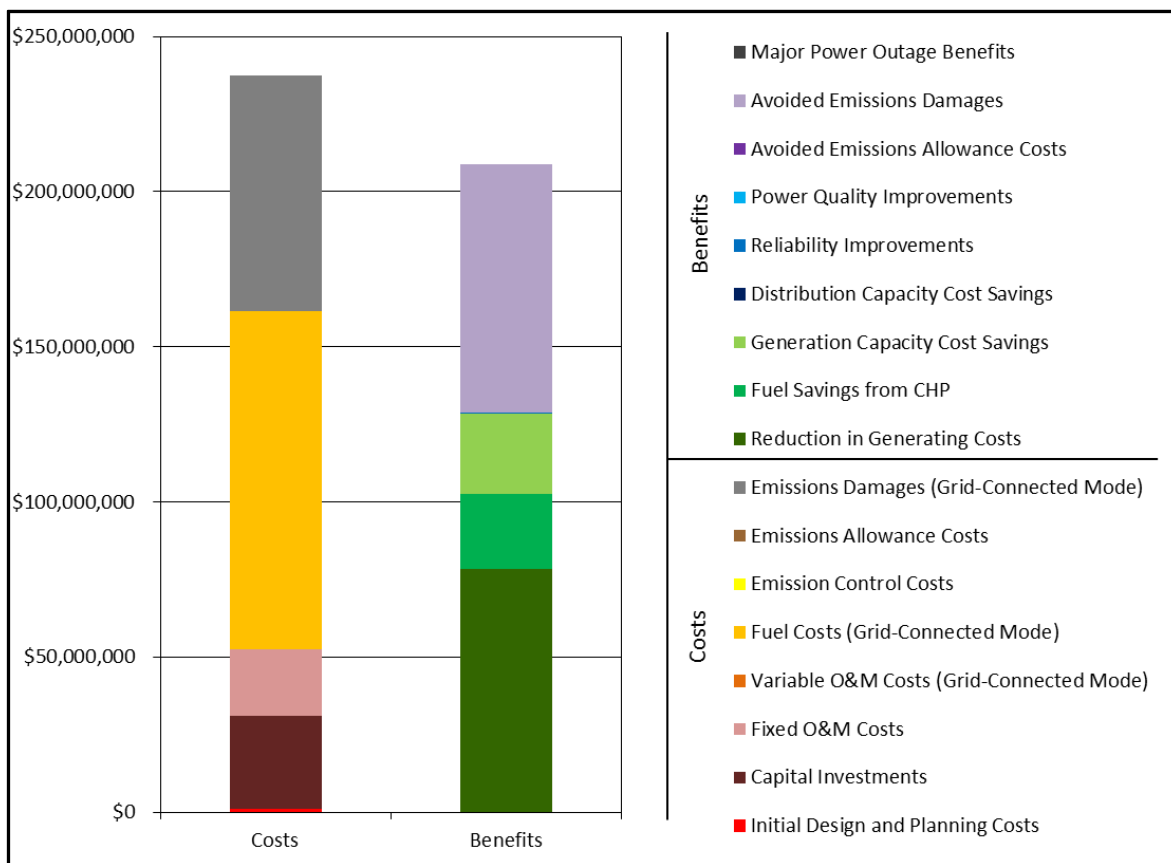


Table 36. Detailed BCA Results, Scenario 1
(No Major Power Outages; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014\$)	Annualized Value (2014\$)
Costs		
Initial Design and Planning	\$1,000,000	\$88,200
Capital Investments	\$30,100,000	\$2,600,000
Fixed O&M	\$21,300,000	\$1,880,000
Variable O&M (Grid-Connected Mode)	\$0	\$0
Fuel (Grid-Connected Mode)	\$109,000,000	\$9,640,000
Emission Control	\$0	\$0
Emissions Allowances	\$0	\$0
Emissions Damages (Grid-Connected Mode)	\$75,700,000	\$4,940,000
Total Costs	\$237,000,000	
Benefits		
Reduction in Generating Costs	\$78,300,000	\$6,910,000
Fuel Savings from CHP	\$24,400,000	\$2,150,000
Generation Capacity Cost Savings	\$25,800,000	\$2,270,000
Distribution Capacity Cost Savings	\$0	\$0
Reliability Improvements	\$279,000	\$24,700
Power Quality Improvements	\$0	\$0
Avoided Emissions Allowance Costs	\$43,000	\$3,800
Avoided Emissions Damages	\$80,100,000	\$5,230,000
Major Power Outage Benefits	\$0	\$0
Total Benefits	\$209,000,000	
Net Benefits	-\$28,400,000	
Benefit/Cost Ratio	0.9	
Internal Rate of Return	-4.2%	

