17 - Red Hood (Brooklyn)

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Notice

A NY Prize Feasibility Study of the Red Hook Community Microgrid

Final Report

By:	Smarter Grid Solutions, IMG Rebel, RH-NYR-CRP, & FBCB6
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2. ABOUT RH-CMG AND ACKNOWLEDGEMENTS

NYSERDA awarded the Project Team a Stage 1 $100,000 grant through their NY Prize competition to fund a feasibility study for the development of a Red Hook Community MicroGrid (RH-CMG).

The NY Prize grant was awarded to the RH-CMG project team, consisting of Friends of Brooklyn Community Board 6, Inc. (FBCB6), the Red Hook New York Rising Community Reconstruction Planning Committee (RH-NYR-CRP), Smarter Grid Solutions (SGS; engineering consultant), and IMG Rebel (financial consultant). Together, the RH-CMG team assessed improved power resiliency for critical facilities and operations that can sustain this South Brooklyn waterfront community both on a day-to-day basis, and in future emergency events by using clean distributed energy and innovative microgrid controls that are financed through pioneering infrastructural investments. This RH-CMG feasibility study and the community's interest in the creation of a reliable and decentralized power system is an outcome of the Red Hook NY Rising Community Reconstruction Plan and Brooklyn Community Board 6's interest in expanding solar PV installations. The RH-CMG is a true community led effort, and is directly related to the goals set through various local planning processes.

Contributing Co-Authors

Smarter Grid Solutions put together this report and associated content, as led by Jeremiah Miller with support from Chris Williams, Paige Medley, and Chad Abbey. Feedback and contributions were also given by the following project team members:

- Craig Hammerman, District Manager – Brooklyn Community Board 6, Executive Director of Friends of Brooklyn Community Board 6, RH-CMG Project Director
- Sarah Phillips, Special Projects Manager – Brooklyn Community Board 6, RH-CMG Project Co-Manager
- Gita Nandan, Chair – Red Hook New York Rising Community Reconstruction Planning Committee; RH-CMG Project Co-Manager
- Marcel Ham, Wim Verdouw, and Jeff George – IMG Rebel, RH-CMG financial consultants

Additional content and feedback was provided by Mary McGee from Industrial Economics for the baseline benefit-cost analysis, and from John Love at NYSERDA.

CONTENTS

3. INTRODUCTION AND EXECUTIVE SUMMARY

The Red Hook Community Microgrid (RH-CMG) feasibility study assessed improved power resiliency for critical facilities and operations that sustained the community during Hurricane Irene and Superstorm Sandy by using clean distributed energy and innovative microgrid controls that are financed through pioneering infrastructural investments. This report is the final deliverable for the RH-CMG feasibility study – the RH-CMG Final Report based on the NY Prize Stage 1 Feasibility Study.

Smarter Grid Solutions (engineering consultant), IMG Rebel (financial consultant), RH-NYR-CRP (stakeholder lead & community co-lead) and FBCB6 (community co-lead & project admin), have performed an assessment of the feasibility of the RH-CMG. The final results of this study are detailed in this report.

3.1. Executive Summary

Red Hook, Brooklyn, NY: The Red Hook Community Microgrid (RH-CMG) showcases the results of an intensive NY Prize feasibility study of establishing a resilient and clean, multi-facility microgrid to serve community emergency services during a prolonged power outage. The Brooklyn, NY neighborhood of Red Hook is a low income New York City locality highly vulnerable to prolonged power outages which was severely impacted during Superstorm Sandy and Hurricane Irene – with the community dark and without electricity for consecutive days, and even for some consecutive weeks. Red Hook likewise experiences periodic outages independent of extreme weather, and at a frequency significantly higher than most of New York City. Recognizing that critical power need, Red Hook has been engaged in community planning and resiliency readiness efforts for several years, with the RH-CMG seeking to integrate the outcomes of several on-going planning process and resiliency projects. At the same time, the RH-CMG joins 82 other New York State communities who competitively won NY Prize funding to assess their own community microgrid options – where NY Prize is a part of a statewide endeavor to modernize New York State's electric grid as part of the Reforming the Energy Vision (REV) and other statewide clean energy and economic development efforts. Red Hook feels that the NY Prize offers an important opportunity for our community to expand and coordinate these innovative ideas, allows for a wide variety of alternative energy and facility nanogrid proposals to be tied together into a cohesive well planned system, and is an important part of a resilient future for the Red Hook Community at large.

Community Planning: The Red Hook NY Rising Community Reconstruction Plan (RH-NYR-CRP)[1] showcases the intensive community-based resiliency planning, from which this NY Prize effort was initiated and therefore continues the goals of clean resilient energy, local workforce development, and sustainable community engagement for infrastructure and livelihood investments. As a highly engaged community, this NY Prize study leveraged those goals through targeted energy audit workforce development with Green City Force and also innovative community outreach and marketing via Kaluk.

Resilient Community Infrastructure: The RH-CMG is defined as an independently owned and operated multi-facility and multi-distributed energy resource (DER) resilient electricity distribution system that maximizes clean energy production while grid connected and seamlessly islands to provide clean critical

[1] http://www.stormrecovery.ny.gov/sites/default/files/crp/community/documents/redhook_nyrcr_plan_73mb_0.pdf

power to Red Hook's emergency services facilities. As per the RH-NYR-CRP findings, the core RH-CMG facilities are Good Shepherd Services Miccio Cornerstone Community Center, The Red Hook Initiative, Visitation Church, IKEA, and the Joseph P. Addabbo Health Center. Connecting to and extending these facility's emergency services, the RH-CMG includes an additional 15 facilities – including low-income multi-unit apartment complexes and commercial facility owners who would share excess power during emergencies. In addition, the project team has worked with NYCHA to assess how to connect the RH-CMG to NYCHA's on-going effort to create a campus microgrid for the Red Hook East and West Houses. When combined, the microgrid would provide emergency power and services for Red Hook that would put it at the forefront of sustainable and resilient communities in the world.

RH-CMG Benefits: The microgrid would provide a wide variety of benefits for Red Hook. The extensive list is detailed throughout the body of the report, whereas below are key highlights:

+ Provide critical emergency services[2] from a diverse group of facilities for a highly vulnerable and low income NYC neighborhood,
+ Maximize clean energy deployments that are interconnected to the microgrid,
+ Supports the most advanced REV demonstration principles: community engagement, advanced smart grids, and transactive markets for high clean energy deployments,
+ Serve as a community infrastructure platform for workforce development as well as social and environmental engagement and education.

RH-CMG Design Summary: The microgrid includes several unique and advanced design attributes:

+ Joint microgrid integration with NYCHA's on-going microgrid project – eventually creating a single microgrid for the whole Red Hook neighborhood and connecting together 20 RH-CMG facilities with 30 NYCHA buildings,
+ Use Active Network Management (ANM) technologies to maximize solar PV generation – including during islanded mode and allow for fully synchronized islanding of multiple facilities with multiple DER from the distribution grid,
+ Leverage Red Hook Initiative's (RHI's) RF Mesh public wifi system for microgrid operation, and
+ Create a parallel microgrid distribution grid that maximizes the use of existing distribution equipment and utilizes new dedicated distribution lines, transformers, and power systems equipment to best meet the community microgrid needs.

Commercial Viability:

+ Leverage private capital for DER development that combines with public incentives to interconnect the RH-CMG facilities and deploy advanced multi-facility microgrid controls. The estimated private investment would cover 85% of the RH-CMG costs, with 15% of the costs covered by public investment,

[2] See the Red Hook NY Rising Community Reconstruction Plan (RH-NYR-CRP) with its associated on-going emergency preparedness effort. The RH-CMG team likewise note that these RH-CMG benefits exemplify Red Hook neighborhood values that cannot be reduced to simple monetary calculation.

+ Will work with the NYC Mayor's Office and Con Edison to ensure commercial ownership/operation is consistent with long-term integrated system planning and resiliency planning for modernizing and hardening Red Hooks distribution grid,
+ Promote public/private partnerships for DER and microgrid equipment (as applicable).

Benefit Cost Analysis:

Table 1 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the RH-CMG if analyzed assuming Red Hook has a radial distribution grid. The results indicate that if there were no major power outages[3] over the 20-year period analyzed (Scenario 1[3]), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 1.8 days per year (Scenario 2). If assessed while assuming Red Hook has a secondary network distribution grid, then the major outages period reduces to 0.9 days per year. In actuality, Red Hook has both a radial and a secondary network grid (much of which is overhead). The body of the report provides additional detail on these findings.[4]

Table 1: Summary BCA Results

Economic Measure	Expected Duration of Major Power Outages (Assuming 7 Percent Discount Rate) for Radial System[4]	
	Scenario 1: 0 days/year[3]	Scenario 2: 1.8 days/year[4]
Net Benefits - Present Value	-$14,700,000	$508,000
Benefit-Cost Ratio	0.7	1.0
Internal Rate of Return	0.4%	6.7%

Opportunities and Lessons Learned:

- The NY prize feasibility funding helped support this community energy resiliency evaluation that would not have been possible otherwise. The RH-CMG team is grateful and believes the findings support continuing this effort into design stage.

[3] Considering "no major power outages" as a base case for Red Hook is not appropriate given its existing electric distribution system is highly vulnerable to power outages due to major storms, aging equipment, and situational issues (tree contact, large truck/equipment movements, etc.). Recent major storms have shown that Red Hook is disproportionately impacted compared to other NYC neighborhoods – therefore the no major power outages Scenario 1 analysis results are not included in this report.

[4] The distribution system in the Red Hook neighborhood has both radial overhead and network components (mostly overhead, some undergrounded), which has implications for the analysis of the microgrid's potential benefits. The BCA model as designed cannot analyze a combined radial and network system. The results presented in the body of this report are based on an analysis that treats the distribution system as a radial system. We also conducted a sensitivity analysis that treats the system as a network system. In the latter case, the net benefits under Scenario 1 would be -$7,450,000, the benefit-cost ratio would be 0.9, and the internal rate of return would be 3.5%; in order for the project's benefits to outweigh its costs, the average duration of major power outages would need to equal or exceed 0.9 days per year (Scenario 2).

- The feasibility study found the system is cost effective when outages occur at or beyond 0.9 to 1.8 days per year[4] – for Red Hook a possibility on average that seems conceivable when combining average extreme weather probability with the outages Red Hook experiences annually (due to aged equipment and above ground lines). This BCA metric serves as a key economic metric (with key details and sensitivities considered immediately below) of commercial viability, where the number of outage days corresponds to when economic costs equal economic benefits[5]. At the same time, strong caution is required in reducing the RH-CMG benefits-costs to this single metric: as previously summarized above, the social, environmental, and critical emergency services of the RH-CMG project defy simple BCA quantification. [2]
- Due to the BCA framework, the analysis needed to consider all of Red Hook connected to a radial distribution grid or secondary network grid, but not both combined like Red Hook's actual grid. At a high level this indicates the complexity of neighborhoods evaluating community microgrids, and for Red Hook the need to continue assessing the design options and refining the BCA framework to more appropriately assess the cost and benefits against their actual grid configuration.
- A quick sensitivity analysis was conducted on the Scenario 2 BCA results in order to evaluate opportunities to improve benefits. It was found that the capital costs and associated revenue benefits for the community solar array and the anaerobic digester dominated the benefit-cost ratio and net present value – thus there is the opportunity to seek options to maximize their revenue or minimize initial and on-going costs so as to improve project economics for the whole microgrid.
- For the feasibility study conceptual design, the bulk majority of the RH-CMG distribution lines and equipment necessitated building new, dedicated microgrid distribution lines and equipment in parallel to Con Edison's existing grid. This is because the cost of putting in parallel lines and equipment was less than the reinforcement costs of using the existing Con Edison lines and equipment. While this scenario will be pursued in discussion with Con Edison for the best approach to proceed to the design stage, it is recognized that at a higher level there needs to be integrated system planning for Red Hook that includes resilient community infrastructure consideration. Undergrounding of all of Red Hook's distribution lines could therefore be incorporated into a new design that includes functionality for a community microgrid – combining and leveraging these efforts for an even more resilient system. The RH-CMG team will continue this conversation with Con Edison and the City and State elected officials to ensure Red Hook's grid is improved in a coordinated and effective manner. This all-inclusive effort correlates with the need for on-going evaluation of the best ownership/operator model for the RH-CMG – and the accompanying legal and regulatory barriers for private versus utility owned.
- Given the number and diversity of RH-CMG facilities and likewise the deployment of extensive smart and clean solar energy, there is a significant opportunity for Con Edison and the City to use building and operating the RH-CMG to test and pilot these advanced technologies for the application elsewhere in the city.

[5] i.e the number of outage days where the benefit-cost ratio = 1. As is typical for infrastructure investment considerations, significant caution is recommend in only using this and other financial metrics to assess the costs and benefits of a project, especially for critical emergency services and wider social and environmental factors. [2]

4. BACKGROUND AND A RESILIENT AND ENGAGED RED HOOK

> ***The NY Prize feasibility study is helping realize the Community Vision as set out by the Red Hook Community:*** *"Empowered by the spirit of unity that helped the Red Hook community survive Superstorm Sandy, our vision for a resilient and thriving future is to work as a holistic community to strengthen the historic waterfront Red Hook Peninsula by minimizing differences and maximizing cooperation among all who live and work here. Mindful of the growing climate-related risks to our beloved community and the immediate need for improved emergency preparedness measures, our actions will serve to help to develop measures that will protect our neighborhood from flood inundation, increase the safety of our citizens, and move towards a resilient community. We are committed to maintaining and expanding affordable housing and increased economic activity with an emphasis on local job development, recognizing the importance of their interdependence. Our rebuilding efforts towards a resilient and sustainable community are focused on a sincere triple bottom line integration of environment, economy, and community, which will require substantial improvement to our long-neglected infrastructure including sewers, transportation, communications, power and energy provision, and education." - the Red Hook NY Rising Community Reconstruction Planning Committee*

A low-income community, the Red Hook neighborhood of Brooklyn, NY, was severely impacted in Superstorm Sandy, and Hurricane Irene clearly showing the vulnerabilities with regard to its power system, with the community dark and without electricity for consecutive days, and even consecutive weeks for some. Red Hook likewise experiences periodic outages independent of extreme weather, and at a frequency significantly higher[6] than most of New York City. Recognizing that critical power need, the RH-CMG seeks to integrate the outcomes of several on-going planning process and resilient based projects, such as the GOSR NY Rising Red Hook CRP plan, the Solarize Brooklyn CB6 Program that will result in the installation of at least 130 kW of low-carbon alternative energy in the district, the Ready Red Hook Community Emergency Preparedness Plan, NYCHA's Microgrid Feasibility Study for Red Hook Houses, and private residential and commercial property owners' current distributed generation projects. Red Hook feels that the NY Prize offers an important opportunity for our community to expand these innovative ideas, allows for a wide variety of alternative energy and local micro-grid proposals to be tied together into a cohesive well-planned system, and is an important part of a resilient future for the Red Hook Community at large.

4.1. A Resilient Red Hook

This NY Prize feasibility study builds on the extensive effort Red Hook has spent to strengthen its neighborhood – building and establishing resiliency socially & culturally, economically, environmentally, and resilient emergency energy systems.

[6] See discussion of SAIFI and CAIDI reliability metrics throughout the report and especially in Section 8.4.

The Red Hook NY Rising Community Reconstruction Plan (RH-NYR-CRP)[7] showcases the intensive community-based resiliency planning, from which this NY Prize effort was initiated. The project goals of this NY Prize effort connect to the community resiliency goals identified in the RH-NYR-CRP. The RH-CMG project goals are as follows:

+ create a low carbon and financially sustainable resilient energy system for the community and its citizens;
+ be a platform for building workforce development training, and career opportunities that are focused on the design;
+ be a means to educate the general public, locally, nationally and globally about energy consumption and production;
+ create financial community re-investment (avoid divestment);
+ create a public amenity, that empowers citizens to live a better life;

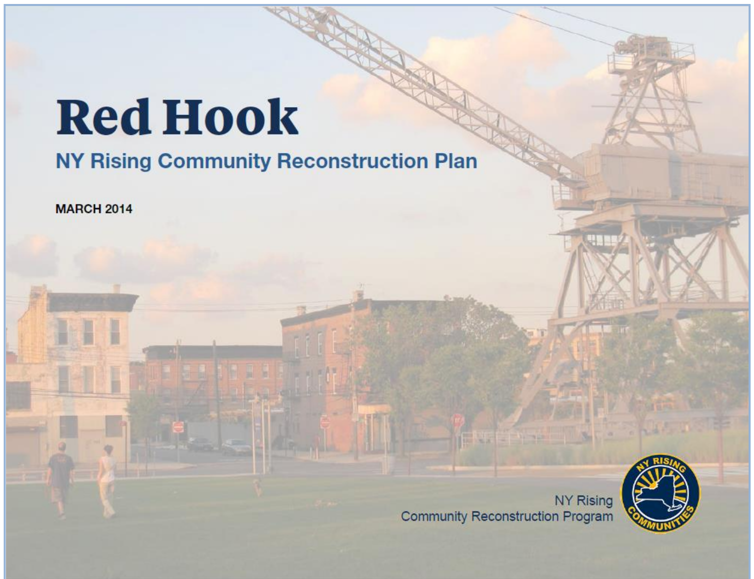


Figure 1: The RH-NYR-CRP details community-based resiliency planning

+ connect the microgrid to other on-going resiliency efforts when feasible;
+ use resiliency indices to judge and weigh the decision making process during its design.

The RH-CMG resiliency efforts moreover contribute to broader New York State efforts to transform the energy industry to meet the 21st century needs of the electric grid – as being led through the Reforming the Energy Vision (REV) process. The RH-CMG feasibility study sought to coordinate with REV work[8] to provide a platform for the delivery of innovative services to Red Hook. The RH-CMG project team supports the REV work underway to demonstrate increased customer engagement and participation in modernizing the electric grid. The project team therefore recognizes how community microgrids test the foundational infrastructure of a modernized grid, such as:

+ Targeted smart grid upgrades: building cost effective and scalable monitoring and control for improved utilization of area power networks.

Figure 2: Connecting the RH-CMG Study to REV

[7] http://www.stormrecovery.ny.gov/sites/default/files/crp/community/documents/redhook_nyrcr_plan_73mb_0.pdf
[8] REV highlights the RH-CMG study: https://youtu.be/DNMcKdNLth8

+ Transactive partnerships: multi-facility and multi-customer microgrids require customer-to-customer and likewise customer-to-utility bidirectional flow of power and information. This transactive exchange of energy, status, and pricing information will be tested through community microgrid applications.

4.2. An Engaged Red Hook

The RH-CMG effort connects and coordinates multiple on-going resiliency efforts in Red Hook:

+ *RH-NYR-CRP* on community resiliency planning;
+ *NYCHA's East & West Houses Microgrid*;
+ *GOSR resiliency funding* for Red Hook emergency services provider emergency generators;
+ *RISE:NYC funding* for commercial property energy resiliency and moreover LMI and public wifi access and resiliency;
+ *Solarize Brooklyn CB6 pilot* in 2015, and recent launch of an on-going community shared solar *Solarize Brooklyn CB6: Sun For All* campaign.