Fixed Costs

The BCA relies on information provided by the Project Team to estimate the fixed costs of developing the microgrid. The Project Team's best estimate of initial design and planning costs is approximately \$1.0 million. The present value of the project's capital costs is estimated at approximately \$30.1 million, including costs associated with installing a microgrid control system; equipment for the substation that would be used to manage the microgrid; the IT infrastructure (communication cabling) for the microgrid; new powerlines and natural gas lines; and the new distributed energy resources. Operation and maintenance of the entire system would be provided under fixed price service agreements, at an estimated annual cost of \$1.9 million. The present value of these O&M costs over a 20-year operating period is approximately \$21.3 million.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the proposed gas-fired turbines and CHP unit. 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.⁷² The present value of the project’s fuel costs over a 20-year operating period is estimated to be approximately \$109 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. In this case, the damages attributable to emissions from the new natural gas generator are estimated at approximately \$4.9 million annually. The majority of these damages are attributable to the emission of CO₂. Over a 20-year operating period, the present value of emissions damages is estimated at approximately \$75.7 million.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. In the case of Sunnyside Yard’s proposed microgrid, the BCA estimates a reduction in demand for electricity from bulk energy suppliers, with a resulting reduction in generating costs of approximately \$78.3 million over a 20-year operating period; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. Cost savings would also result from improvements in fuel efficiency provided by the new CHP system. The BCA estimates the present value of fuel savings over the 20-year operating period to be approximately \$24.4 million. The reduction in demand for electricity from bulk energy suppliers, coupled with a reduction in demand for heating fuel, would also avoid emissions of CO₂, SO₂, NO_x, and particulate matter, yielding emissions allowance cost savings with a present value of approximately \$43,000 and avoided emissions damages with a present value of approximately \$80.1 million.⁷³

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.⁷⁴ Based primarily on standard capacity factors for natural gas generators, the Project Team estimates the project’s impact on demand for generating capacity to be approximately 15.5 MW per year (the team estimates no impact on distribution capacity).

⁷² 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.

⁷³ Following the New York Public Service Commission’s guidance for benefit cost analysis, the model values emissions of CO₂ using the social cost of carbon (SCC) developed by the U.S. Environmental Protection Agency. [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 SO₂ 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.

⁷⁴ 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.

Based on this figure, the BCA estimates the present value of the project's generating capacity benefits to be approximately \$25.8 million over a 20-year operating period.

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

Reliability Benefits

An additional benefit of the proposed microgrid would be to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately \$25,000 per year, with a present value of approximately \$280,000 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:⁷⁵

- System Average Interruption Frequency Index – 0.11 events per year.
- Customer Average Interruption Duration Index – 181.2 minutes.⁷⁶

The estimate takes into account the number of small and large commercial or industrial customers the project would serve; the distribution of these customers by economic sector; average annual electricity usage per customer, as provided by the Project Team; and the prevalence of backup generation among these customers. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.⁷⁷ 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.

⁷⁵ www.icecalculator.com.

⁷⁶ The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for Consolidated Edison.

⁷⁷ <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 0.9; i.e., the estimate of project benefits is approximately 90 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

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.^{78,79}

As noted above, Sunnyside Yard’s microgrid project would serve three large commercial facilities and two schools. The project’s consultants indicate that at present, only one facility, Penn Station, is equipped with backup generators; two existing backup diesel generators can support approximately 50 percent of the facility’s service requirements. Operation of these units costs approximately \$12,400 per day. In order to provide complete power during an outage, Penn Station would rent and operate additional portable diesel generators at a cost of \$43,979 per day. The remaining four facilities could maintain service by bringing in portable generators; Table 37 lists the associated costs. In the absence of backup power – i.e., if the backup generator failed and no replacement was available – all of these facilities would experience a loss in service capabilities of between 75 and 100 percent (see Table 37).

⁷⁸ 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.

⁷⁹ 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.

Table 37. Backup Power Costs and Level of Service, Scenario 2

Facility Name	Cost of Maintaining Service with Portable Generator (\$/Day)	Percent Loss in Service when Backup Generation is Not Available
Amtrak’s Sunnyside Yard and Facility	\$26,763	100%
Sunnyside Train Traction Propulsion System	\$126,802	100%
LaGuardia Community College	\$43,979	75%
Middle College High School at LaGuardia	\$4,990	75%

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:

- Amtrak’s Penn Station Service Building would rely on its existing backup generators to provide 50 percent of service capabilities while the generators operate. In order to provide complete power during an outage, this facility would rent and operate additional portable diesel generators. If the backup generators fail, the facility would experience a total loss of service capabilities.
- The remaining facilities would rely on portable generators, experiencing no loss in service capabilities while the units are in operation. If the portable generators fail, the loss in service capabilities would range from 75 to 100 percent, as shown in Table 37.
- 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 economic consequences of a major power outage also depend on the services the facilities of interest provide. The analysis varies by facility, as described below:

- For the three train transportation related facilities, the analysis is based on the U.S. Department of Energy’s Interruption Cost Estimate (ICE) Calculator and an assumed 24 hours of microgrid demand per day during an outage:⁸⁰
 - For Amtrak’s Penn Station Service Building, the value of service is estimated at approximately \$380,000 per day;
 - For Amtrak’s Sunnyside Yard and Facility, the value of service is estimated at approximately \$268,000 per day; and
 - For the Sunnyside Train Traction Propulsion System, the value of service is estimated at approximately \$564,000 per day.

⁸⁰ <http://icecalculator.com/>.

- For the two schools, the value of service is estimated using budget information scaled to an average daily value.⁸¹
 - For LaGuardia Community College, the value of service is estimated at approximately \$337,000 per day. This figure is based on the college’s budget for the 2015 fiscal year and 24 hours of microgrid demand during an outage.⁸²
 - For Middle College High School at LaGuardia, the value of service is estimated at approximately \$11,000 per day. This figure is based on the school’s budget for the 2016 fiscal year and 12 hours of microgrid demand during an outage.⁸³

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for all facilities is approximately \$524,000 per day.

Summary

Figure 14 and Table 38 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 4.9 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.

⁸¹ Note these values are at best a rough approximation of the social welfare loss attributable to a loss of power at the school, as it does not account for the potential to reschedule lost school days when power is restored; the impact of disruptions in schedule on the productivity of teachers, or school administrators; the effect of an extended outage on the cost of operating and maintaining the school; and other factors that would more accurately characterize the impact of a loss of service during an extended outage.

⁸² LaGuardia Community College Preparation of the Fiscal 2016 Operating Budget. (Pg. 8 of

http://www.lagcc.cuny.edu/uploadedFiles/Main_Site/Content/Divisions/Administration/Business_Office/operating_budget.pdf

⁸³ NYC Department of Education, Galaxy Table of Organization Budget, Middle College HS. Accessed March 21, 2016.

https://www.nycenet.edu/offices/d_chanc_oper/budget/dbor/galaxy/galaxybudgetsummaryto/display2.asp?DDBSSS_INPUT=Q520.

Figure 14. Present Value Results, Scenario 2
(Major Power Outages Averaging 4.9 Days/Year; 7 Percent Discount Rate)