NYSOLAR SMART
Group Purchasing Case Study
Powered by SunShot U.S. Department of Energy

NYSolar Smart Solarize Brooklyn CB6

Location: Brooklyn, NY
Contracted kW: 118.29 Kilowatts
Economic Impact: > $670,750
Discount per watt: Quixotic: $0.07 EcoMen: $0.02
Campaign Team: Sustainable CUNY, Brooklyn Community Board 6, NYC Mayor's Office of Sustainability, NYC Economic Development Corporation
Installer Partners: Quixotic Systems, EcoMen Solar
Timeline: 12 May 2015 – 30 September 2015

Cost compared to CB6 2015 residential avg: - $1.97/watt
Closure rate of contracts presented: ~18.6%
Workshops and attendees: 9 workshops with 325 attendees
Contracts signed: 22
Contracts presented: ~118
Program sign-ups: 357

Financing Used	No Financing	Loan	Lease	PPA
% of projects	86%	14%	0%	0%

Figure 3: CB6's Solarize Program Engages Red Hook on Energy Sustainability

Beyond how these programs demonstrate the diversity and engaged stakeholders throughout Red Hook, two specific RH-CMG efforts showcase the workforce development engagement during the project – (1) working with Green City Force to support RH-CMG facility energy audits, and (2) using Red Hook based Kaluk Marketing's unique word of mouth promotion services to engage Red Hook's citizens.

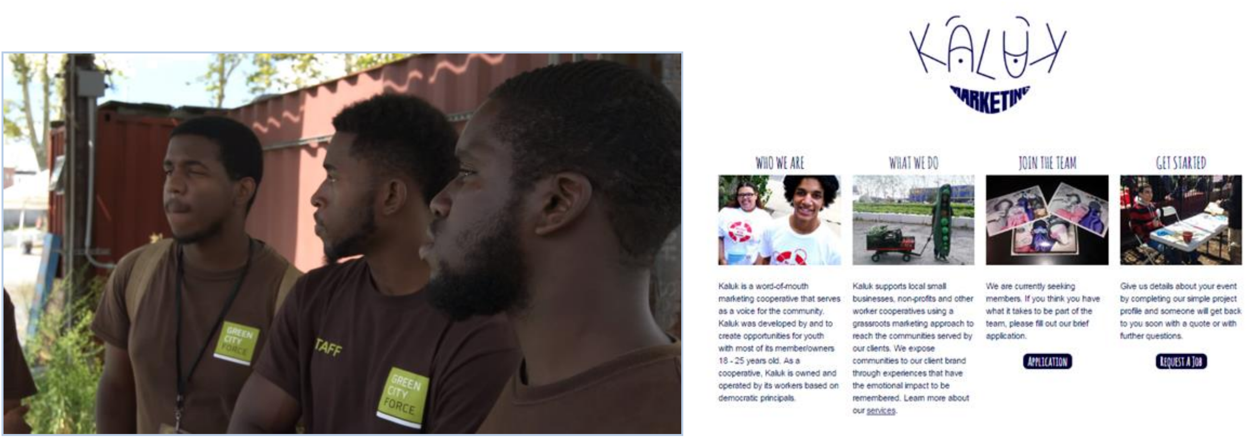


Figure 4: The RH-CMG Engaged Red Hook via Workforce Development Opportunities[9]

[9] Green City Force: http://www.greencityforce.org/ and also Kaluk: http://www.kaluk.coop/

4.3. Defining a Community Microgrid

A public or community microgrid is a part of the distribution grid where the power flow can be controlled locally or remotely using its local energy resources, that when operating in microgrid island mode disconnect from the area power grid during planned or unplanned regional outages. A community microgrid would interface to multiple independently owned facilities.

Conceptually for the RH-CMG, the project team investigated connecting as many Red Hook facilities to the community microgrid that would provide the most economic and best emergency value to the Red Hook community. Underpinning this assessment are resilient facility options (also referred to as nanogrids) that provide individual facility options for emergency power during prolonged grid outages. These resilient energy concepts are presented below.

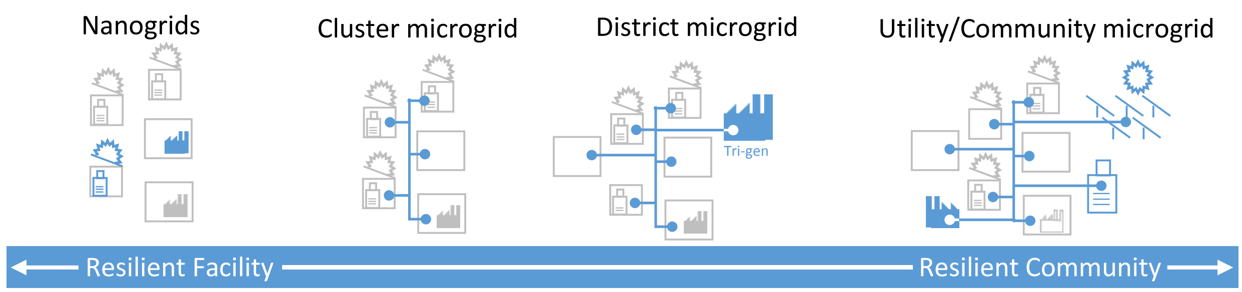


Figure 5: Conceptual Spectrum of Microgrids

In reference to the RH-CMG, the following definitions apply for these microgrid concepts:

Nanogrids: every facility audited is evaluated for its own resilient nanogrid option – focusing on solar PV and battery energy storage, and if applicable micro-CHP.

Cluster Microgrid: grouping of near-by facilities, some of which have distributed energy resources, which share power and microgrid services. This microgrid connects a few facility nanogrids and uses existing utility distribution systems; or if more economical uses private microgrid distribution.

District Microgrid: connects a district generation source (e.g. district combined heat and power; e.g. district tri-generation) to a few facility nanogrids. This concept uses existing utility distribution systems or if more economical uses private microgrid distribution. The district generation source defines this microgrid scheme as a large anchor generator[10] that includes distributing heat and/or cooling as well.

Utility/Community Microgrid: connecting large distributed generation sources to a broad set of community facilities via isolating significant amounts of an existing utility distribution circuit, or extending private microgrid distribution to many community facilities. This is the most complex microgrid option that includes managing multiple large distributed energy resources in coordination with many independent facilities. The RH-CMG conceptually currently reflects this form of

[10] "Anchor" generator defined in the sense that the generator is much larger compared to other generation or energy storage systems available to the microgrid. Hence the availability and performance of the large generator *anchors* the other energy resources and typically serves as a voltage reference for other microgrid energy resources.

microgrid, with the on-going effort to incorporate NYCHA's district microgrid (which itself is currently in conceptual design).

Please note, campus microgrids are conceptually similar, where their defining characteristic is only having a single interfacing point with the utility distribution system and/or a single owner entity. Community microgrids are defined here as having multiple points of common coupling interfaces with the utility and with multiple independent entities collaborating for ownership and governance.

4.4. Evaluated Microgrid Facilities

The core targeted microgrid assessment facilities were identified as part of the Red Hook emergency planning process. They are:

1. Good Shepherd Services Miccio Cornerstone Community Center – 110 West 9th Street, Brooklyn, NY 11231;
2. The Red Hook Initiative – 767 Hicks Street, Brooklyn, NY 11231;
3. Visitation Church – 98 Richards Street, Brooklyn, NY 11231;
4. IKEA – 1 Beard Street Brooklyn NY 11231; and
5. Joseph P. Addabbo Health Center – 120 Richards Street, Brooklyn, NY 11231.

Out of these facilities, only IKEA has an islanded power production capability in the form of a 600 kW emergency diesel generator. Additional facilities were evaluated to join and support the RH-CMG to ensure power provision for Red Hook's critical emergency needs, provide for site emergency power, and to connect supporting facilities to the microgrid. These additional facilities are: NYCHA's Red Hook Houses, PS 15, PS 676, the Red Hook Library, the South Brooklyn Community High School, the Red Hook Justice Center, Mercy Home, low and moderate income housing from the Carroll Gardens Association and likewise from the Red Hook Homes Co-op, Gowanus Bay Terminal, Added Value Red Hook Community Farm (with its off-grid solar PV, batteries, and micro-wind), Linda Tool and Die, and Tamco Mechanical Inc & Marine Spares International. While not audited, additional facilities that the Project Team would further evaluate for inclusion in the RH-CMG include: Pioneer Works, FDNY Engine 202 / Ladder 101, and the Red Hook Recreation Center. Additional information on these facilities and their role in community emergency planning can be found in the Red Hook NY Rising Community Reconstruction Plan (RH-NYR-CRP) report.[11]

[11] http://www.stormrecovery.ny.gov/sites/default/files/crp/community/documents/redhook_nyrcr_plan_73mb_0.pdf

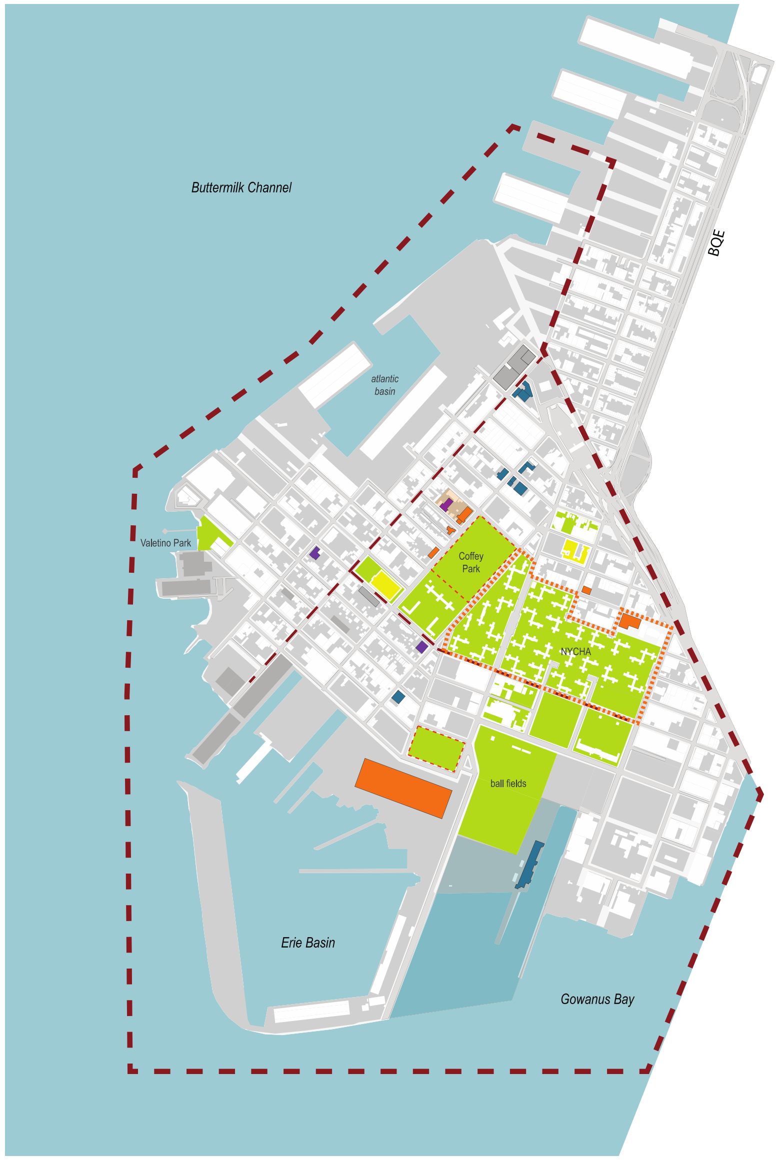


Figure 6. Map of Red Hook project boundaries and site locations.

This report covers the RH-CMG conceptual design and system infrastructure by connecting these facilities via a mixed utility and private wires microgrid configuration. This is reviewed below in the system architecture section and will be considered in future commercial viability and benefit-cost analysis reports.

5. MICROGRID CAPABILITIES AND TECHNICAL DESIGN

5.1. Conceptual Design Summary

The RH-CMG conceptual design is described below. It is designed to maximize connecting together Red Hook's emergency services providers along with facilities that would have excess power to share in the event of insufficient self-generation. At the same time, the RH-CMG is designed to maximize connecting as much clean solar energy to the microgrid as available on the facilities' rooftops that together would be operated in a seamless and automated way to maintain power in the event of a planned or unplanned grid outage. A description of the conceptual design is below, followed by an evaluation of the microgrid capabilities and additional technical details.

Microgrid Equipment and Attributes:

+ Distribution: part-utility (5%) & part-private/dedicated (95%, both RH-CMG and NYCHA's) at 4.16kV.
+ Extensive Distributed Energy Resource (DER) - nineteen new distributed energy resources (DERs): six natural gas-fired units (two of which are micro combined heat and power units); nine photovoltaic arrays; three ESS batteries; and one anaerobic digester; and five currently installed DERs: a diesel generator and photovoltaic array located at IKEA; and a wind turbine, photovoltaic array, and ESS battery located at the Added Value community farm.
    - Maximize solar PV
    - Connect large DG to ensure continuous power
    - Battery ESS to ensure power quality and availability
+ RF Mesh Communications via extending Red Hook Initiative's wifi network
+ Microgrid Controller
    - Based on Active Network Management (ANM) technologies for MPCC synchronized islanding

The preliminary estimated location for NYCHA's private microgrid distribution lines are shown in the figure below in purple – note that their design is independent and on-going with the agreement to work towards interfacing with the RH-CMG. The preliminary and approximate location of NYCHA's CHP and emergency generators are shown in the figure (green & grey barrels respectively) – one at the farthest east of the development, and one farthest west of the development. For simplicity, NYCHA facilities are not shown in the figure. Summing to 8 MW, these NYCHA emergency generators serve as anchor generation for the combined NYCHA and RH-CMG system.

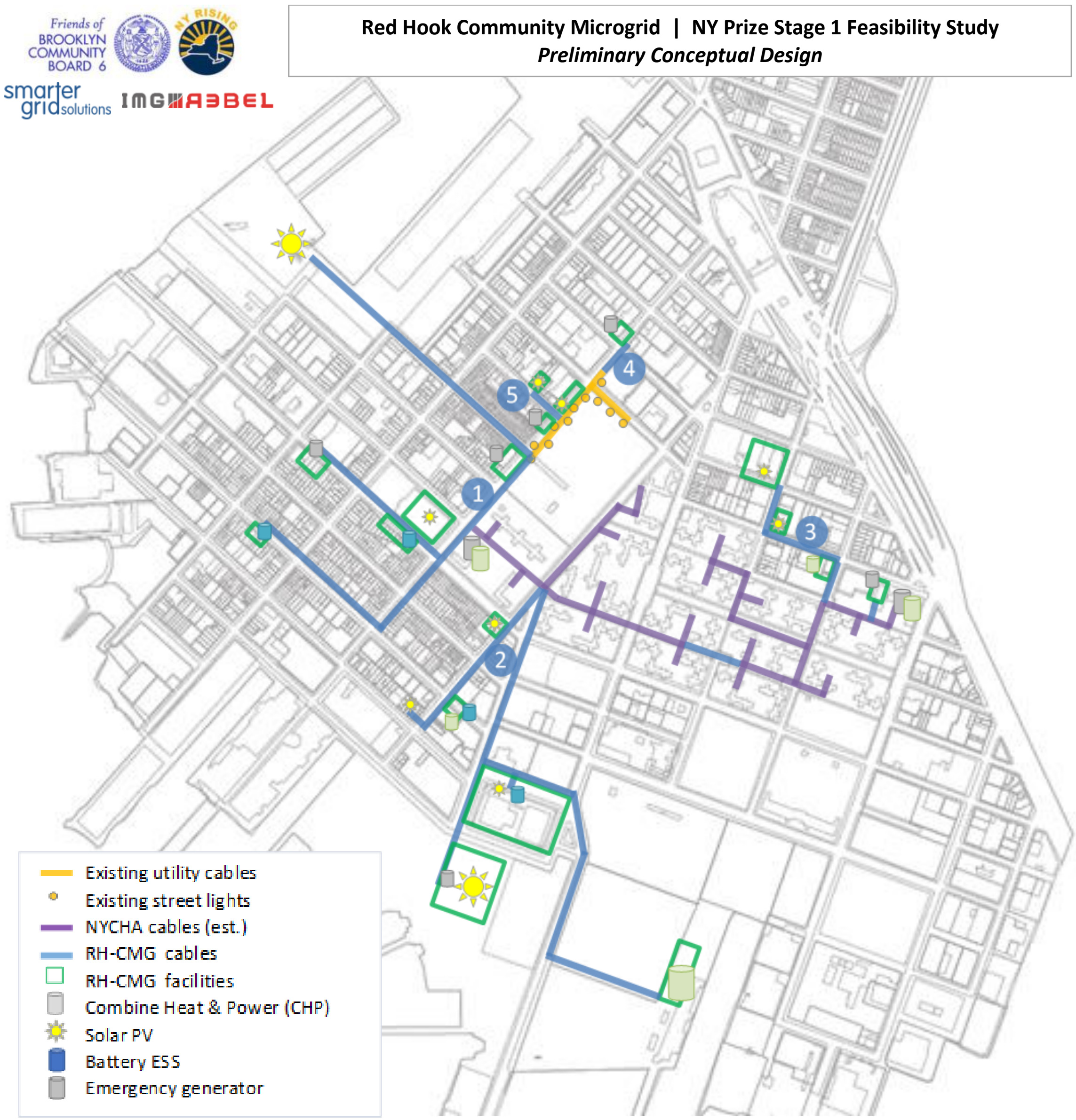


Figure 7: RH-CMG Conceptual Design

Each RH-CMG facility is outlined in the figure via the green rectangles. The southwest corner of Red Hook is served by a Con Edison radial auto-loop transfer circuit, with the branch near Visitation Church, the Red Hook Justice Center, and Addabbo Health Clinic having a simple microgrid isolation opportunity: indicated in orange in Figure 7. All other RH-CMG facilities have limited microgrid carve out options[12], and as such private RH-CMG distribution lines connect these facilities: indicated in blue in Figure 7, and numbered 1-5 for each section. Synchronizing switches will need to be located at the tie-in location of

[12] Most of Red Hook has secondary mesh distribution circuits, as such there are limited microgrid carve out options (e.g. prohibitively expensive reinforcements compared to private wires).

each RH-CMG cable to the NYCHA/Con Edison cable. Large RH-CMG generation are indicated on the figure – a potential community solar PV system at the Cruise Ship Terminal or other nearby sites proven to have structurally capable roofs, and a potential anaerobic digester at the Gowanus Bay Terminal industrial manufacturing site that is still under evaluation. Small generation (solar, microCHP, natural gas emergency generators), and battery energy storage are indicated in the figure. Pre-existing generation includes the 2 MW solar PV array and 600kW emergency diesel generator at IKEA, and the 7.5kW solar PV array, 150W wind generator (not shown), and the 34kWh (2.8kW; 12-hr) battery energy storage at Added Value farm.

5.2. Microgrid Capabilities

• Does the microgrid serve at least one but preferably more, physically separated critical facilities located on one or more properties? Yes, as per Figure 6 and Figure 7.