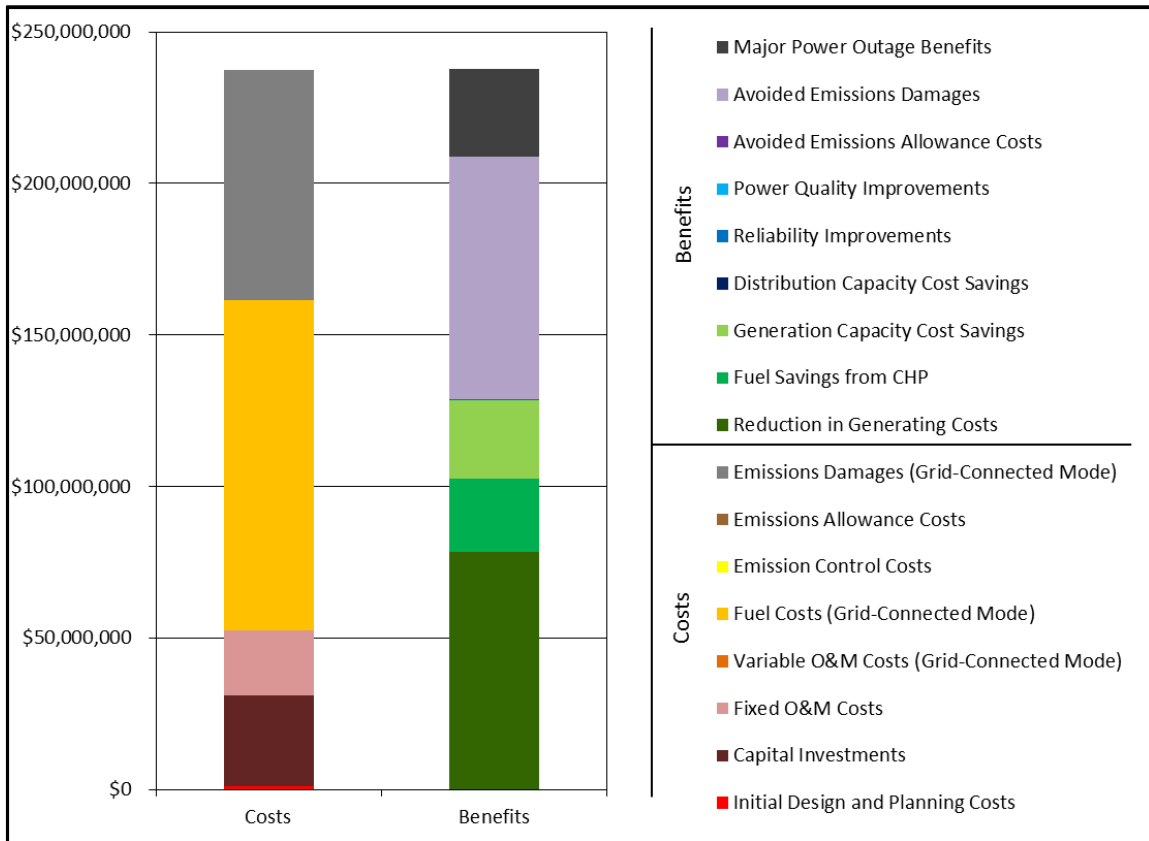


Table 38. Detailed BCA Results, Scenario 2**(Major Power Outages Averaging 4.9 Days/Year; 7 Percent Discount Rate)**

Cost or Benefit Category	Present Value Over 20 Years (2014\$)	Annualized Value (2014\$)
Costs		
Initial Design and Planning	\$1,000,000	\$88,200
Capital Investments	\$30,100,000	\$2,600,000
Fixed O&M	\$21,300,000	\$1,880,000
Variable O&M (Grid-Connected Mode)	\$0	\$0
Fuel (Grid-Connected Mode)	\$109,000,000	\$9,640,000
Emission Control	\$0	\$0
Emissions Allowances	\$0	\$0
Emissions Damages (Grid-Connected Mode)	\$75,700,000	\$4,940,000
Total Costs	\$237,000,000	
Benefits		
Reduction in Generating Costs	\$78,300,000	\$6,910,000
Fuel Savings from CHP	\$24,400,000	\$2,150,000
Generation Capacity Cost Savings	\$25,800,000	\$2,270,000
Distribution Capacity Cost Savings	\$0	\$0
Reliability Improvements	\$279,000	\$24,700
Power Quality Improvements	\$0	\$0
Avoided Emissions Allowance Costs	\$43,000	\$3,800
Avoided Emissions Damages	\$80,100,000	\$5,230,000
Major Power Outage Benefits	\$28,800,000	\$2,570,000
Total Benefits	\$238,000,000	
Net Benefits	\$413,000	
Benefit/Cost Ratio	1.0	
Internal Rate of Return	6.8%	

The Project Team assumed an electricity sales price of \$0.081 per kWh in Sunnyside Yard. This is the supply cost for Con Ed, the average amount spent by Con Ed to import electricity into their distribution system. On a long term, fixed volume PPA, the Project Team believes this to be the most accurate pricing model. Industrial Economics modeled the location-based marginal price (LBMP) for the local NYISO zone to price electricity sales. The LBMP is effectively the average spot market price, peaking on summer afternoons and dropping to nearly zero in low demand hours. While the LBMP would be an appropriate price for intermittent and unreliable grid sales, the proposal herein supports reliable, continuous electricity injections into the Con Ed grid. The New York City LBMP is \$35.36 per MWh⁸⁴, or \$0.035 per kWh, a more than 56% reduction in price from the supply cost. The benefits allowed for capacity cost reductions do not bring the electricity prices to parity. This has a predictable influence on the economics of the projects and is the driving force behind the divergent cost benefit analyses developed by the Project Team and by IEc. The Project Team is unaware of any community microgrid business model or generation set that is financially self-sufficient at the LBMP.

⁸⁴ Average according to IEc cost-benefit model.

5. Summary and Conclusions

5.1 Lessons Learned and Areas for Improvement

The lessons learned from the microgrid feasibility study are divided into two parts. The first part in Section 5.1.1 highlights issues specific to the Amtrak NYC microgrid to be addressed moving forward. The second part in Sections 5.1.2 and 5.1.3 addresses statewide issues, replicability, and the perspectives of many stakeholder groups. These lessons learned may be generalized and applied across the State and other NY Prize communities.