• Does the microgrid serve both critical and non-critical loads at those facilities? • Does the microgrid design describe the electrical and thermal loads served by the microgrid when operating in islanded and grid parallel modes? • Does the microgrid design provide the distributed energy resources and thermal generation resources to continuously meet electrical and thermal demand in the microgrid? Both critical and non-critical loads will be served by the microgrid for some facilities, and only critical loads for other facilities. For all RH-CMG facilities, 6.3 MW peak power is needed to support all loads, whereas 4.2 MW is needed for microgrid operation based on the facility audits and stakeholder input. Cost effective DER deployment opportunities were identified for each facility such that total DER could maximize the use of solar energy and rely on the natural gas backup generation and energy storage to continuously meet electrical demand. There are no community thermal loads served by the RH-CMG. Facility thermal loads were evaluated as a part of each facility audit to ensure required microgrid electrical interfacing is met (e.g. motors/pumps for hot water; e.g. electric ignition of combustion chamber for hot water boiler; etc.). Detailed modeling and simulation of DER and load profiles will be carried out during the detailed design. Table 2 below presents the recommended energy resources per facility for the RH-CMG. Please note, NYCHA's energy resources are not listed but are considered as part of the on-going agreement to support integrating these two parallel microgrid efforts.

As part of the conceptual design, facility load and DER's are managed via an active network management (ANM) microgrid controller, which includes autonomous, and real-time DER management, with repeatable time-bounded responses that include escalating actions and failsafe modes. Emergency load will continuously be met based on available generation that maximizes clean energy production.

Table 2: Microgrid Energy Resources

Facility number; Distributed Energy Resource Name	Facility Name	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Average Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh		Description
						Quantity	Unit	
1. Backup Generator	Addabbo Health Clinic	Natural Gas	0.200	0	1.330	9.99	MMBtu/MWh	New. Elevated backup natural gas emg. generator; rooftop; facility black start capable,
2. Solar PV	Visitation Rectory	Solar	0.005	6.2	0.017	N/A	Choose an item.	New. Rooftop PV; smart four quadrant inverter control
3. Solar PV	RH Justice Center	Solar	0.020	24.6	0.067	N/A	Choose an item.	New. Rooftop PV; smart four quadrant inverter control
4. Backup Generator	Mercy Home	Natural Gas	0.050	0	0.333	9.99	MMBtu/MWh	Replacement (damaged during Sandy). Elevated backup natural gas emg. generator; elevated pad; facility black start capable
5. Backup Generator	NYCHA (Ind. microgrid devel.)	Natural Gas	8	0	96	9.99	MMBtu/MWh	New. Elevated backup natural gas emg. generators (2); elevated pad; facility black start capable
6. Solar PV	Miccio Center	Solar	0.020	25.0	0.069	N/A	Choose an item.	New. Rooftop PV; smart four quadrant inverter control
7. Solar PV	RHI	Solar	0.005	6.2	0.017	N/A	Choose an item.	New. Rooftop PV; smart four quadrant inverter control
8. Solar PV	PS 676	Solar	0.030	37.8	0.104	N/A	Choose an item.	New. Rooftop PV; smart four quadrant inverter control
9. MicroCHP	Carroll Gardens	Natural Gas	0.005	30.4	0.083	9.99	MMBtu/MWh	New. Replace DHW, natural gas microCHP. Within boiler room, basement; facility black start capable
10. Solar PV	PS 15	Solar	0.030	37.8	0.104	N/A	Choose an item.	New. Rooftop PV; smart four quadrant inverter control
11. Backup Generator	Tamco	Natural Gas	0.050	0	0.333	9.99	MMBtu/MWh	New. Elevated backup natural gas emg. generator; rooftop; facility

Facility number; Distributed Energy Resource Name	Facility Name	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Average Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh		Description
						Quantity	Unit	
								black start capable
12. Backup Generator	RH Comm. High (GSS)	Natural Gas	0.100	0	0.665	9.99	MMBtu/MWh	New. Elevated backup natural gas emg. generator; rooftop; facility black start capable
13. Solar PV	RH Public Library	Solar	0.030	37.8	0.104	N/A	Choose an item.	New. Rooftop PV; smart four quadrant inverter control
14. Battery ESS	RH Homes Co-op 135 Coffey	Other - please specify	TBD	TBD	TBD	N/A	Choose an item.	New. Battery Energy Storage System (ESS); basement; smart four quadrant inverter control; frequency dispatch
15. Battery ESS	RH Homes Co-op 71 Wolcott	Other - please specify	TBD	TBD	TBD	N/A	Choose an item.	New. Battery Energy Storage System (ESS); basement; smart four quadrant inverter control; frequency dispatch
17. Backup Generator	IKEA	Diesel	0.600	0	7.2	9.76	MMBtu/MWh	Existing. Elevated backup diesel emg. generator
17. Solar PV	IKEA	Solar	2	2,461	6.7	N/A	Choose an item.	Existing. Rooftop PV, requires inverter retrofit; smart four quadrant inverter control
18. Solar PV Carport	Linda Tool & Die, 42 Van Dyke	Solar	0.020	24.6	0.067	N/A	Choose an item.	New. Carport PV; smart four quadrant inverter control
18. MicroCHP	Linda Tool & Die, 163 Dwight St	Natural Gas	0.010	61.3	0.168	9.99	MMBtu/MWh	New. MicroCHP, Ground floor; facility black start capable
18. Battery ESS	Linda Tool & Die, 163 Dwight St	Other - please specify	0.030	TBD	TBD	N/A	Choose an item.	New. Battery Energy Storage System, Ground floor; smart four quadrant inverter control, frequency dispatch
19. Solar PV	Added Value	Other - please	0.008	9.5	0.025	N/A	Choose an item.	Existing. Groundmount PV; smart

Facility number; Distributed Energy Resource Name	Facility Name	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Average Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh		Description
						Quantity	Unit	
		specify						four quadrant inverter control
19. Battery ESS	Added Value	Other - please specify	0.034	TBD	TBD	N/A	Choose an item.	Existing. Battery ESS in shipping container, 4ft flood barrier; smart four quadrant inverter control
19. Wind	Added Value	Other - please specify	0.002	4.0	0.011	N/A	Choose an item.	Existing. Micro-wind turbine
20. Anaerobic Digester	GBX	Other - please specify	4	24,400	68	N/A	Choose an item.	New. 2MW for self-consumption, 2MW IPP export; facility black start capable
21. Solar PV	Cruise Ship Terminal	Solar	2	2,461	6.8	N/A	Choose an item.	New. Community solar PV, rooftop on pier buildings; smart four quadrant inverter control

• Does the microgrid design provide on-site power in both grid-connected and islanded mode? Yes, for facilities with solar PV, battery energy storage, and micro-CHP. Whereas for facilities that only have natural gas backup generators, no – these generators would not provide grid connected power (except for demand response). Provision of priority critical load as matched by available primary energy resources will be through a Principles of Access (POA)[13] arrangement. Insufficient energy resources to cover load will therefore entail disconnecting lower priority loads subject to the POA agreement of the community microgrid. On the other hand, if the microgrid has excess generation while in island mode, the POA scheme will determine which generation to curtail. A POA load and generation prioritization approach matches current critical load needs with available generation. POA prioritization therefore is contractually established, and likewise technically implemented via the control scheme priority stack. In establishing the POA arrangement, the following principles are suggested: (1) prioritization of critical loads and likewise generation for certainty in curtailment order, (2) efficient utilization of microgrid distribution assets, (3) simple implementation that is easy to understand, and (4) fair and equitable in the allocation of curtailment costs and benefits and likewise meeting community emergency services.

• Does the microgrid distributed energy resources provide 24 hrs per day and 7 days per week utilization of the power? • Does the microgrid design include an uninterruptible fuel supply for DER for no less than one week? • If generation in the microgrid is dependent to the supply of natural gas or other fuels, what are the arrangements for continuous access to these supplies? What agreements will be made for fuel supply under catastrophic events and for what duration would these supplies support microgrid operation? • Does the microgrid design describe how many days of continuous operation can be achieved with current fuel storage capability? If additional fuel storage is required, provide a description of needs required for this or otherwise describe how fuel security is to be managed? The RH-CMG connected solar PV will be interconnected to the local grid and thus will generate with available sun. The microCHP and anaerobic digester will operate continuously throughout the year, as will the ESS batteries in order to maximize their unit cost/benefits during normal daily operation. The natural gas emergency generators are anticipated to only be used in the event of microgrid islanding or during grid demand response periods. Yes, the microgrid generation is estimated to provide 72+ hours of power (indefinite with sufficient natural gas fuel supply). Beyond maximizing the inclusion of solar PV in the microgrid (that would offset natural gas and diesel fuel during islanded operation), no additional provision has been included in the design for catastrophic loss of fuel supply due to how natural gas pipelines are undergrounded and generally resilient to severe adverse weather. Active network management real-time notification sends microgrid operations as well as DER owners' status availability updates to troubleshoot curtailment, outages, failure to respond, etc.

• What percentage of the total power consumption in the microgrid will be supplied by resources in the microgrid? Local utility? When grid connected, the distributed generation would provide for 6.2 MW of power (including intermittent solar energy) which is 100% of RH-CMG peak power needs.

• Are microgrid resources designed to follow the electrical load while maintaining the voltage and frequency when running parallel connected to grid? When connected to the grid, the microgrid DER would use the grid for voltage and frequency reference, and would not follow facility electric load.

[13] Principles of Access (POA) arrangements are suggested for their contractual and corresponding control scheme for establishing certainty in critical electric resource provision. The scheme will be modeled for instance on similar approaches in the United Kingdom: e.g. http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Flexible-Plug-and-Play-(FPP)/Project-Documents/FPP_Principles_of_Access_report_final.pdf

When islanded, the microgrid controller would call on DER to provide volt, VAR and various ancillary services as required. System specification includes smart inverter functionality that includes these capabilities.

• Does the microgrid design provide a means for two-way communication and control between the distributed energy resources owner/operator and the local distribution utility through automated, seamless integration? Or, is the transition initiated by the microgrid operator? It is anticipated that the microgrid controller would interface with utility enterprise systems such that islanding can be initiated from the utility control room or from the microgrid controller. In the event of an area power outage, the microgrid controller would automatically initiate transitioning to island mode. For integration, it is anticipated that the microgrid will use open standards-based protocols such as DNP3 and Modbus for integration and/or visibility appropriate with the local distribution utility.

The conceptual design includes quick disconnection (via protection schemes) from the main grid at the inception of an islanding event. A synchronization scheme shall also be included for reconnection to the main grid. This requires monitoring of both the main grid and the microgrid at all times. The location of the synchronization scheme is located at the synchronization switch that tie the microgrid to NYCHA's as well as Con Edison's systems.

• Does the microgrid design include secure control/communication systems from cyber-intrusions/disruptions and protect the privacy of sensitive data? Yes, the microgrid control system and communications system design considered NERC Critical Infrastructure Protection (CIP), NISTIR 7628 standard for smart grid cyber security, as well as ISO 27001 certified Information Security Management System (ISMS).

• How does the microgrid design provide resiliency to likely adverse weather and environment conditions that are the most likely to impact facilities (generation, delivery, and customer connections) at the specific location (community)? Where cost effective and appropriate for critical operation, microgrid resiliency can be achieved by ensuring that there are back-ups for all primary islanding equipment. Local controllers shall act as primary actors, with local backup schemes. Where viable, underground cabling for both power and communications are preferred over overhead or wireless, to ensure connectivity in severe weather conditions. Where viable, primary generation and associated microgrid equipment will be raised above the flood line.

• Does the microgrid design provide black start capability? Yes, at least one generator shall be equipped with a black start[14] scheme. Preferably for higher resiliency, a primary generator and a backup generator shall have the black start capability integrated into their local controllers. This capability will allow a delayed islanded mode operation after a main grid power failure event. A delayed transition may be considered for infrastructure cost optimization, or it may happen due to a failure in the primary transition schemes. In any case the black start scheme shall be put in place as an essential primary or secondary scheme for highly resilient microgrids.

[14] Black-start for the microgrid is defined as the process of restoring electric power to the islanded loads from an outage period. When restoring power, the black-start enabled generator(s) must have fast acting control to rapidly match generation output to connected load, offer voltage source operation, and also be designed for stable operation during periods of large reactive power absorption/injection.

• Does the microgrid design consider energy efficiency options that minimize the need for additional generation assets? Yes, as a part of the feasibility study, site energy audits include ASHRAE Level II audits of energy efficiency options.

The project team also partnered with Green City Force to support these audits in two ways. The first is that low and moderate income (LMI) residential housing – included in the potential microgrid facilities, the Carroll Gardens Association and likewise the Red Hook Co-op Homes – are being connected to Green City Force's program for offering NYSERDA EmPower audits for eligible units. The audits are therefore connecting LMI eligible residents to EmPower energy efficiency and sustainability deployments today that will bring down their current energy bills and educate them on these green technologies. The second way is that a small Green City Force team (5 person) is working with Smarter Grid Solutions for workforce development on commercial energy auditing. As an in-kind support from Green City Force, this advances and broadens their skills to commercial energy efficiency options which the project team would like to leverage further during the RH-CMG design stage. This partnering led to Green City Force supporting energy auditing of the Red Hook Library.

• Does the microgrid design address installation, operations, maintenance and communications for the electric system that serves all the generation and loads within the electrical boundary of the microgrid from commissioning of equipment and systems through system and operational testing of the microgrid controller and the distribution utility? Yes, the conceptual design considered installation, operations, maintenance and communications for integrating the microgrid with utility systems and during islanded operation.

• To what extent does the microgrid design involve clean power supply sources that minimize environmental impacts, including local renewable resources, as measured by total percentage of community load covered by carbon-free energy generation? The RH-CMG conceptual design aims to maximize the deployment of clean, renewable energy that generates carbon-free energy. This clean generation will be used in grid connected and islanded mode. The feasibility study includes the consideration of generic real-time control technologies that have proven capabilities to increase the local grid hosting capacity by 100%-200%. As per the description and conceptual design (Figure 7) in Section 5.1, the RH-CMG will connect nine solar PV arrays (i.e. nine facilities with solar PV), which individually each demonstrated cost effective deployment under a PPA ownership model.

• To what extent does the microgrid design demonstrate tangible community benefits, including but not limited to, (e.g. jobs created, number of customers served, number of buildings affected, scale of energy efficiency retrofits, support for emergency management personnel during catastrophic events most likely to occur in the area)? The RH-CMG connects together critical emergency services buildings, as per Red Hook's NY-Rising emergency preparedness plan, that would provide energy resiliency to those facilities such that all residents of Red Hook and the surrounding area could access these services during a prolonged grid power outage. Services include temporary shelters, minor medical facilities, social and life-saving services (e.g. food preparation and mobilization centers), and power services (e.g. mobile phone charging) and communications access (e.g. email, RHI public wifi access). Consistent with the design described in Section 5.1, the RH-CMG seeks to maximize the number of facilities that can be supported by the microgrid via sufficient and reliable, cost effective distributed generation. As mentioned above, the project team worked with Green City Force – a local non-profit that supports workforce development – in order to train and engage their members in commercial energy auditing. This extended their residential energy auditing training and experience that they receive as a Green City

Force member. Building on this small feasibility stage effort, the RH-CMG project team recognizes the importance of job creation in the microgrid and grid modernization industry, and will seek to leverage the microgrid's deployment to strengthen the community socially, economically, and environmentally. The project team anticipates that during the detailed design phase that they will be able to leverage Green City Force's experience to further support the development of investment grade EE and DG audits.

• Does the microgrid design incorporate capabilities that improve the resiliency and reliability of the distribution system to which it is connected? Provide confirmation from the utility improvement in resiliency and reliability are expected. When integrated with the current grid, the microgrid would not adversely impact non-microgrid customers. For those facilities served by the microgrid, their resiliency would be improved by microgrid islanding operation. In terms of utility reliability relative to peak load constraints at the substation, Con Edison has determined that the substation serving Red Hook does not have near-term load constraints and thus the microgrid would not provide a direct benefit.

• Does the microgrid provide capabilities to expedite power system restoration in adjacent areas (for customers other than those in the microgrid)? No.

• Are their proposed operational plans between the microgrid operator/owner and the distribution utility? No. Further evaluation on owner/operator options – including the potential for utility ownership/operation of the microgrid distribution equipment and control systems – will be determined during the detailed design.

5.3. Additional Technical Design Details

• Does the microgrid design identify the electrical and thermal infrastructure on the simplified equipment layout and one-line diagrams and differentiate between new, updated and existing infrastructure? • Does the microgrid design provide an equipment layout diagram and a one-line diagram depicting new, updated or proposed equipment, including location of the distributed energy resources and utility interconnection point (Point of Common Coupling (PCC))? Yes – see Figure 7 for the high-level system conceptual design one-line diagram. DER PCC would be at the facility control panel to isolate and switch from grid connected to islanded microgrid. Some existing DER are already deployed in Red Hook, including IKEA's solar power installation, 2MW solar PV, and 660 kW emergency generator. Added Value already has their 7.5 kW solar PV, a 34 kWh battery energy storage system, and a 2kW wind turbine. RHI has some existing RF Mesh communications nodes in Red Hook.

• Does the microgrid design take into account interconnection issues at the PCC? Upgrades to the substation? Feeder? • Has the local utility evaluated the interconnection impact on the feeder? High-level DER costs included typical interconnection integration costs. Distribution reinforcements and additional new equipment (overhead conductors, poles, smart switches, etc.) are identified within the conceptual design. DER interconnection issues will be identified through CESIR studies as part of the detailed design.

• Does the microgrid design meet with the local utilities requirements for communications? • Does the microgrid design provide the communications infrastructure required to support microgrid operations with the utility? Can the utility monitor the microgrid activity at the PCC? Does the communications allow for disconnection by the utility during emergencies or risk to the stability of the interconnected distribution system? • Does the microgrid design provide the microgrid control architecture and how it interacts with distributed energy resources controls and building energy management systems, if applicable? • Does the microgrid design provide for a controller to manage the microgrid functions?

Con Edison directed the RH-CMG team to specify the microgrid communications independent of their review – because they currently do not have a standard for such systems. The communication and controller systems were specified to include integration with utility systems, as per the following figure.

For the RH-CMG facilities, there are no existing BEMS controls, therefore all DER device and load control, and the microgrid controller will be new. The microgrid control architecture shown in the following figure leverages an active network management control architecture to maximize DER revenues when grid connected, and provides autonomous and deterministic microgrid islanding. DER controllers are co-located with each DER. The location of the microgrid controller has not been finalized, but is anticipated that it could be located in either the RHI offices, or NYCHA's east or west generation facility.