5.1.1 Amtrak NYC Lessons Learned

The Amtrak NYC proposal is unlike any other community in the Project Team’s portfolio for reasons of exceptional electrical complexity, the electrical and geographic scope of the project, and the organizational considerations of working with an entity as large and diverse as Amtrak. Large, urban transit systems bring with them a fundamentally different set of considerations and hurdles than do small, rural communities with a single feeder and a megawatt of load.

As described extensively above, the multiple electrical distribution systems and frequencies within Amtrak’s footprint, coupled with several different interfaces with the Con Ed transmission and distribution system, required significant disentanglement in order to propose a footprint and generation assets. The Project Team participated in more meetings and conversations, both in person and remote, with Amtrak and Con Ed managers and engineers than it did with any other community. Identifying exactly which substations feed which facilities and how the redundancies in the system are characterized took significantly longer than anticipated. Overlaying multiple frequencies and matching several generation assets with the appropriate loads and locations required a significantly more complex effort than in any other NY Prize community in the Project Team’s portfolio.

The scale of Amtrak NYC also contributed to the complexity. Simply acquiring all necessary information from Con Ed and Amtrak was a significant undertaking. Because the project spans boroughs, there are multiple responsible parties in Con Ed to whom the Project Team turned in search of feeder layouts and electrical load data. The Manhattan (Penn Station) portion of the project has one Con Ed contact, and the Queens (Sunnyside Yard) portion had another. Moreover, there are separate contacts for electrical infrastructure and information and natural gas information. Reaching out to the appropriate individual was not a given, and data acquisition was a long-term, back and forth process. This is not fundamentally different than in other communities, but the number of actors and the scale of the proposal added complexity.

The Amtrak NYC microgrid provided a singular challenge that was not seen across the Project Team’s portfolio and may not exist in any other NY Prize community. Whereas for standard facility loads in the Amtrak footprint or elsewhere it is not a technical hurdle to meet peak demand if generation is size at that peak, peak power demands associated with electric traction power are not as simply addressed. The nearly instantaneous nature of peaks as trains accelerate out of the station requires much more available generation than an asset that matches the wattage

of the peak. As discussed above, traction requirements add significant generation minimums to adequately meet peaks in islanded operation. Absent the additional generation, the system is unable to fully power the traction system in islanded operation.

Lastly, Amtrak is a large organization with many initiatives in process at a given time and multiple sources of critical project data. The primary contact for the Project Team, the senior energy manager at Amtrak, was helpful in providing load and contextual information and various Amtrak engineers assisted the Project Team in understanding the feeder layout and the various electrical requirements present on the system. Without the latter clarifications, the task of understanding the electrical system would have been Herculean given that Amtrak’s internal distribution system is more complex than any utility feeder layout in a non-NYC footprint.

5.1.2 Statewide Replicability and Lessons Learned

Through the process of developing deliverables for multiple communities over several months, the Team has discovered and considered new questions surrounding microgrid development. These questions address technical viability, financial structures, policy considerations, and other constraints that could inhibit the development or expansion of microgrids in New York State.

Technical. The existing electrical and natural gas infrastructure in a community is the chief determinant of what is possible. The existing Con Ed electrical infrastructure around Sunnyside Yard complicated the design process, but using Amtrak infrastructure allows load following and advantageous prices for power sales. The “mesh” Con Ed system around LCC and MCHS, combined with the extensive use of transit-based distribution systems, complicates technical replicability. However, any footprint with an electrified rail system and internal distribution capacity could support a similar design.

Natural gas infrastructure is well developed in the coverage area and can support continuous operation of the proposed natural gas generators. However, existing pipelines must be minimally extended to reach the generators. The availability of natural gas infrastructure is a major contributor to project feasibility. In communities without natural gas, generation is typically limited to solar PV, battery storage, and the tie in of existing diesel backup generation, given the high costs of biomass and the larger footprints required for wind. Given the intermittency of solar, and the low capacity factor in New York State (approximately 15%), solar installations of a few hundred kW generally do not provide reliable generation for an islanded microgrid without paired storage assets. In contrast, natural gas-fired generation provides a high reliability baseload, is relatively clean and efficient, and allows for cogenerated thermal energy sales if there is a proximate off-taker. In the Amtrak NYC footprint, natural gas is an absolute requirement given the large baseload generation demanded by the system and the limited footprint within which to work.