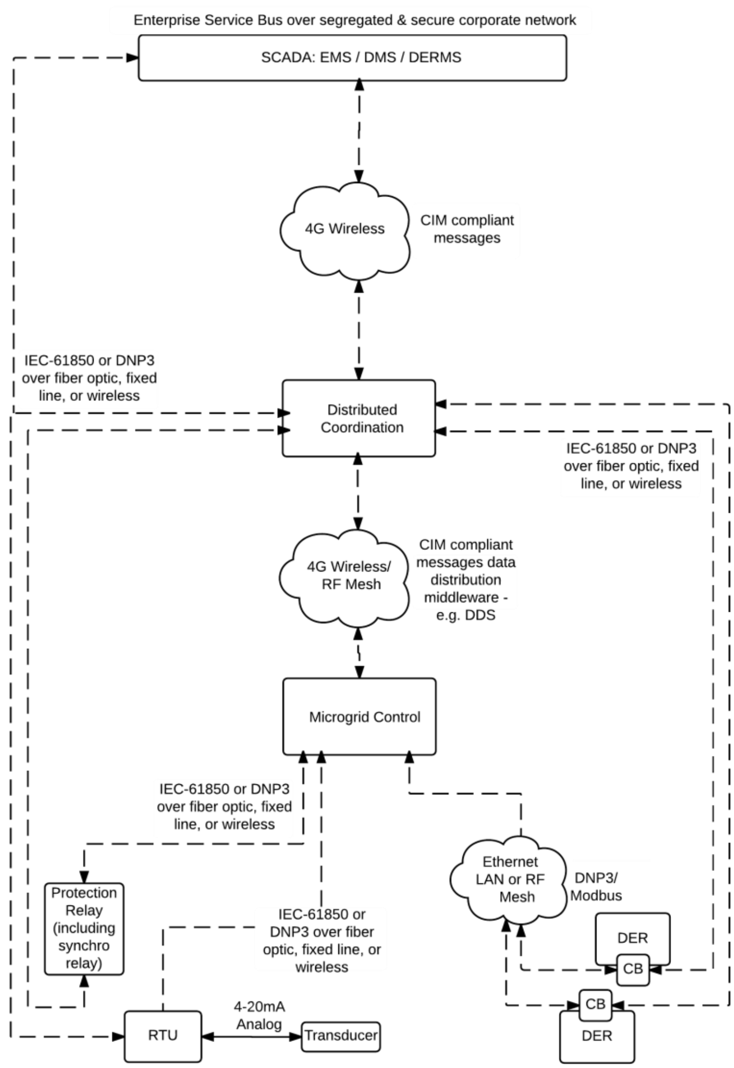


Figure 8: Generic Microgrid Architecture

• Does the microgrid design provide a brief written description of the services that could be provided by the microgrid controls including, but not limited to the following:

+ Automatically connecting to and disconnecting from the grid: synchronizing switches have been included for all Con Edison, RH-CMG, and NYCHA circuits. In the event of synchronizing switch failure, a DER device controller is included to ensure failsafe operation. At the same time, DER device controllers include distributed logic allowing facility failsafe operation (e.g. facility generation providing critical loads, with no generation export to the microgrid until synchronization criteria is met).
+ Load shedding schemes: All loads will be assigned a priority within the control scheme, referred to as a principles of access (POA) control paradigm. If there is insufficient generation to meet all loads, then loads with lower POA priority are shed. When excess generation is available, these lower priority POA loads are able to switch back on. This POA matching of supply and demand is resolved on a second-to-second basis (subject to DER response timers) that leverages the active network management control architecture. The principles of access DER and load scheme will be designed and contractually established as part of the final design.
+ Black start and load addition: Each facility with emergency backup generation, microCHP, and/or battery ESS will be capable of black start. Additional load will be added subject to the POA load priority scheme.
+ Performing economic dispatch and load following: Load following will take place via the POA control scheme mentioned above. It is anticipated that economic dispatch of DER will be considered within the POA priority stack for DER and load – thus reflected in bulk pricing. Real-time POA generation curtailment and/or load shedding ensures safe operation of the microgrid, and is itself not subject to economic dispatch. Please note, advanced active network management schemes can include forecasting and scheduling elements, such that 15 minute interval TOU pricing could be included in DER dispatch. The RH-CMG will incorporate this functionality if determined a priority during the final design.
+ Demand response: Load following will take place via the POA control scheme mentioned above. While grid connected, DER with available demand response capabilities will interface with Con Edison or through an aggregator and their provision of demand response will support additional revenue. Examples of DER include natural gas backup generators, and battery ESS.
+ Storage optimization: native battery ESS controllers will optimize storage use, scheduling, and lifetime performance. The local device DER controller for the microgrid will interface to ensure availability in the event of an islanding event.
+ Maintaining frequency and voltage: several DER include frequency dispatch, and several DER include P and/or Q control voltage rise management. As mentioned prior, DER support for low voltage conditions is an advanced functionality that will be considered in the final design, if applicable.
+ Photovoltaic information and controllability; forecasting: all DER, including solar PV, will be fully observable and controllable. Forecasting for economic dispatch will be evaluated for its inclusion in the final design, but is not required for reliable microgrid operation.

- Coordination of protection settings: preliminary protection requirements have been evaluated for this conceptual design. Additional coordination requirements or additional protection will be considered as part of the modeling and simulation for the final design.
- Selling energy and ancillary services: applicable DER with ancillary services capabilities will be considered to support additional revenue.
- Data logging features: active network management systems typically leverage existing utility data logging systems. The requirements for a data logging system will be considered as part of the final design.
- How resilient are the microgrid and building controls?: the active network management scheme proposed applies a critical systems design philosophy to the microgrid controls. The system is autonomous (second-to-second, no operator-in-the-loop), deterministic (time bounded response), redundant where required, and includes escalating and failsafe modes through part-central and part-distributed logic.
- Discuss the impact of severe weather on the microgrid and building controls: the highest risk to the microgrid from severe weather will be any exposed overhead conductors. The controllers and their enclosures themselves will be rated for their operation environment (e.g. weather rated if mounted outside).

• Does the microgrid design identify the locations of new and existing microgrid and building controls on the simplified equipment layout diagram? Microgrid DER control locations correlate with communication node locations – see Figure 9.

• Does the microgrid design identify the new and existing information technologies and telecommunications infrastructure on the equipment layout diagram? • Does the microgrid design provide the information technologies and telecommunications infrastructure and protocols required for the microgrid? • How vulnerable are the information technologies and telecommunications infrastructure to catastrophic events that are most likely to impact the microgrid? Yes, as seen in the following figure. The conceptual design anticipates leveraging and extending RHI's RISE:NYC resilient RF Mesh wifi communications systems. The design assumes the communication nodes would be public & microgrid dedicated communications nodes so as to meet security and reliability communication needs. By using RHI's system, the microgrid supports continuing direct workforce development within Red Hook.

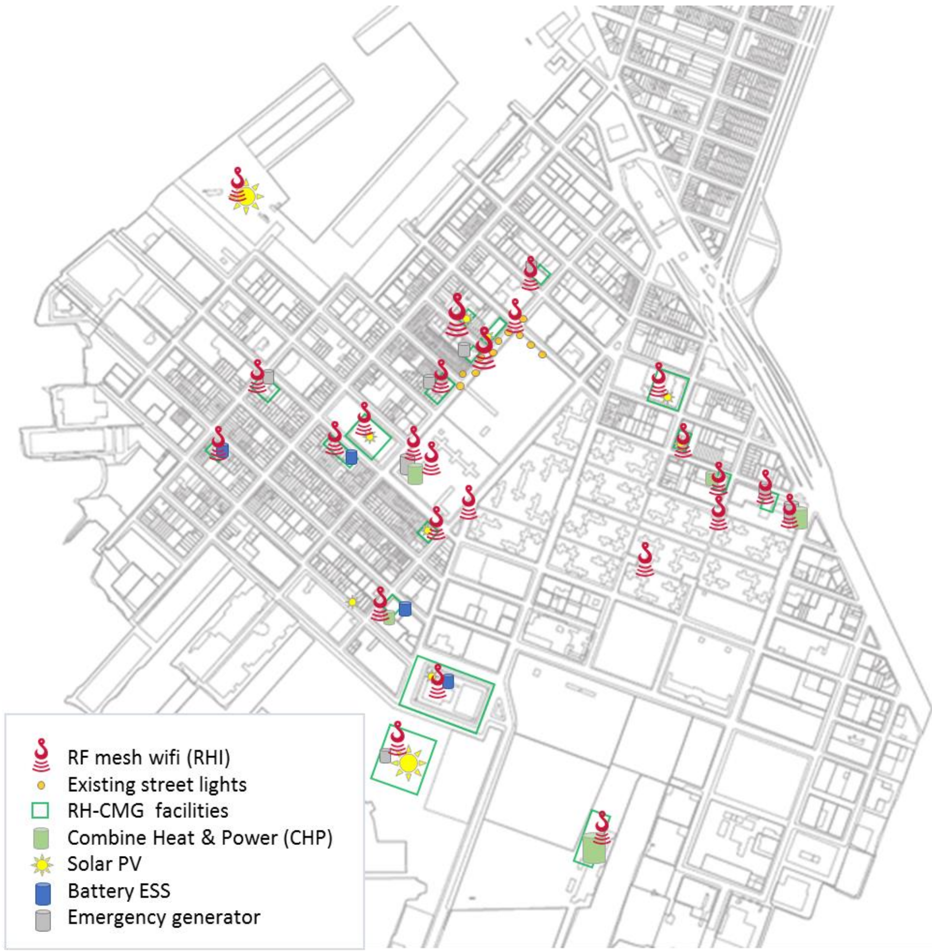


Figure 9: RH-CMG Communications Nodes – RHI RF Mesh

The combined RH-CMG and NYCHA microgrid system will leverage Red Hook Initiative's (RHI's) RF mesh wifi system, including their RISE:NYC experience, and where applicable that equipment, to further build out the RF mesh network. The following characteristics apply:

- RF mesh network;
- Each RH-CMG, and NYCHA generation facility will include a RF mesh gateway node. The gateway nodes will be co-located with the microgrid facilities as per the numbering in Table 2;
- Each RF mesh gateway node will itself include a backup solar PV and battery system, ensuring wifi availability in the event of a grid and microgrid outage. The design will replicate the RISE:NYC design and implementation currently on-going within Red Hook. Nearly all RH-CMG sites will require new gateway nodes, and all sites will require the resilient solar and battery system;

- Open, consensus-based communications and control protocols will be used for interfacing with Con Edison's enterprise DER coordinator, the microgrid controller, and the DER device controllers. Examples include IEC 61850, ICCP, DNP3, and Modbus;
- The microgrid will interface with utility systems as per Figure 8. The microgrid controller and DER controllers will continue to function under loss of communications with the utility. If the loss of communications happens while grid connected, the failsafe mode will ensure the grid is operated safely (e.g. DER do not export to the grid due lack of situational awareness from a communications loss). If the loss of communications happens while islanded, the microgrid will continue to operate in microgrid mode and will report its status to the utility when communications return. If the loss of communications happens while transitioning to or from islanded mode, the DER controller failsafe response for transition mode will take place to ensure the safety to the facility and the grid. Specific DER failsafe responses will be defined in the final design.

Each RF mesh gateway node will include an independent solar PV and battery backup. Smarter Grid Solutions has experience implementing active network management schemes using RF mesh, and if during the final design it is determined that additional communications security and/or availability is required, then Smarter Grid Solutions will work with the project team to incorporate additional cost effective communication systems.

• Does the microgrid design provide approximate location and space available for microgrid equipment/resources? Yes, individual facility audits identified the location and space needs for microgrid equipment.

• Does the microgrid design fully describe the electrical infrastructure (feeders, lines, relays, breakers, switches, current and potential transformers (CTs and PTs) and thermal infrastructure (steam, hot water, cold water pipes) that are a part of the microgrid? • Does the microgrid design provide what additional investments in utility infrastructure may be required to allow the proposed microgrid to separate and isolate from the utility grid? • Does the microgrid design provide the basic electrical system protection mechanism within the microgrid boundaries? Please see Figure 7 for the one-line diagram for the electrical infrastructure. There are multiple interconnection points with the grid. The RH-CMG distribution lines will be dedicated to the microgrid and installed in parallel to Con Edison's existing circuits. NYCHA's preliminary microgrid design is anticipated to have a similar parallel set of NYCHA distribution lines. The following are the microgrid distribution system specifications and design criteria:

- Con Edison's existing distribution cable is a 4kV radial feeder branch, stepped down to 120/240V by pole-mounted transformers ranging from 75-225kVA. In order to carve out this network pocket, the following additional reinforcement equipment is required:
    - Visitation Church: new 75kVA transformer to supply microgrid via existing overhead system and riser to isolated underground network.
    - Addabbo Health Clinic: new 150kVA transformer on adjacent pole to pick up customers previously served by existing transformer.
- A synchro-check relay to isolate Con Edison's radial feeder branch.
- All RH-CMG distribution circuits are 4kV, and each facility served by the RH-CMG circuit will require a new step down transformer to 120/208V (pole-mounted if overhead, else vault

installed for underground) are needed for each facility. The following describe synchronous isolation equipment requirements.

- A synchro-check relay to synchronize Con Edison's cable to #5 RH-CMG cable – connects the Red Hook Justice Center to this circuit.
- A synchro-check relay to synchronize Con Edison's cable to #4 RH-CMG cable – connects the Tamco to this circuit.
- A synchro-check relay to synchronize Con Edison's cable to #1 RH-CMG cable.
- A synchro-check relay to synchronize #1 RH-CMG cable to NYCHA's west circuit.
    - 5 relays to isolate NYCHA's facilities from Con Edison's secondary network
    - A synchro-check relay to isolate NYCHA's west circuit.
- A synchro-check relay to synchronize #2 RH-CMG cable to NYCHA's west circuit.
- A synchro-check relay to synchronize #3 RH-CMG cable to NYCHA's east circuit.
    - 4 relays to isolate NYCHA's facilities from Con Edison's secondary network
    - A synchro-check relay to isolate NYCHA's east circuit.
- Note: the Miccio Center will be served by the microgrid, but at this time it is still to be determined if included as a part of NYCHA's microgrid, or as a private wire RH-CMG extension from NYCHA system (as shown in the figure). If not included in NYCHA's microgrid, then a synchro-check relay would be required for this facility.
- Note: protection of the microgrid boundary will be provided through the monitoring and coordination of the relays to ensure a safe and synchronized transition to or from islanded mode. Additional protection engineering needs (e.g. fault current isolation) will be evaluated in the final design.

• Does the microgrid design take into account providing the resiliency of the electrical and thermal infrastructure to the forces of nature that are typical to and pose the highest risk to the location/facilities? Describe how the microgrid design provides resiliency to disruption caused by such phenomenon and for what duration of time? Discuss the impact of severe weather on the electrical and thermal infrastructure? The project team's microgrid conceptual design prefers undergrounding cables, but given their much higher costs performed the benefit-cost analysis for overhead distribution lines consistent with Red Hook's existing distribution infrastructure. While undergrounded cables will be more resilient to the forces of nature and other factors that today currently affect Red Hooks power reliability, their higher costs need to be evaluated from a broader integrated system planning and an emergency power valuation process that includes the social and environmental factors that will be considered in the future project deliverables. NYCHA's preliminary anticipated design will underground their microgrid distribution lines. It is anticipated that the microgrid will be able to be maintain critical emergency power for 72 hours and beyond as per NY Prize requirements. The availability of natural gas throughout this duration will be the determining factor.

• Does the microgrid design describe how the proposed microgrid will operate under normal and emergency conditions? The following joint RH-CMG and NYCHA microgrid system operational modes apply:

- Grid connected – here the microgrid DER operate in grid mode, with coordination as applicable via Con Edison SCADA/DERMS/DMS/ANM enterprise controller.
- Figure 8 generically show the Con Edison enterprise controller – to – microgrid controller – to – device DER controller architecture. The facility device DER controllers manage against facility

priorities (e.g. maximizing clean energy generation) and grid constraints (e.g. export, import, voltage) as issued by the Con Edison enterprise controller;

- Islanding preparation – the Con Edison enterprise controller issues a near-zero power flow set-point that the microgrid controller manages against to facilitate smooth transition in the event of islanding;
- Transition management – the microgrid controller and Con Edison enterprise controller coordinate in order to facilitate transition to islanded mode or to be brought back into grid connected mode. This is realized through detection of change in status of the electrical sectionalizing point, reflected as a change of state in Con Edison enterprise controller;

Islanded operation – the microgrid control operates the microgrid; operation of the microgrid is independent of the interconnected grid and the microgrid's status is made unavailable to Con Edison's DER controller; the microgrid controller's energy priority states can maximize clean energy when available to meet real-time microgrid loads.

• Does the design include operating agreements, decisions rules and communication procedures between the microgrid operator and the utility necessary to operate the microgrid? Similar to the lack of Con Edison communications standards for microgrid integration (as previously mentioned), there is an ongoing need to work with Con Edison to develop operating agreements and decision rules, as well as the communication procedures that would depend on the owner/operator structure that will be determined during the detailed design.

• Does the microgrid design provide hourly load profile of the loads included in the microgrid and identify the source of the data? If hourly loads are not available, best alternative information shall be provided? The best alternative data availability is utility monthly meter data for the RH-CMG facilities. Except at the peak load aggregate, this data it is not included in this report due to the proprietary nature of each facility's energy consumption. Interval meter data gathering will be included in the detailed design phase.

• Does the microgrid design provide a description of the sizing of the loads to be served by the microgrid including a description of any redundancy opportunities (ex: n-1) to account for equipment downtime? The facility audits identified all cost effective DER options so as to have each facility maximize its own generation contribution to the microgrid, and at the same time maximizing solar energy deployments. The combined DER therefore approach N-1 redundancy for all the sites. Thus sufficient solar resources exist that during some periods (e.g. spring and fall months with high solar irradiance) there would be sufficient solar energy generation to offset all or most natural gas generation. On the other hand, the emergency natural gas generation could provide all or nearly all emergency power during periods of no solar generation. This analysis will be modeled and confirmed as part of the detailed design.

6. COMMERCIAL, FINANCIAL AND LEGAL VIABILITY

The following sub-sections below present the commercial viability, financial viability, and legal viability of the RH-CMG. Overall the key finding is that when combined with private investment the RH-CMG costs are at the same anticipated level of funding of the NY-Prize Stage 3 awards (e.g. $5m to $8m). On-going O&M costs for the RH-CMG would need evaluation in the design stage to ensure sufficient revenue. Lastly, the RH-CMG ownership/operator options have not been finalized, thus there is the need to continue conversations with Con Edison and the City and State officials for determining the most cost effective owner/operator that likewise is legally allowed. Stage 2 funding would afford the needed design funding to finalize these scenarios and the best option.

6.1. Commercial Viability

• To what extent does the microgrid business plan leverage private capital to the maximum extent possible as measured by total private investment in the project and the ratio of public to private dollars invested in the project? The RH-CMG plan leverages private investment to support facility distributed generation deployment that is microgrid integration capable. Public investment would support the RH-CMG distribution lines and equipment, communications system, and microgrid controller. The following table breaks down these categories:

Table 3: Breakdown of Private and Public Investment

Description	Private Investment ($million)	Public Investment ($million)
Total generation and storage	Small generators: $2.61m Community solar: $12.00m Anaerobic Digester: $13.00m	
Microgrid equipment		Communication sys: $0.14m Microgrid controls: $1.00m DER device controls: $0.27m Dist. Lines/Equip:[15] $3.62m
Total Investment	**$27.61m**	**$5.02m**
Percentage	**Private Investment: 85%**	**Public Investment: 15%**

• Does the microgrid business plan identify the number of individuals affected by/associated with critical loads should these loads go unserved? When critical loads go unserved, approximately 3000 individuals are affected. This number does not include residents of NYCHA housing (est. 6000 – 8000). The latter still benefit from the services provided by the emergency services supported through the microgrid (e.g. Visitation Church, RHI, etc. – as per the Red Hook NY Rising Community Reconstruction Plan (RH-NYR-CRP)[16] that developed community-based resiliency plans).

• Does the microgrid business plan identify any direct/paid services generated by microgrid operation? We anticipate to have approximately 400 kW of demand response (not including NYCHA).

• Does the microgrid business plan identify each of the microgrid customers expected to purchase services from the microgrid? Yes – see Figure 7 for the RH-CMG facilities.

• Does the microgrid business plan identify other microgrid stakeholders; what customers will be directly or indirectly affected (positively or negatively) by the microgrid? In terms of energy, Red Hook residents will be affected positively as they will benefit from continued electricity supply at specific locations during emergencies. In terms of costs, especially on-going operations costs, the Project Team

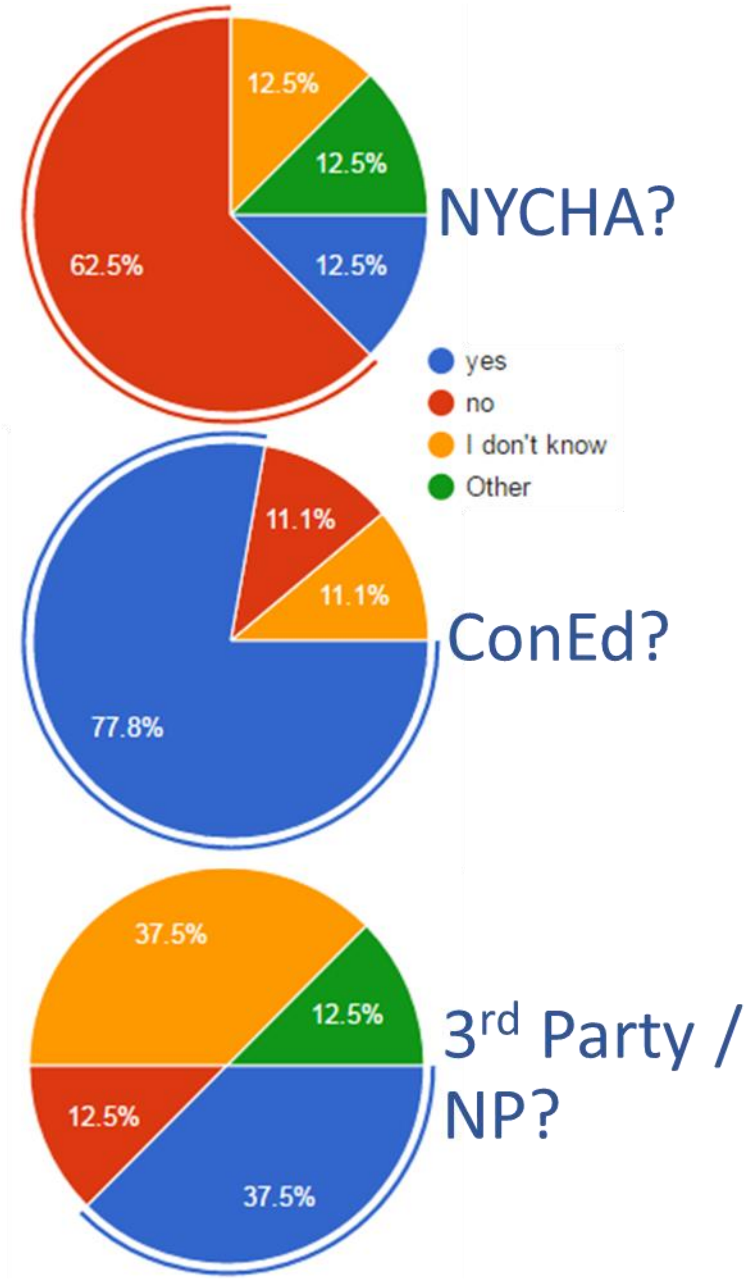
[15] Note that the values shown are for overhead pole mounted microgrid distribution lines and equipment. Underground cables and equipment were estimated to cost nearly 5 times more than the overhead system: increasing the capital costs by approximately $11m.
[16] http://www.stormrecovery.ny.gov/sites/default/files/crp/community/documents/redhook_nyrcr_plan_73mb_0.pdf

is exploring options for microgrid O&M cost recovery fees and their distributional burden. It is assumed that these costs need just and reasonable recovery, noting that many Red Hook organizations are public, non-profit, and commercial entities with limited financial means, which is also true for low and moderate income Red Hook residents. Fees beyond their financial means may be unjust and/or unreasonable, which will need to be carefully considered during the detailed design phase. In terms of physical effects, the microgrid is anticipated to use above ground cabling and electrical equipment (transformers, switchgear, etc.) similar to Con Edison's existing overhead distribution equipment. These components would therefore add additional equipment that would be visible and would be spaced in the public right of way (e.g. along sidewalks, crossing streets). Transformers and switches would emit noise, but this is estimated to be 60-70 dBA, which is likely at or below background urban noise. The emergency generators would emit noise, but given their small size and infrequent use, their positive effect during microgrid operations is anticipated to outweigh the negative noise effect. Electromagnetic emissions effects are also anticipated to be at or below area background levels.

• Do the microgrid design and business plan take into account the relationship between the microgrid owner and the purchaser of the power? The ownership structure of the microgrid facility is still under evaluation. These ownership options include: NY utility ownership (Con Edison or any NY utility, including NYPA); NYCHA owned and operate; or a 3rd party/Non-Profit owner and operator. User fees are expected to cover the microgrid's operational expenses. The exact ownership (discussed in more detail below) and fee structure will be determined in Phase 2 Detailed Design.

When ownership options were presented to the stakeholder in the survey, the participants responded to the following question:

+ "Would you be willing to have _________ own and operate our Red Hook Community Microgrid?", with the blank Con Edison, NYCHA, or a 3rd Party. Their responses are as follows below.



NYCHA? Other response:

"Perhaps if NYCHA is willing/able to coordinate with larger community"

3rd Party / NP? Other response:

"I don't know enough about other options - but yes would be open to hearing more about this"

Additional elaboration from stakeholders:

+ "Our building is owned by another RH-CMG facility, the leasee is a non-profit, and it is operated in partnership with a NY State agency. Any facility issues would need to be approved by all three parties."
+ "Because of the regulatory approvals require by the State, Con Edison has the advantage, expertise, availability of resources and equipment in place to coordinate with NYCHA."

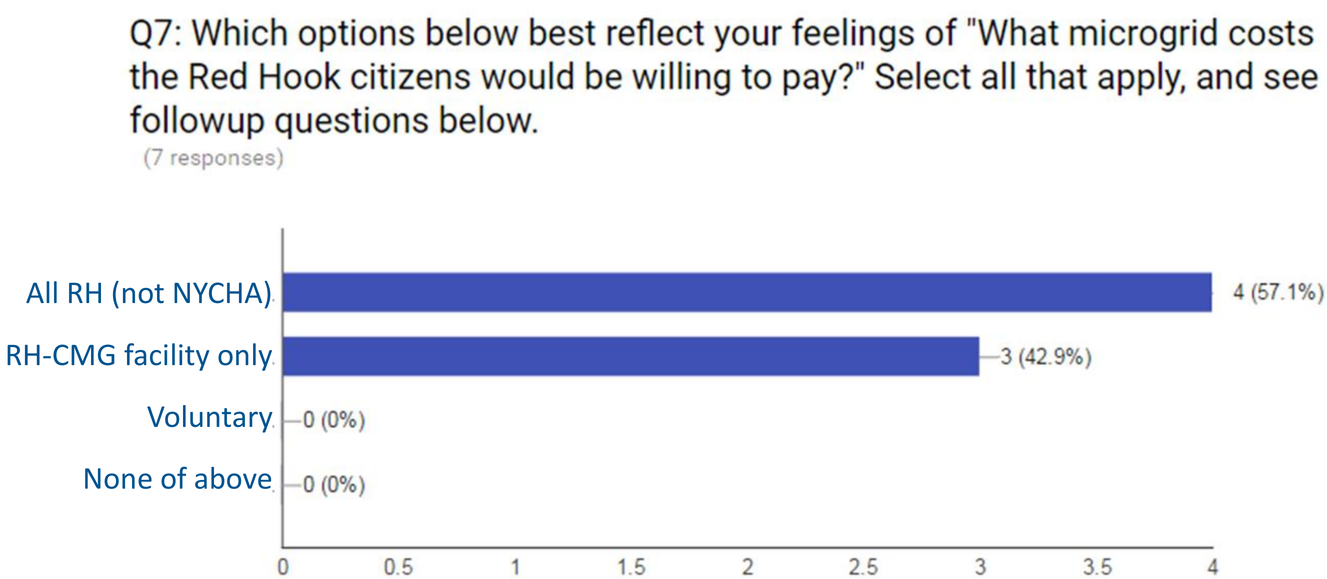
+ "It should have a body of community members serving in leadership who receive support to be able to attend meetings and complete their responsibilities (i.e. stipends for missed work, child-care, translation in meetings and of all materials, leadership training and development, etc.)."

• Does the microgrid business plan indicate which party/customers will purchase electricity during normal operation? During islanded operation? While in normal grid connected mode, all microgrid participants interface to Con Edison's grid as per existing grid connected relationships. Existing tariffs (e.g. net metering, standby rates, etc.) apply. For the solar PV, microCHP, and anaerobic digester generation, the associated facilities (11 total) would benefit from this generation daily by reducing their reliance on importing utility electricity. For this study their economics were assessed such that this net metered energy would be at or below the cost of their current electricity: providing every facility with cost effective grid connected generation.

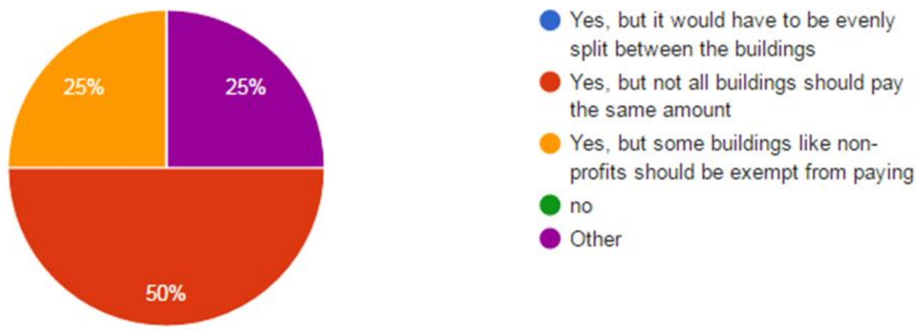
When islanded, microgrid participants would match real-time generation availability with critical load needs as per a Principles of Access (POA) control framework. POA would therefore dictate priority provision of emergency power against correlated POA contracts for dispatch order, and therefore transactive purchase agreements. POA governs both generation and load.

The team has identified three different ownership options that will be discussed above. The exact ownership and associated fee structure will be determined in detailed design.

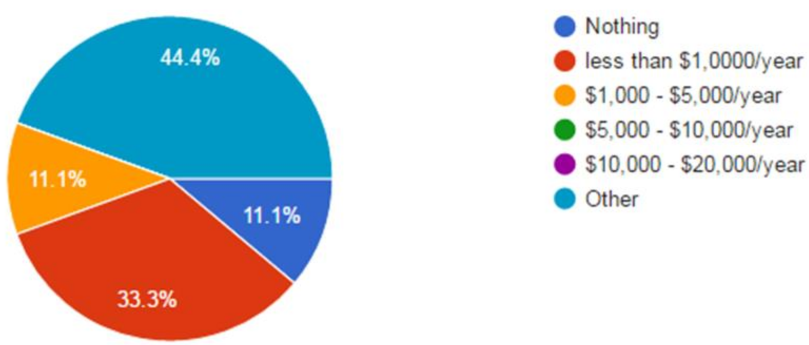
In terms of understanding facility willingness to pay for RH-CMG power, the following facility stakeholder survey questions apply:

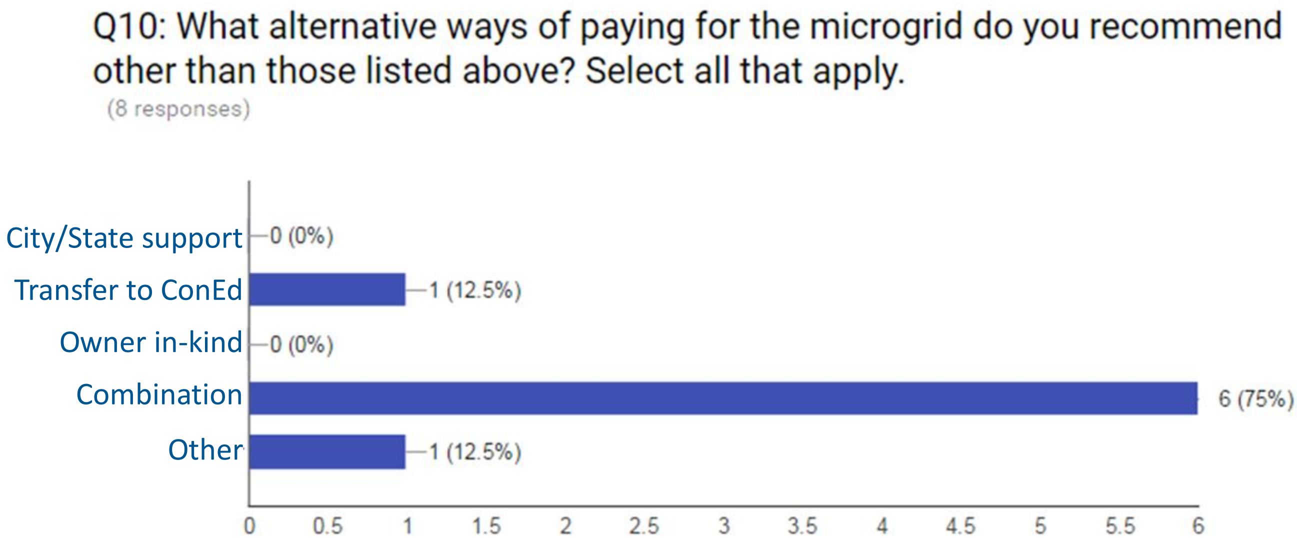


Q8: Do you think it is fair & reasonable to charge participating buildings to pay for the annual operating costs of the RH-CMG?
(8 responses)



Q9: How much per year would your building/organization be willing to pay to support the Annual Operating Costs of the RH-CMG?
(9 responses)





Project Team takeaways from these survey responses are as follows:

+ Just, fair and reasonable microgrid fees for cost recovery are critical to the community stakeholders. Stage 2 Detailed Design will need to consider how to recover operations fees from a combination of sources and appropriate options for LMI residents, businesses, non-profits, and public stakeholders.
+ A combined approach to meeting microgrid costs supports the on-going stakeholder engagement that proceeded and supported the Stage 1 NY Prize effort.

• Does the microgrid business plan identify necessary contractual agreements with critical and non-critical load purchasers? Planned POA agreements will be used for both critical and non-critical load that likewise include generation.

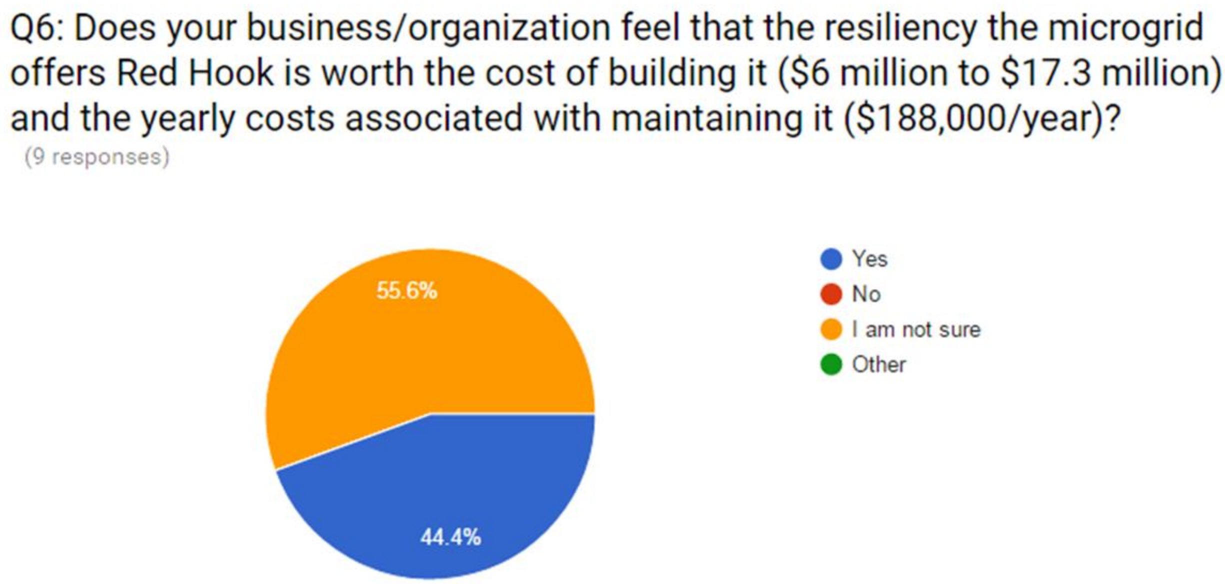
• How does the microgrid business plan plan to solicit and register customers (i.e. purchasers of electricity) to be part of their project? Initial and core microgrid facilities have been identified in the Red Hook NY Rising Community Preparedness Plan, with additional facilities added to develop the conceptual design. See Figure 7 for facilities.

• Does the microgrid business plan provide any other energy commodities (such as steam, hot water, chilled water) that the microgrid will provide to customers? No.

• How does the microgrid business plan provide value to its participants, to the community at large, the local electric distribution utility and the state of New York? The RH-CMG will provide emergency power to emergency services providers for the community during prolonged outages. Con Edison did not identify any value benefits the microgrid would provide them, whereas for New York State the microgrid would test community infrastructure investment ideas that support the broad ambitions of REV. It is anticipated that the microgrid could be replicated for similar communities throughout New York State.

• What benefits and costs will the community realize by the construction and operation of this microgrid? Red Hook will benefit from emergency power as well as workforce development. Furthermore, the microgrid can strengthen a sense of community. Specific costs and benefits are covered in detail in the Benefit Cost Analysis.

In terms of RH-CMG facility stakeholder feedback on the value of community resiliency of having the microgrid relative to capital and operational costs, the following survey question summarizes their responses:



Our Project Team takeaway from these responses is that while no negative ("no") responses were given, due to the significant on-going operation costs there were a slight majority of facility stakeholder that would need additional engagement regarding the value of community energy resiliency. Such engagement will be part of the detailed design effort.

• How would installing this microgrid benefit the utility? Its customers? What costs would the utility incur as a result of this microgrid? Are these covered in the interconnection agreement with the utility? Con Edison has not identified any specific benefit for installing the Red Hook Microgrid (e.g. no opportunities for area substation load relief). However, the Red Hook Microgrid can have an important demonstration effect, showing how microgrids can be used to make communities more resilient. Con Edison could leverage the experience gained from this innovative project, both in terms of promotion and know-how for the future development of microgrids, and if applicable in terms of ownership model, could own and operate the microgrid distribution equipment. If Con Edison would own the RH-CMG distribution equipment, then this would translate into reduced outages for the RH-CMG facilities (i.e. improved SAIFI, CAIDI metrics), and given these facility's provision of critical emergency services would support better customer approval.

Reinforcement costs (e.g. additional dedicated transformers) have been included in the conceptual design such that hardware/integration costs to Con Edison would be borne by the microgrid developer.

• What is the proposed business model for this microgrid? • Does the business plan include an analysis of strengths, weaknesses, opportunities and threats (SWOT)? As mentioned earlier, three ownership models are currently under evaluation, and will need to be finalized during the Stage 2 Detailed Design phase as certain key information remains to be confirmed (e.g. whether Con Edison is willing to take over the ownership of the microgrid at completion). Under each of the ownership models considered, the proposed microgrid will interface and be combined with NYCHA's campus microgrid. Furthermore, the microgrid's DER will be privately owned and operated (with third party power purchase agreements as applicable – e.g. public and non-profit facilities), and the microgrid communications (RF Mesh) will be privately owned and operated by Red Hook Initiative (RHI).