Financial. Across the portfolio of communities managed by the Project Team, natural gas availability, presence of thermal energy off-takers, and overall project size are the main drivers of financially viable projects. Simply, natural gas generation is more cost efficient and provides highly reliable revenue streams through electricity sales, and may offer thermal energy sales as

an added revenue stream that is unavailable to a PV driven system. Given the high cost of battery storage, it is difficult to make a compelling case for a small solar PV-battery system as a reliable baseload option. However, Con Ed offers lucrative incentives for battery storage units that are installed within its service territory inside New York City, provided that they provide peak demand reduction during the summer months.

Project financial structures are also important to consider. Revenue from these projects is mainly driven by the sale of electricity and thermal energy, if available; however, microgrid control components and infrastructure may require \$600,000 or more of capital investment and will not initially produce significant revenue streams. The case for private investors to finance microgrid infrastructure is fairly weak, as most private investors would prefer to selectively invest in revenue-generating DERs. NYSERDA may need to create new policies that compensate utilities for microgrid ownership and operation if NYS wishes to see more microgrids developed across the state. This project proposal is one of the few that demonstrates significant returns and is likely to attract investor interest.

Policy. State policy does not currently address microgrids in a cohesive or holistic manner, nor have utility programs adequately recognized microgrid operations in their policies. DR is a potentially lucrative revenue stream in New York; however, current policies do not address microgrid DR participation. For instance, interpretations of the existing NYISO DR programs suggest that microgrids could take payments for islanding in times of high demand on the macrogrid. This scenario, while advantageous from a load shedding perspective, would also remove the microgrid connected generation simultaneously, leaving the macrogrid in a net-neutral position. While the nature of DR payments in such situations is not clear, the Project Team suggests explicit guidance from the NYPSC and the various utilities regarding their respective policies. Due to this lack of clarity, DR revenue from islanded operation has generally been excluded from the Project Team's revenue analysis.

Lastly, local community involvement is an important contributor to microgrid design success. Though even the most robust community engagement may not overcome highly unfavorable infrastructure, it is nonetheless imperative for steady forward progress. Throughout the Amtrak NYC project, support from Amtrak has been robust and the community has been moderately engaged. In other communities, as in NYC, the Project Team has been in close and frequent contact with administrators, elected officials, and non-governmental community representatives; this type of engagement is necessary to not only build support among prospective facilities but also to engage on ownership models, generation options, and other considerations that will directly affect the feasibility of the proposal. The engagement and commitment from the community is instrumental to the Project Team's ability to make recommendations that are acceptable and reasonable to the community. In those communities that are more removed from the process it is difficult to make firm recommendations, and the Project Team runs the risk of suggesting solutions that are, for whatever reason, unpalatable to the community.

Scalability. Scalability is governed by three factors. The structure of the electrical infrastructure, defined in the technical lessons learned section above, is a key factor to expansion of the microgrid. At some point of expansion, it becomes necessary to link multiple feeders, and having proximate feeders of the same voltage and connected to desirable facilities is an important criteria. This proposal, through the inclusion of LCC and MCHS, links multiple feeders across the Amtrak and Con Ed distribution system at the significant cost of new medium-voltage distribution lines. Within the Amtrak-owned distribution system, there is an opportunity to scale both the 60 Hz and 25 Hz footprints along largely existing infrastructure. A positive resolution to the provision of instantaneous peaks for traction control and additional generation assets could support train traction along Amtrak rails north into Westchester County and potentially east on LIRR rails into Nassau County.

Second, widespread AMI infrastructure makes expansion far less complicated and allows for the selective disconnect of facilities that are not microgrid participants. The proposed microgrid is not an AMI remote disconnect based design; however, the utility of AMI is evident in other projects in the Project Team’s portfolio. An expansion of the microgrid into Con Ed territory and away from Amtrak facilities would be greatly eased by the inclusion of remote-disconnect enabled AMI meters.

Lastly, as the microgrid grows larger, more switches and controls need to be installed, connected, and maintained for smooth islanding and grid-reconnect processes. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are also likely to push back if the microgrid grows to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the local utilities to find acceptable footprints that meet the goals of NYSERDA and respect the operational concerns of the utilities.

5.1.3 Stakeholder Lessons Learned

Developers. Many of the NY Prize project proposals require the Phase III award to achieve positive economics, and several more will remain in the red even with the grant. At this time there is no incentive for developers to participate in the build-out or operation of proposed microgrids that demonstrate negative returns. The potential for developer involvement is highest in communities with relatively high electricity prices and the presence of thermal energy off-takers; these conditions drive project profitability. Moreover, many of the municipalities are interested in part or full ownership of the projects, but either do not have available funds or lose the project economics without the available tax credits and incentives. In these situations, there may be opportunities for developers to leverage the tax benefits through design-build-own-operate arrangements.