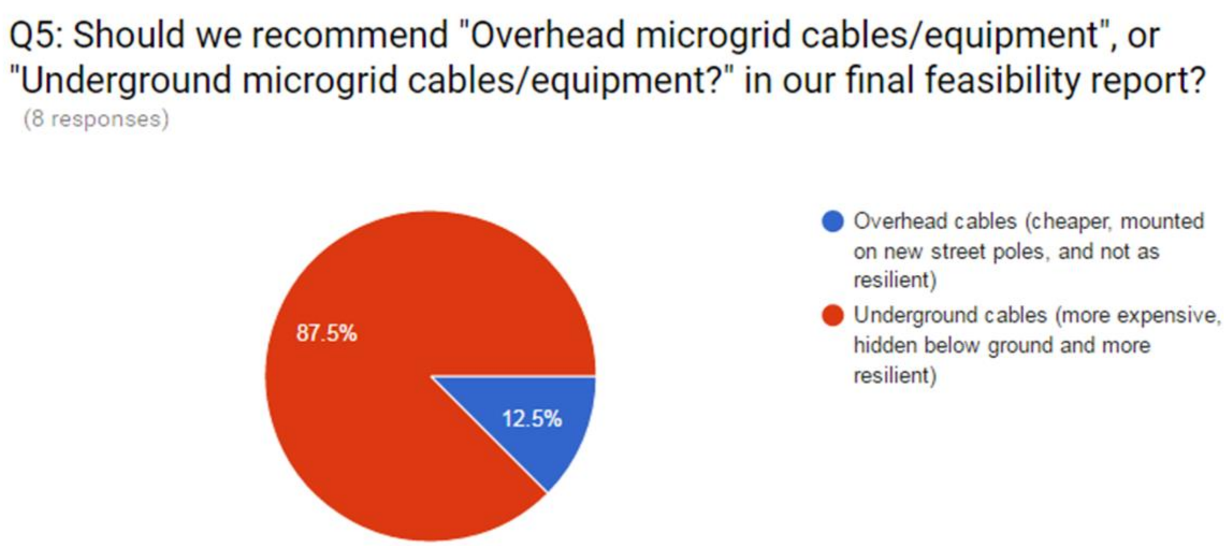
For the microgrid distribution equipment (conductors, switchgear, transducers, transformers, etc.) and controls (microgrid controller, DER controllers, etc.), the following ownership models are under consideration:

+ ***Utility owned and operated microgrid distribution equipment and controls***
    - Strengths: No regulatory approval required; utility ownership could be contracted via competitive RFP available to any NYS utility, including NYPA,
    - Weaknesses: Would need to incorporate in utility distribution, which is a slow process.
    - Opportunities: Could allow for costs to be recovered by all utility rate payers (as opposed to just Red Hook rate payers). Could test REV demonstration criteria as well as advanced REV concepts (e.g. Distributed Energy Resource (DER)-to-DER markets). Utility may cover maintenance and operation fees.
    - Threats: Uncertain interfacing and combining with NYCHA's campus microgrid, which could potentially result in two owners/operators.
+ ***NYCHA owned and operated (or via NYCHA's campus microgrid owner/operator) microgrid distribution equipment and controls***
    - Strengths: Leverage NYCHA's contract for its on-going and funded parallel microgrid effort.
    - Weaknesses: Requires regulatory approval. Would NYCHA need to be registered as a regulated utility?
    - Opportunities: Reduction/elimination in administration/oversight costs.
    - Threats: Requires long-term community engagement for joint governance as NYCHA does not have a specific interest in the community microgrid sites. NYCHA has a poor history of performing sufficient maintenance and operations, which is of a concern to the community (confirmed through outreach). Assume local utility would seek regulatory injunction.
+ ***Third party owned and operated microgrid distribution equipment and controls (e.g. ESCO; e.g. special purpose community non-profit; etc.)***
    - Strengths: Most direct community governance ownership model. Most ambitious test of REV goals.
    - Weaknesses: Requires regulatory approval. Would the established entity need to be a regulated utility?
    - Opportunities: Most adaptable ownership and governance model to incorporate future community goals (e.g. additional clean energy; etc.).
    - Threats: Assume local utility would seek regulatory injunction.

• What makes this project replicable? Scalable? The project demonstrates grid edge automations to test ambitious REV goals: DER-to-DER markets and community investment in infrastructure at the grid edge. The microgrid can serve as a demonstration project that can be replicated elsewhere in NY State and beyond. Once the microgrid is in place, it can be expanded to include other facilities. In addition, the project shows a real community engagement process that can be replicated; showing how reliable and decentralized energy systems can be connected to community emergency plans to create more resilient communities. Workforce development partnerships that are established through the Red Hook community microgrid can also be replicated easily throughout the state and country.

• What is the purpose and need for this project? • Why is reliability/resiliency particularly important for this location? Will it meet a disaster recovery or unmet infrastructure need? As of today, Red Hook has a lower electric reliability compared to most of New York City (due to the neighborhood's low elevation, waterfront location, the vulnerability of the existing overhead system and its configuration design). This project would bring emergency power to a neighborhood that is highly vulnerable to a wide variety of climate change impacts – including storm outages, heat, inland flooding, heavy wind storms - hence making it more resilient. In the case of an outage, the microgrid will switch to islanding mode, allowing it to provide electricity to critical and some non-critical facilities for an unlimited period of time (assuming availability of natural gas). The microgrid is designed for a 72-hour period (and indefinitely with sufficient natural gas fuel), which is identified in the Red Hook Community Emergency Preparedness Plan, also identified by OEM as the period of time in which a community must expect to be self-reliant, until city agencies can mobilize.

As per the RH-CMG conceptual design, it is assumed that the microgrid will need to use overhead distribution lines and equipment due to how funding for underground cabling is beyond that available from NY Prize. Undergrounding the cables would make the RH-CMG system even more resilient to extreme weather, so we surveyed our facility stakeholders for their preference, as found below.



The majority RH-CMG facility stakeholder therefore prefer underground cabling, thus our Project Team takeaway is the need to continue to work with the City and utility on options for hardening and undergrounding Red Hook's existing distribution system, along with options for building out the RH-CMG via undergrounding cables and equipment if sufficient funding is available.

• Does the microgrid system provide an overall value proposition to each of its identified customers and stakeholders?

+ Microgrid facilities: provide clean resilient energy to meet critical loads.

+ Red Hook Community: provide critical emergency services (medical, food, supplies, communication, connectivity) in the event of a prolonged outage.
+ Utility: demonstrate how to optimally use existing utility equipment and how to work together to build new infrastructure to meet the community's resiliency goal.
+ Microgrid suppliers and partners: serve as a benchmark site to demonstrate community microgrid technologies in the U.S.
+ NY State: example of one of the most unique opportunities to test REV goals.

• Does the microgrid system provide added revenue streams, savings, and/or costs for the purchaser of its energy? Cost savings include avoiding expenses related to renting emergency generators, fuel (in the case of stakeholders who adopt solar power), lost revenues due to outage, etc. Additional costs and benefits are covered in more detail in the Benefits Cost Analysis.

• Does this microgrid system promote new technologies? The project would demonstrate and promote the use of smart grid edge switchgear (relays, etc.) and controllers (master, PLC, etc.) that coordinate and manage multiple DER in real-time to maximize use of clean solar energy. Most microgrids are fossil fuel based (natural gas or diesel generators) and relatively simple (e.g. single facility, or campus microgrids), whereas our approach is one that can maximize clean energy production across multiple facilities during islanded mode such that fossil fuel use is minimized and energy generation is managed relative to real-time critical loads – a DER control approach that is innovative due to the control systems complexity of having so many facilities and DER.

• Does the microgrid system promote any public/private partnerships (P3s)? Yes. Final PPP arrangements to be determined during Stage 2 detailed design. Anticipated P3s:

+ Third party owned solar PV for public and non-profit microgrid facilities
+ Microgrid owner/operator as discussed previously

• Are any project financiers or investors identified in the microgrid team? The project financiers will be identified based on the previously discussed owner/operator options. DER will most likely be financed using private capital and existing subsidy programs. Furthermore, some emergency generators already have allocated funding (such as the Addabbo Health Center's generator). The additional infrastructure (communication systems, distribution equipment and controller) will mainly be grant funded, efficiently leveraging NY Prize monies. Project team member IMG Rebel specializes in developing innovative financial solutions for infrastructure and thus will identify opportunities during the detailed design.

• Are any legal and/or regulatory advisors part of the microgrid team? No legal advisors are currently part of the team. The project team has been approached by individuals seeking to join during the detailed design phase. The project team will vet additional advisors prior to Stage 2 process and as part of the Stage 2 submission.

• Are the benefits and challenges of employing any new microgrid technologies listed?

+ DER
    - Solar PV, CHP, natural gas emergency generators, and battery energy storage, which are all proven and mature technologies.

- Each facility DER will only be deployed if the facility is able to rationalize economic deployment when grid connected. For example, battery storage will only be deployed if it can be operated on a day-to-day basis.

+ Communications
    - RH Mesh wifi system is a proven technology and one which RHI has been building out in Red Hook for several years. The RH Mesh system is being expanded through funding by the NYC EDC Rise NY program, supporting the further development.
+ Microgrid controller and device controllers
    - Smarter Grid Solutions has 10 years of experience building and deploying some of the most advanced clean smart grid systems in the world. While deploying the community microgrid control solutions would require development work, Smarter Grid Solutions is confident that its control architecture and framework can meet the unique microgrid challenges as well as the sought after advanced functionality: e.g. synchronized islanding of multiple point-of-common-coupling (PCC); second-to-second microgrid control under intermittent solar PV generation; etc.

• Has the microgrid design addressed the permitting and/or special permissions required to construct this project? Are they unique or would they be required of any microgrid? Unique regulatory barriers exist for some ownership/operations options. These all relate to the ownership and operation of the microgrid relative to traditional utility and generator roles & responsibilities (jurisdiction monopoly; crossing a public right of way; qualifying facility status under PURPA; etc.). For a more detailed discussion, please refer to the discussion above on weaknesses and threats.

In terms of permits for DER, the all typical permitting for DER would be required (e.g. interconnection; DOB building permit; etc.), along with permits for the standby natural gas generators (e.g. Local Law 111).

• What is the proposed approach for developing, constructing and operating the microgrid system? As discussed in more detail below, grant funding is a critical component to develop the project. The approach to develop, construct and operate the project is therefore as follows:

+ Pre-NY Prize Stage 2 Detailed Design activities
    - Obtain firm commitment from Con Edison, NYCHA, IKEA and all other key partners.
    - Continue community outreach and determine ownership model.
    - Add legal counsel to the team.
+ Win NY Prize Stage 2 Detailed Design funding
    - Perform detailed design, finalize commercial ownership model, and ensure financial grade energy audits, deployment specifications, and RFP specifications for competitive solicitation.
    - Parallel support to microgrid facilities for DER detailed design, procurement and deployment (which are to be commercially viable as standalone projects through commercial PPAs). Examples include grid connected rooftop solar PV. Systems are to be deployed such that controls and communications are microgrid ready (e.g. open,

consensus-based communications and controls protocols that are extendable and scalable, i.e. DNP3, Modbus, etc.).

  - Apply for Stage 3 funding.

+ Win NY Prize Stage 3 Buildout funding
  - Perform competitive RFP for applicable microgrid systems (distribution lines and equipment, smart switchgear, controllers, etc.). Select winner and oversee construction, site testing, and commissioning of the microgrid.
  - Perform communications system buildout.
  - Commission microgrid with owner/operator.

+ Operate microgrid
  - Red Hook Community Microgrid governance and performance will be evaluated as a part of on-going administration to ensure microgrid meets community goals.

• How are benefits of the microgrid passed to the community? The key benefit of the microgrid is improved resilience, which is directly passed on to the community. Many of the benefits of improved resilience are hard to quantify, including an increased sense of security, more community involvement, capacity development, etc. Other benefits, such as avoided costs incurred during an emergency (costs of relocation, renting equipment, etc.), are more easily quantifiable but depend heavily on the frequency and nature of emergencies (e.g. flood, versus outage due to wind, versus Con Edison equipment failure due to old age).

Depending on the exact ownership model and associated fee structure, the community will most likely have to contribute to the ongoing operating costs. Upfront investments in DER is expected to be recovered through commercial PPAs whereas upfront investment in distribution lines and communication equipment is to be grant funded.

• Is a project operational scheme (including, but not limited to, technical, financial, transactional and decision making responsibilities) developed that will be used to ensure this system operates as expected? • How does the project owner plan to charge the purchasers of electricity services? How will the purchasers' use be metered? The project will use a Principles of Access (POA) approach such that the real-time safety and reliability of the microgrid will be managed against the POA control framework, which is specified and agreed to during the contracting. Real-time bi-directional power flow is measured and can be used to meter import and/or export of energy. The team has identified three different ownership options (see above). The exact ownership and associated fee structure will be determined during detailed design.

• Are there business/commercialization and replication plans appropriate for the type of project? NY Prize would offer the opportunity to test and evaluate the commercial & REV opportunities for community microgrids with advanced control functionality and many independent actors. Based on this experience, the proposed solution could be replicated to enhance resilience in other communities in New York state and beyond.

• How significant are the barriers to market entry for microgrid participants? Once in place, the microgrid control scheme is designed to be extendable and scalable. Market entry to additional participants would leverage the Principles of Access framework such that new participations would not adversely affect existing participants and could weigh their financial and power cost/benefits before entry.

• Does the proposer demonstrate a clear understanding of the steps required to overcome these barriers? Smarter Grid Solutions has proven commercial experience working with stakeholders and scaling solutions for enhanced clean energy interconnection, energy storage integration, additional support for power quality. It has all required capabilities to support and facilitate the future expansion of the microgrid.

In terms of microgrid functionality, Smarter Grid Solutions is carrying out advanced pilot and demonstration activities in REV for NYS, and elsewhere in North America. Examples include T&D deferral under high clean energy deployments, advanced energy storage analytics, autonomous demand response, and cutting-edge evaluation of DER-to-DER markets, alternative utility revenue and business models, LMP's, and smart grid as a service. All of these are new advanced market features/mechanisms, thus the need for NY Prize piloting to test market ideas.

6.2. Financial Viability

In terms of the RH-CMG facilities and their community resilient energy characterization, the Red Hook community emergency services microgrid market has been identified and characterized in the present report.

In terms of community microgrid commercial development, community microgrids need NY Prize and REV clarity to address the ownership and regulatory barriers. E.g. if the local utility does not own and operate the community microgrid, will the community microgrid be regulated like a utility? E.g. commercial arrangements for two independent facilities to contract for and share emergency power are still very new, thus need NY Prize to facilitate market sharing of ideas, experiences, lessons learned, etc.

• Does the microgrid design address the categories and relative magnitudes of the revenue streams and/or savings that will flow to the microgrid owner? Will they be fixed or variable? The microgrid's DER (with the exception of the generators) will produce energy throughout the year. Through commercial PPAs, this will allow DER owners to earn back their investment. Although this revenue stream is somewhat fluctuating, it will be relatively stable over the course of a year. Furthermore, during power outage, the availability of electricity will result in cost savings as users avoid incurring extra costs (renting emergency generators, fuel, etc.) and/or losing revenues. These cost savings are highly variable and depend on the frequency of power outages – see additional details in the Task 4 BCA deliverable.

• Does the microgrid system require other incentives? How does the timing of those incentives affect the development and deployment of this project? For the Red Hook microgrid to proceed, NY Prize funding will be required to cover the costs of critical infrastructure, including distribution lines and communication equipment. Furthermore, NY Sun funding will be required for the solar PV projects, and additional support from City and State stakeholders is needed to procure solar PPA's for public and non-profit microgrid facilities. On-going conversations with those stakeholders is already taking place. Furthermore, certain components of the microgrid have already secured grant funding, such as the Addabbo Health Center's generator via NYS GOSR funding.

• Does the microgrid design identify categories and relative magnitudes of the capital and operating costs that will be incurred by the microgrid owner? Will they be fixed or variable? The project's capital costs can be cut into three categories:

+ DER for which financing is to be secured: $26M (including the Cruise Terminal solar PV and Anaerobic Digester). Financing will be based on commercial PPA, combining debt and equity and potentially some subsidy to ensure overall financial viability of PPA.
+ Emergency generators and equipment that already have funding secured (including NYCHA's generators as well as the Addabbo health center's generator). These elements are critical for the project, but are provided "for free."
+ All additional microgrid infrastructure (batteries, other emergency generators, switches, controllers, transformers, distribution lines, etc.): $6M (or $17M if underground cables are utilized). This third category will need to be grant funded.

The project's operating costs are estimated to be $188k per year. These will need to be recovered from the microgrid's ultimate beneficiaries, direct users and/or the microgrid's owner, depending on the selected ownership model.

• Does the business model for this project ensure that it will be profitable? The microgrid's overall profitability depends on the selected ownership model. Assuming NY Prize funding for deployment, key profitability depends on mechanisms to recover recurring O&M costs. The exact ownership and associated fee structure will be determined in phase 2.

• Does the microgrid design include a description of a potential financing structure during development, construction and operation of the microgrid? The project's DERs will be individually financed through a combination of debt, equity and potentially subsidy, backed by a PPA. Over the life of the PPA, the debt financiers will be paid off and the equity investor will earn a reasonable return. The other components will be grant funded and do not have a particular financing structure. During operations, the project's operating costs will need to be recovered from the microgrid's ultimate beneficiaries, direct users and/or the microgrid's owner, depending on the selected ownership model.

• Is the financial viability of the microgrid dependent on investment credits and subsidies? DER development assumes existing incentives (NYSERDA, city, state, and federal) would be used for their deployment. Microgrid equipment (communications, controller, distribution equipment, switches) would require NY Prize funding.

• Is the operational viability of the microgrid dependent on special tariff arrangements? No. The conceptual design presented here is based on existing tariffs. Additional evaluation could take place during detailed design in order to work the utility to better value microgrid services, alternative revenue, and cost recovery opportunities.

• Does the financial viability of the microgrid depend on subsidies from the local utility or government or operating arrangements with customers served by the microgrid? Financial viability would change depending on the owner/operator options, as previously discussed.

6.3. Legal Viability

• Does the microgrid design address and comply with the legal terms/conditions/requirements necessary to develop and operate the microgrid? • Does the microgrid design describe any known, anticipated, or potential regulatory hurdles, as well as their implications that will need to be evaluated and resolved for this project to proceed? There are regulatory barriers for some of the ownership structure previously identified. Such key barriers include if the microgrid would need to be regulated as a utility, microgrid equipment crossing public right of ways, microgrid operation coordination with the local utility, etc. If such ownership structure is selected during detailed design as the preferred deployment framework, the microgrid will require DPS approval.

• If the project will include a contract between a municipality and a private party, has the project team considered all applicable State and municipal procurement and contracting laws and guidelines, and taken appropriate steps to ensure that such laws and guidelines have been or will be complied with? Not applicable.

• Does the microgrid design describe the potential project ownership structure and project team members that will have a stake in the ownership? • Has the project owner been identified? Please see discussion of the three possible ownership structures and the project team above.

• Does the project owner (or owners) own the site(s) where microgrid equipment/systems are to be installed? If not, what is the plan to secure access to that/those site(s)? Facility ownership was evaluated as part of the Stage 1 energy audits. Some of the facilities own their building (including Visitation, Mercy Home, and RH Justice Center) whereas other facilities are leased (including RHI). Facility stakeholder engagement is already on-going to ensure feasibility assessment includes commitment to proceed, including considering deployment at leased facilities. For leased sites, Stage 2 letters of commitment will include bilateral commitment from the host site owner and the facility operator participating in the microgrid.

• What is the approach to protecting the privacy rights of the microgrid customers, e.g with respect to meter data? The proposed microgrid's controls and communications signals meet the highest cybersecurity standards. Furthermore, microgrid administration will include data privacy governance.

7. OTHER CRITERIA

• To what extent does the proposer offer more than the minimum cost share? The project team anticipates meeting or exceeding the minimum cost share in order to successfully compete for Stage 2 funding.

• Are the qualifications and roles of the proposing team and subcontractors clearly defined and demonstrate the capability to successfully complete a Stage 2 Detailed Engineering Design, Financial and Business Plan Assessment? Friends of Brooklyn Community Board 6 and the Red Hook New York Rising Community Reconstruction Planning Committee have experience with community engagement and are trusted community entities. The other project partners have experience implementing innovative infrastructure projects that benefit communities. More specifically, Smarter Grid Solutions has ample experience in deploying massive levels of renewables on the grid and developing island microgrids, creating clean resilient power supply for communities in the US and the UK. IMG Rebel has advised public and private entities on project structuring and project finance across the US and internationally, in particular for public-private partnership projects. This includes renewable energy projects, toll roads, bridges and other pieces of critical infrastructure.

The team is still in the process of refining the project. As such, contractors and suppliers are not yet identified. Our approach for selecting the appropriate set of implementers will be as detailed below to ensure competent bidders and competitive pricing.

Systems contractors/suppliers:

+ DER: competitive private DER developers
+ Communication systems: Red Hook Initiative
+ Microgrid distribution equipment: as per ownership/operator options discussed previously
+ Microgrid controller: competitive solicitation to build and commission with microgrid owner/operator

The project team is actively evaluating the roles and responsibilities for Stage 2 and Stage 3 detailed design and the need, if any, for additional team members. The following currently apply:

+ Project team oversight/project management: Brooklyn Community Board 6 and Red Hook NY Rising Community Reconstruction Plan Committee.
+ Engineering lead: Smarter Grid Solutions
+ Financial lead: IMG Rebel
+ Systems:
    - DER: competitive private DER developers
    - Communication systems: Red Hook Initiative
    - Microgrid distribution equipment: as per ownership/operator options discussed previously
    - Microgrid controller: competitive solicitation to build and commission with microgrid owner/operator

• What are the potential utility distribution system benefits attributable to the projects planned operation relative to other competing projects in the utilities' service territory? What will be required of the utility to ensure this project creates value for the purchaser of the electricity and the community? The utility will need to provide Stage 2 detailed design support to ensure technically viable solutions are developed to use distribution assets within the microgrid. Furthermore, the utility will need to provide technical support to develop the contract specification for the Stage 3 buildout and subsequent operations for grid integration operation of the microgrid. If utility microgrid ownership/operation is applicable, then the utility will need to be involved throughout the detailed design and deployment.

• Does the proposer provide evidence that a broad coalition of public interests have teamed up in support of project development (e.g., Regional Economic Development Council(s), low- to- moderate income tenants associations, local/regional emergency management, etc.)? Friends of Brooklyn Community Board 6 and the Red Hook New York Rising Community Reconstruction Planning Committee have experience with community engagement and are trusted community entities. Additional and on-going outreach will include Red Hook community groups, NYCHA, Con Edison, NYPA, DCAS, Mayor's Office OLTP and also ORR, NYS GOSR, RISE:NYC vendors and facilities, NYS GOSR, and the Red Hook residents and businesses, as well as NYSERDA and NY DPS.

• Have letters of commitment for project support that is necessary to carrying out the work plan been secured from project participants? Does the applicant have a letter of commitment from the utility? Letters of commitment will be secured for all RH-CMG facilities as part of the Stage 2 application.

Engagement and discussion of key facility commitments already include NYCHA, IKEA, and GBX. The project team is currently in the process of seeking a letter of commitment from Con Edison.

• Does the microgrid project demonstrate advances in practices for project planning and development? Are there any unique or creative technology vendor commitments/ participation, ownership options, operating agreements with the local utility, plans to implement energy efficiency, leverage existing incentive programs, or propose new and innovative ones?

In terms of project planning and development as well as creative technologies/partnerships, Smarter Grid Solutions will leverage its experience working with utilities to perform modeling and simulation of the microgrid distribution system in order to maximize value of the system. This would include maximizing clean energy interconnection via real-time ANM control technologies, as well as maximizing use of existing distribution equipment.

In terms of financial options, IMG Rebel will apply its unique experience in advising communities in innovative financial solutions – helping Red Hook bridge the gap between their infrastructure needs and financial resources by focusing on developing public-private partnerships (P3s), innovative capital financing, project delivery strategies, efficient management, and performance improvement.

While private ownership of the RH-CMG would be innovative given its scale and advanced functionality, significant legal/regulatory barriers would need to be addressed. At the same time, Con Edison ownership the microgrid would also be innovative in terms of working with the community to harden emergency services energy resiliency and creating a microgrid that would support REV, as discussed below.

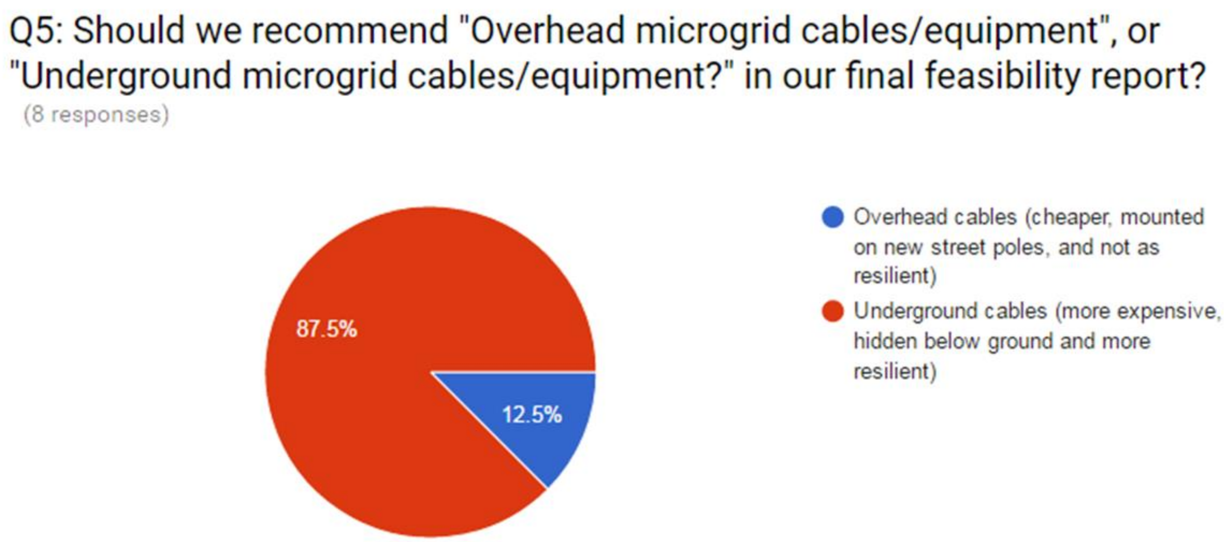
• Does the microgrid design increase the amount of actionable information available to customers—providing a platform for customers to be able to interact with the grid in ways that maximize its value?
The feasibility study used generic ANM technologies for the microgrid controller capabilities that included considering integration with the local area power network that will enable real-time monitoring and control. The ANM microgrid application will therefore differentiate itself by its ability to integrate with, and if required be coordinated by, existing utility control systems, in particular distribution automation systems. This functionality makes the microgrid capable of interacting with these systems to reduce outage times and therefore maximize the reliability of the area power system as a whole, while minimizing the duration of islanded operation.

• Does it serve a low to moderate income area or does it serve an urgent need for the community? Yes. The RH-CMG would support emergency services for all of Red Hook, which includes 6000+ LMI residents (NYCHA and various LMI residential housing throughout Red Hook – e.g. the RH-CMG facilities include four multi-tenant LMI facilities representing 76 residential units).

As of today, Red Hook has a lower electric reliability compared to most of New York City (due to the neighborhood's low elevation, waterfront location, the vulnerability of the existing overhead system and its configuration design). This project would bring emergency power to a neighborhood that is highly vulnerable to a wide variety of climate change impacts – including storm outages, heat, inland flooding, heavy wind storms - hence making it more resilient. In the case of an outage, the microgrid will switch to islanding mode, allowing it to provide electricity to critical and some non-critical facilities for an unlimited period of time (assuming the availability of natural gas). The microgrid is designed for a 72-hour period (and indefinitely with sufficient natural gas fuel), which is identified in the Red Hook

Community Emergency Preparedness Plan, also identified by OEM as the period of time in which a community must expect to be self-reliant, until city agencies can mobilize.

As per the RH-CMG conceptual design, it is assumed that the microgrid will need to use overhead distribution lines and equipment due to how funding for underground cabling is beyond that available from NY Prize. Undergrounding the cables would make the RH-CMG system even more resilient to extreme weather, so we surveyed our facility stakeholders for their preference, as found below.



The majority RH-CMG facility stakeholder therefore prefer underground cabling, thus our Project Team takeaway is the need to continue to work with the City and Con Edison on options for hardening and undergrounding Red Hook's existing distribution system, along with options for building out the RH-CMG via undergrounding cables and equipment if sufficient funding is available.

• Is the area being served in a presidentially declared county from a 2011-2013 disaster? Yes. Red Hook was severely impacted by Hurricane Sandy and is within Kings County which is a designated county (EM-3351[17]).

• Is it clear how the microgrid will assist in long term recovery of the area? Yes – as per the emergency preparedness plan identified in the Red Hook NY Rising Community Reconstruction Plan (RH-NYR-CRP)[18] report.

• To what extent does the microgrid design satisfy or support the Reforming the Energy Vision (REV) objectives? The RH-CMG project team supports the REV work underway to demonstrate increased customer engagement and participation in modernizing the electric grid. The project team therefore recognizes how community microgrids test the foundational infrastructure of a modernized grid, such as:

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17 https://www.fema.gov/disaster/3351. Please note that given Red Hook's waterfront location, additional emergency designations also apply: e.g. Hurricane Irene, etc.

18 http://www.stormrecovery.ny.gov/sites/default/files/crp/community/documents/redhook_nyrcr_plan_73mb_0.pdf

+ Targeted smart grid upgrades: building cost effective and scalable monitoring and control for improved utilization of area power networks.
+ Transactive partnerships: multi-facility and multi-customer microgrids require customer-to-customer and likewise customer-to-utility bidirectional flow of power and information. This transactive exchange of energy, status, and pricing information will be tested through community microgrid applications for DER-to-DER markets.

Have the microgrid technologies (including but limited to: generation, storage, controls) been used or demonstrated before? If yes, describe the circumstances and lessons learned. Smarter Grid Solutions has proven commercial integration and operation for controlling 26 different types of DER and with a variety of distribution grid assets for bidirectional power flow and interfaced for supporting power quality (Volt/VAR/frequency/etc.).

Lessons learned include (1) energy storage is not required to deploy with solar and wind energy when real-time control systems are incorporated within the design, but when included the control system enables the real-time coordination of storage with clean energy to optimize facility energy and provide grid services, (2) the on-going need for synchronization and industry wide open, consensus based standards for interoperability (e.g. OpenADR, SunSpec, OCPP, etc.), (3) on-going need for grid modernization standards that include community microgrid integration (e.g. IEEE 1547; IEEE 2030;) – especially for advanced functionality like low voltage ride through, DER providing Volt/VAR, and operations under microgrid islanded and transitioning model. In terms of control equipment, there is an on-going need for NY Prize style funding to further pilot advanced control architectures – e.g. peer-to-peer distributed control systems that can scale to thousands, even millions of devices.

8. BENEFIT-COST ANALYSIS METHODOLOGY, ASSUMPTIONS, AND DETAILED RESULTS

The following methodology and assumptions were applied by Industrial Economics in creating the baseline benefits-costs analysis (BCA).

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

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

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

This analysis relies on an Excel-based spreadsheet model developed for NYSERDA to analyze the costs and benefits of developing microgrids in New York State. The model evaluates the economic viability of a microgrid based on the user's specification of project costs, the project's design and operating characteristics, and the facilities and services the project is designed to support. 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.[19] 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.[20]

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

[20] 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

8.1. Fixed Costs

The BCA relies on information provided by Smarter Grid Solutions and IMG Rebel to estimate the fixed costs of developing the microgrid. The project team's best estimate of initial design and planning costs is approximately $1.3 million. The present value of the project's capital costs is estimated at approximately $33.2 million, including costs associated with a microgrid controller; DER device controllers; circuit breakers; integration with Con Edison enterprise systems; five overhead distribution lines; two transformers; and the new DERs.[21,22] Operation and maintenance (O&M) of the entire system would be provided under fixed price service agreements, at an estimated annual cost of $1.2 million.[23] The present value of these O&M costs over a 20-year operating period is approximately $13.0 million.

8.2. Variable Costs

One variable cost associated with the proposed project is the cost of natural gas to fuel operation of the proposed gas-fired combined heat and power units. To characterize these costs, the BCA relies on estimates of fuel consumption estimated by the project team and projections of fuel costs from New York's State Energy Plan (SEP), adjusted to reflect recent market prices.[24] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $71,000.

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 estimated 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

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beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

[21] The required distribution lines could be installed overhead or underground. The conductors that would be replaced are overhead; therefore, the analysis assumes that the new conductors would be installed overhead due the substantially higher cost for undergrounding and also due to limited NY Prize funds. Underground installation would increase the project's capital costs by $11.3 million (present value over 20 years).

[22] The project team expects the RH-CMG to be integrated into an ongoing NYCHA microgrid effort. The costs reported for the RH-CMG project assume that it would be linked to the NYCHA system's infrastructure. It is important to note, however, that the RH-CMG project would be designed to provide a fully synchronized transition to and from island mode (beyond what NYCHA is seeking). This advanced functionality would require a microgrid controller, as well as distributed device controllers and smart switches. The cost of these components is included in the RH-CMG project's estimated capital costs.

[23] The project team anticipates that the proposed anaerobic digester at GBX would be operated by a third party under a power purchase agreement (PPA). The team provided information on the terms of this agreement as a basis for characterizing the costs associated with the digester (including both its fixed and variable costs). At $0.17/kWh, total payments under the PPA would be approximately $2.1 million annually. The analysis includes these costs in its estimate of the project's fixed O&M costs. Note that payments under the PPA would likely be designed to cover the third party's financing costs, and to provide a return on its investment. If this is the case, annual payments under the PPA will likely overstate the true social cost of the anaerobic digester.

[24] 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.

attributable to emissions from the new natural gas generator are estimated at approximately $246,000 annually. The majority of these damages are attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $3.8 million.

8.3. 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 Red Hook's proposed microgrid, the primary source of cost savings would be a reduction in demand for electricity from bulk energy suppliers, with a resulting reduction in generating costs. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $10.9 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. The reduction in demand for electricity from bulk energy suppliers, coupled with a reduction in demand for heating fuel, would also avoid emissions of CO_2, SO_2, NO_x, and particulate matter, yielding emissions allowance cost savings with a present value of approximately $6,000 and avoided emissions damages with a present value of approximately $8.9 million.[25]

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.[26] Based on available capacity for backup natural gas generators and battery units, the project team estimates the project's impact on demand for generating capacity to be approximately 3.3 MW per year. Based on this figure, the BCA estimates the present value of the project's generating capacity benefits to be approximately $5.5 million over a 20-year operating period. Distribution capacity benefits are expected to be approximately 3.8 MW per year (considering available capacity for solar and wind resources); the BCA estimates the present value of this benefit to be approximately $9.5 million.

8.4. 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 $110,000 per year, with a present value of approximately $1.2 million over a 20-year operating period. This estimate is calculated using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[27]

+ System Average Interruption Frequency Index (SAIFI) – 0.884 events per year.

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

[26] 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.

[27] www.icecalculator.com.

+ Customer Average Interruption Duration Index (CAIDI) – 117.0 minutes.[28]

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 estimated 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.[29] 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.

8.5. Power Quality Benefits

The power quality benefits of a microgrid may include reductions in the frequency of voltage sags and swells or reductions in the frequency of momentary outages (i.e., outages of less than five minutes, which are not captured in the reliability indices described above). The analysis of power quality benefits relies on the project team's best estimate of the number of power quality events that development of the microgrid would avoid each year. From Con Edison, the project team estimates that on average one such event would be avoided annually. The model estimates the present value of this benefit to be approximately $0.6 million over a 20-year operating period.

8.6. 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 – of which Red Hook has been and is highly vulnerable to these events. 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.[30,31]

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[28] The analysis is based on site-specific SAIFI and CAIDI values reported by Con Edison to the project team.

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

[30] 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.

[31] 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

As noted above, Red Hook's microgrid project would serve a number of residential and commercial facilities, including three schools and three manufacturing facilities. At present only two facilities, IKEA and Value Added farm, are equipped with backup power sources. Operation of the backup diesel generator at IKEA costs approximately $2,500 per day. No additional costs are associated with operating the wind, solar, and battery units at the farm. Most of the remaining facilities could maintain service by bringing in portable generators. The cost of installing a portable generator is estimated at $600 per facility; daily operating costs are estimated at $1,000 per facility, with additional costs for fuel. In the absence of backup power – i.e., if the backup generator failed and no replacement was available – all facilities would experience a loss in service capabilities of between 90 and 100 percent (see Table 4). Four facilities (Tamco, the RH Public Library, GBX, and the street lights) are considered non-critical community emergency loads and would not rent backup generators in order to maintain service during an outage; as a result, any outage would lead to a complete loss of service at these facilities.

The assessment of Scenario 2 makes the following assumptions to characterize the impacts of a major power outage in the absence of a microgrid:

+ IKEA and the farm would rely on their existing backup generators, continuing to provide 80 percent and 100 percent of service capabilities, respectively. If the backup generators fail, the facilities would experience a total loss of service.
+ The remaining facilities (with the exception of Tamco, RH Public Library, GBX, and the street lights) would rely on portable generators, experiencing either zero or 80 percent loss in service capabilities while the units are in operation. If the portable generators fail, the facilities would experience a loss in service between 90 and 100 percent.
+ If backup power is not available at Mercy Home, evacuation of the facility would likely become necessary. Evacuation would lead to an additional cost of approximately $2,000.
+ Tamco, RH Public Library, GBX, and the street lights would in all cases experience a complete loss in service.
+ In all cases, the supply of fuel necessary to operate backup generators would be maintained indefinitely.
+ At each facility, there is a 15 percent chance that the backup generator would fail.

The economic consequences of a major power outage also depend on the estimated value of the services the facilities of interest provide. The analysis varies by facility, as described below.