This proposal exhibits strong returns, and has commensurately garnered the most interest from the private development community.

Utilities. The Project Team often experienced problems with information flow. The Project Team would request information about feeders, switches, and other infrastructure from the utilities to inform the best possible microgrid design. However, the utilities were often guarded about

providing the full data request in the absence of a design proposal, leading to something of a catch-22 in that neither party was able to adequately answer the request of the other without the desired information. These holdups were incrementally resolved to the satisfaction of both the Project Team and the utilities, but gathering data required significantly more time and dialogue than expected. The utilities may have been unprepared for the volume and detail of data requests from the Project Team, and the expected detail of the overall feasibility study may not have been fully communicated to each party.

Investor-owned-utilities in the Project Team’s portfolio, including Con Ed in NYC, were uniformly against allowing a third party operational control of utility-owned infrastructure. This view is understandable, however it engenders a particularly difficult situation if the utility does not support the microgrid development. In such situations, the microgrid will generally be forced to construct duplicate infrastructure, which is both prohibitively expensive and against the spirit of the NY Prize. In general, utilities which support the integration of their infrastructure to the extent technically possible allow for more expansive microgrid possibilities. In the case of the Amtrak NYC footprint, this consideration is somewhat less important as Amtrak maintains an extensive, internal distribution system for its facilities and traction power.

Academics. Academic considerations in microgrid development may center around three areas. First, research into relatively small grid systems with multiple generators (some spinning, some inverter-based), temporally and spatially variable loads, and multidirectional power flows may inform better designs and more efficient placement of generation and controls relative to loads. Linking these findings to train traction support applications may enhance the viability of transit oriented microgrids in both New York and elsewhere.

Second, financial structures for collection of revenue from distributed energy resources and control infrastructure must be optimized. To-date, most microgrids in the United States have been campus-style developments in which the grid serves a single institution and can be easily segregated from the macrogrid. Community microgrids consisting of multi-party owned facilities and generation are a new concept, and literature on how best to own and operate such developments is not yet robust. Lastly, and related to financial structures, research into the management and possible values from a “grid of grids” could reveal new value streams that derive from microgrid control and distribution infrastructure, which would incentivize private investors and utilities to own microgrid infrastructure.

Communities. Engaged communities are important, but so too are realistic expectations of what a microgrid might include. Many communities expected dozens of facilities, or entire towns, to be included in the microgrid without understanding the limitations of the electrical and gas systems, the utility’s operation requirements, or simple cost feasibility. While the Project Team worked with each community to scope out and incrementally refine the facilities for inclusion, there is still much work to be done communicating the infrastructural realities of microgrid development. Setting expectations ahead of future microgrid initiatives will help communities begin with more concise and actionable goals for their community microgrids.

NYSERDA. NYSERDA awarded 83 Phase I feasibility studies, providing a wide canvas for jumpstarting microgrid development in the state but also placing administrative burdens on the utilities and on NYSERDA itself. As NYSERDA is aware, the timelines for receiving information from utilities were significantly delayed compared to what was originally intended, and this has impacted the ability of the Project Team to provide deliverables to NYSERDA on the original schedule. As mentioned in the Utilities Lessons Learned section above, better communication between the State and the utilities may have preemptively alleviated this bottleneck.

Second, microgrid control infrastructure is expensive, and distributed energy resources require some scale to become revenue positive enough to subsidize the controls. Therefore, many NY Prize project proposals are not financially feasible without the NY Prize and myriad other rebate and incentive programs. In practical terms, this means that, while the NY Prize will create a body of knowledge around the development of community microgrids that did not previously exist, it is unlikely to spur unbridled growth of community microgrids in the State without policy changes. This is especially true in regions with relatively low electricity costs.

5.2 Benefits Analysis

This section describes the benefits to stakeholders associated with the project. The microgrid will provide more resilient energy service, lower peaking emissions, ensure critical and important facilities remain operational during grid outages, and support the goals of New York's REV.

5.2.1 Environmental Benefits

New York State's normal energy portfolio is very clean, with primary energy sources being hydropower and nuclear. Therefore, having a microgrid powered by a natural gas-fired CHP and natural gas-fired reciprocating generators will increase the overall emissions per kWh. However, the natural gas generators are cleaner than many peaking assets, which come online when statewide demand is high, and are significantly cleaner than the existing diesel backup generators at Penn Station and the portable diesel backup generators that support Amtrak facilities Sunnyside Yard. Cogenerated steam from the CHP will displace existing boilers at Penn Station, increasing the overall efficiency of thermal energy production in the area. The proposed microgrid also offers a platform for expanding renewable generation in the future. The microgrid's generation assets will not exceed current New York State emissions limits for generators of their size and will not need to purchase emissions permits to operate.

5.2.2 Benefits to New York City

Critical Amtrak facilities and two schools will receive resilient backup power from the proposed generation assets, ensuring they are available in outage situations and reducing the need for further investments in backup generation. The electricity generated with the solar PV array and the natural gas-fired generators will offset higher-emission peaking assets during peak demand events. The additional electricity supply will also obviate the need for Penn Station to run its diesel generators whenever there is a grid interruption, reducing local emissions. The microgrid

will also provide a foundation for supporting train traction power when utility service is lost, and maintaining critical evacuation mechanisms.

5.2.3 Benefits to Residents in and around New York City

Residents of New York City and the surrounding community stand to gain from access to a broad range of critical services anytime the microgrid is forced into islanded operation by an outage on the grid. Even if they are not formally connected to the microgrid, local residents will have access to shelter and transit services in the event of an outage. In the future, the microgrid could be expanded to connect more facilities or power more of Amtrak's traction system. A fully islanded traction system would allow essential transportation services to function indefinitely in the event of an outage, creating resilient and redundant means by which to evacuate New York City.

5.2.4 Benefits to New York State

New York State will benefit from the continued localization of energy resources, reducing load and congestion on the grid. Moreover, the expansion of distributed energy resources will further the goals of REV and provide a more resilient overall grid. A successful implementation of the microgrid will provide a proof of concept for the ownership and operation of a single ownership microgrid. In addition, the lessons learned described in Section 5.1 are widely applicable to the further development of REV and future NY Prize efforts into Phase II and III.

5.3 Conclusion and Recommendations

The Project Team has concluded the proposed microgrid is feasible. The microgrid meets all of the NYSERDA required capabilities and most of its preferred capabilities.

Major challenges included working with Con Ed regarding the proposed interconnections and new distribution infrastructure, securing a thermal energy off-taker, and determining the appropriate mix of generation assets to support Amtrak's complex system as well as Penn Station and the two education facilities. Moreover, providing support to the instantaneous traction peaks will be a complex undertaking. While the team believes a successful solution is available and will use Phase II to integrate the technology with the existing design, a failure to fully address islanded traction power will negatively impact the resilience benefits of the microgrid. A failure to address any one of these conditions in future phases would make it difficult to develop and operate the microgrid as it is currently proposed. If challenges are resolved, the microgrid stands to be a case study in collaborative operation. The proposed microgrid is one of the few commercially feasible projects in the Team's portfolio.

The proposed microgrid is replicable to other transit systems with similar electrical layouts, and could be scalable along Amtrak's train traction and facilities systems with additional generation and new controls. The Penn Station footprint could expand to support electrical or steam loads at Madison Square Garden. It also provides a proof of concept for a natural gas-driven microgrid in a highly congested major metropolitan area. If successful, it will be a source of new operational information gleaned in operating a true community microgrid within the context of investor

owned utility infrastructure and control systems. While the Project Team expects hiccups, there is significant value for Con Ed as a distributed system platform operator if a critical mass of microgrids can be established within their footprint, particularly those like Amtrak NYC with significant generation capacity.

This microgrid project will also help accelerate New York State's transition from traditional utility models to newer and smarter distributed technologies, and it will help achieve the REV goals of creating an overall more resilient grid, reducing load and congestion, expanding distributed energy resources, reducing GHG emissions, and constructing more renewable resources. It will also encourage citizens within the community to invest and get involved in local energy generation and distribution and will foster greater awareness of these issues.

Finally, the project will demonstrate the widely distributed benefits of microgrids paired with distributed energy resource assets. The utility will see improved grid performance, the community will reap the positive benefits of living in and around the microgrid, and industrial customers will benefit from the value of avoided outages. Therefore, the Project Team strongly recommends the consideration of the Amtrak NYC microgrid in Phase II of NY Prize.

Appendix

Metering data for typical 24-hour load profiles were provided by Con Ed. They are included in this feasibility study to show which facilities have highest and lowest load demands at different times of the day. Analyzing these load demand curves has allowed the team to develop a better overall understanding of the generation capacity needed to sustain the microgrid. Con Ed does not provide interval data for loads less than 500 kW, so the Project Team used a simulator to profile typical 24-hour load curves for the Middle College High School at LaGuardia facility.

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