+ For residential facilities (Mercy Home, Carroll Gardens, and the three co-ops), the analysis assumes that all residents would be left without power; the impact is valued as a social welfare loss.
+ For the facilities that would function as a shelter during an outage (the RH Justice Center, the Miccio Center, and the three schools), the value of service is estimated, collectively, at approximately $35,000 per day. This estimate is based on standard Red Cross rates for the cost

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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.

of providing food and shelter, coupled with an estimate of the number of people (690) that the facilities could accommodate in the event of an emergency.[32,33]

+ For the remaining facilities, the analysis is based on the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator:[34]
+ For IKEA and the community farm, the value of service is estimated at approximately $206,000 per day, assuming 24 hours of microgrid demand during an outage;
+ For Addobbo Health Clinic, the Visitation Church Rectory, and the RH Public Library, the value of service is estimated at approximately $77,000 per day, assuming 24 hours of microgrid demand during an outage;[35]
+ For RHI, Tamco, Linda Tool & Die, and GBX, the value of service is estimated at approximately $646,000 per day, assuming 18 hours of microgrid demand during an outage;[36]
+ For IKEA and the farm, the value of service is estimated at approximately $48,000 per day, assuming eight hours of microgrid demand during an outage.

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 $746,000 per day.

8.7. Summary

Figure 10 and Table 4 present the results of the BCA for Scenario 2 assuming all of Red Hook has an overhead radial system.[4] The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 1.8 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

[32] The number of people supported by a shelter is based on FEMA guidance stating that 40 square feet per person is usually necessary for evacuation shelters; see pg. 25, https://www.fema.gov/pdf/about/odic/fnss_guidance.pdf.
[33] http://www.redcross.org/images/MEDIA_CustomProductCatalog/m30240126_FY14FundraisingDollarHandles.pdf
[34] http://icecalculator.com/
[35] In addition to the value of service estimated for the RH Public Library, this facility can provide computer and communication access for emergency services. The value of these services is not explicitly accounted for in our estimate; therefore, the BCA may understate the benefits of maintaining power at this facility.

[36] In addition to the value of service estimated for RHI, this facility can provide access to Wi-Fi for the community and act as a meeting, organizing, and communications space. The value of these services is not explicitly accounted for in our estimate; therefore the BCA may understate the benefits of maintaining power at this facility.

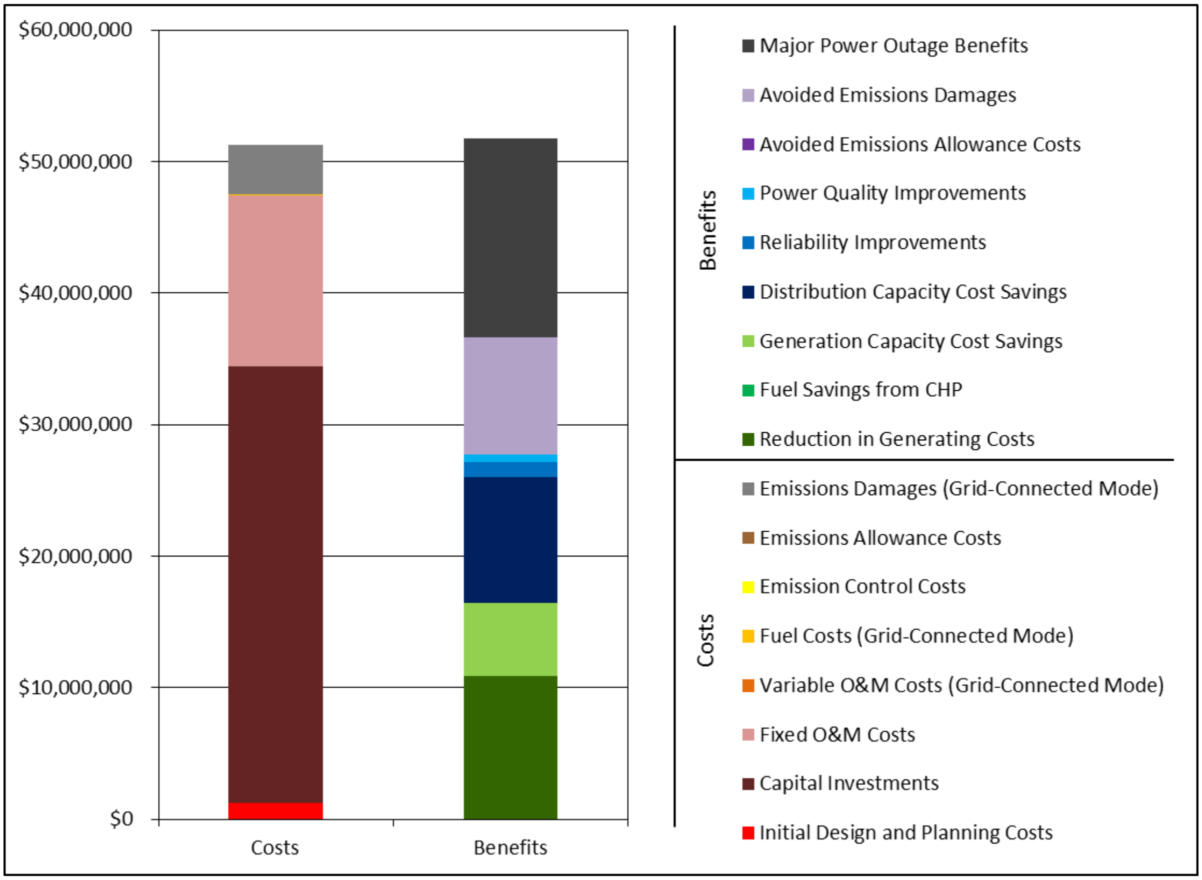

Figure 10: Present Value Results, Scenario 2 (Major Power Outages Averaging 1.8 Days/Year; 7 Percent Discount Rate)

Table 4: Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 1.8 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$1,250,000	$110,000
Capital Investments	$33,200,000	$2,860,000
Fixed O&M	$13,000,000	$1,150,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$71,000	$6,260
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,760,000	$246,000
Total Costs	**$51,300,000**	
Benefits		
Reduction in Generating Costs	$10,900,000	$960,000
Fuel Savings from CHP	$6,820	$601
Generation Capacity Cost Savings	$5,530,000	$488,000
Distribution Capacity Cost Savings	$9,540,000	$842,000
Reliability Improvements	$1,200,000	$106,000
Power Quality Improvements	$572,000	$50,500
Avoided Emissions Allowance Costs	$5,980	$527
Avoided Emissions Damages	$8,890,000	$580,000
Major Power Outage Benefits	$15,200,000	$1,340,000
Total Benefits	**$51,800,000**	
Net Benefits	**$508,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.7%**	

8.8. Appendix CBA Figures and Tables

For completeness, the Scenario 1 and Scenario 2 figures and tables for all RHCMG scenarios (radial and network grids) are included below.

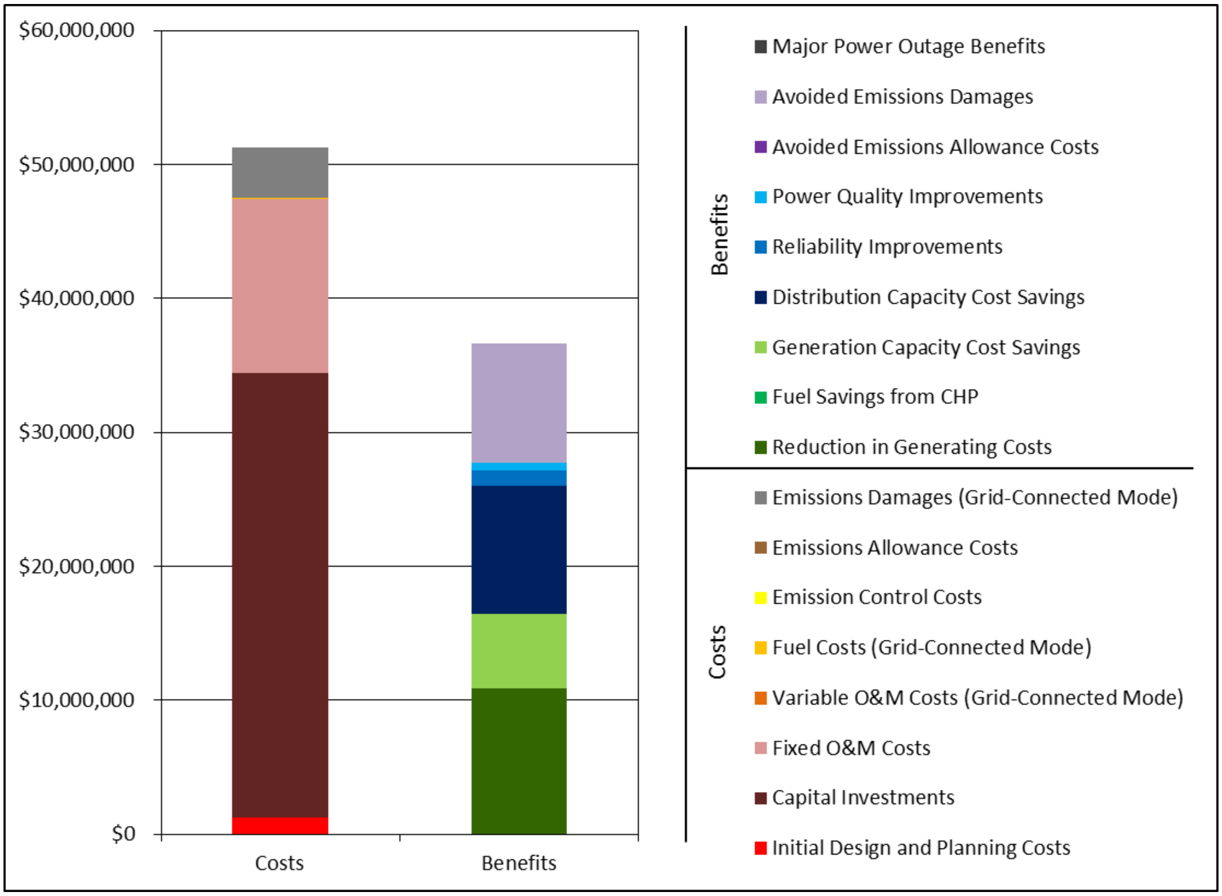

Figure 11: Present Value Results, Scenario 1 Radial Grid (No Major Power Outages; 7 Percent Discount Rate)

Table 5: Detailed BCA Results, Scenario 1 Radial Grid (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	$1,250,000	$110,000
Capital Investments	$33,200,000	$2,860,000
Fixed O&M	$13,000,000	$1,150,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$71,000	$6,260
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,760,000	$246,000
Total Costs	**$51,300,000**	
Benefits		
Reduction in Generating Costs	$10,900,000	$960,000
Fuel Savings from CHP	$6,820	$601
Generation Capacity Cost Savings	$5,530,000	$488,000
Distribution Capacity Cost Savings	$9,540,000	$842,000
Reliability Improvements	$1,200,000	$106,000
Power Quality Improvements	$572,000	$50,500
Avoided Emissions Allowance Costs	$5,980	$527
Avoided Emissions Damages	$8,890,000	$580,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$36,600,000**	
Net Benefits	**-$14,7000,000**	
Benefit/Cost Ratio	**0.7**	
Internal Rate of Return	**0.4%**	

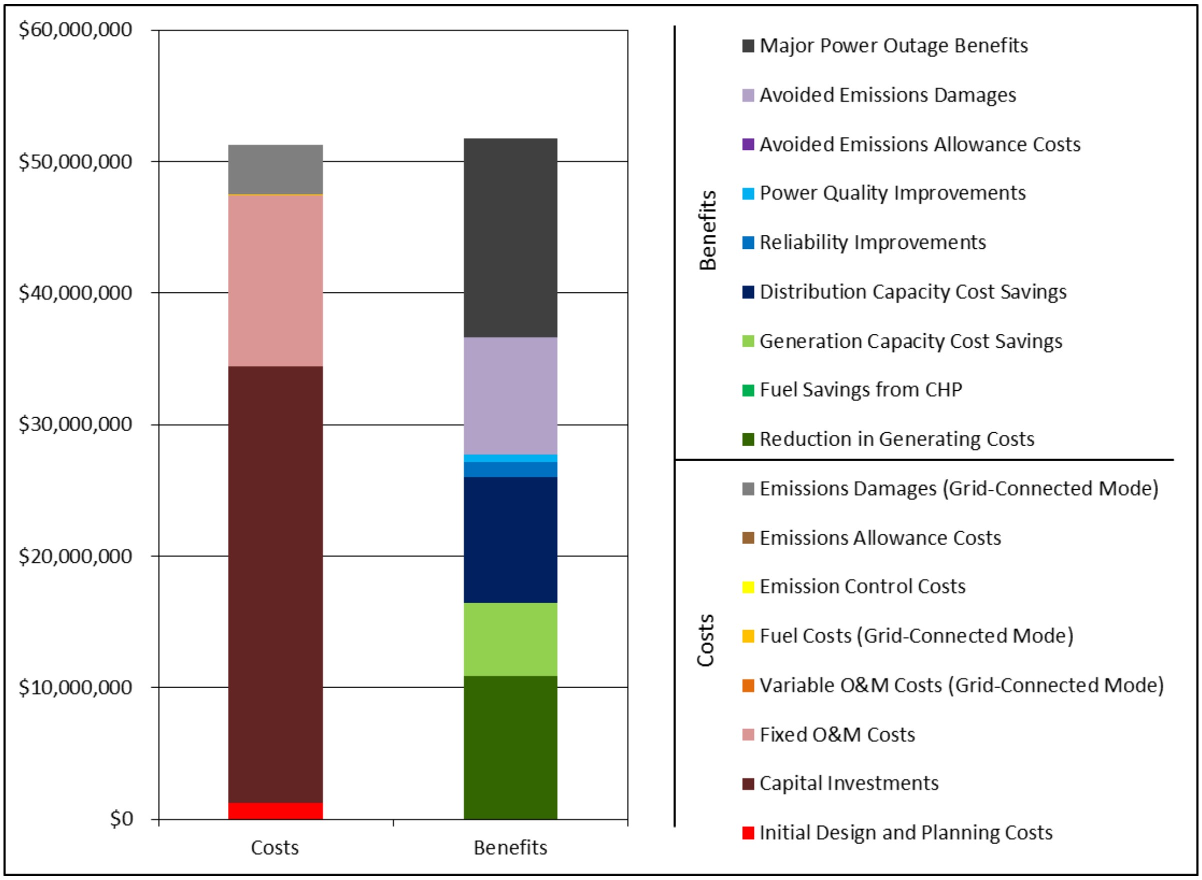

Figure 12: Present Value Results, Scenario 2 Radial Grid (Major Power Outages Averaging 1.8 Days/Year; 7 Percent Discount Rate)

Table 6: Detailed BCA Results, Scenario 2 Radial Grid (Major Power Outages Averaging 1.8 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$1,250,000	$110,000
Capital Investments	$33,200,000	$2,860,000
Fixed O&M	$13,000,000	$1,150,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$71,000	$6,260
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,760,000	$246,000
Total Costs	**$51,300,000**	
Benefits		
Reduction in Generating Costs	$10,900,000	$960,000
Fuel Savings from CHP	$6,820	$601
Generation Capacity Cost Savings	$5,530,000	$488,000
Distribution Capacity Cost Savings	$9,540,000	$842,000
Reliability Improvements	$1,200,000	$106,000
Power Quality Improvements	$572,000	$50,500
Avoided Emissions Allowance Costs	$5,980	$527
Avoided Emissions Damages	$8,890,000	$580,000
Major Power Outage Benefits	$15,200,000	$1,340,000
Total Benefits	**$51,800,000**	
Net Benefits	**$508,000**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.7%**	

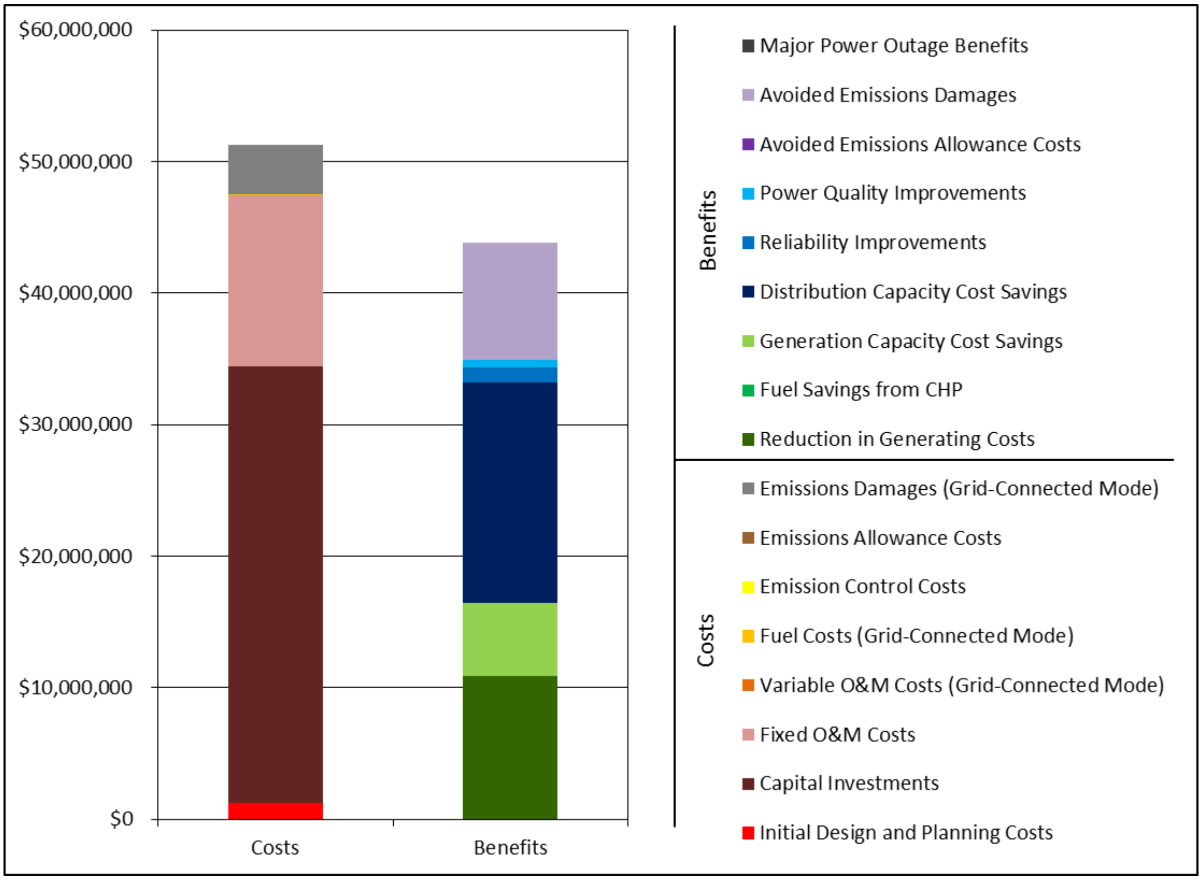

Figure 13: Present Value Results, Scenario 1 Secondary Network Grid (No Major Power Outages; 7 Percent Discount Rate)

Table 7: Detailed BCA Results, Scenario 2 Secondary Network Grid (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	$1,250,000	$110,000
Capital Investments	$33,200,000	$2,860,000
Fixed O&M	$13,000,000	$1,150,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$71,000	$6,260
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,760,000	$246,000
Total Costs	**$51,300,000**	**$4,370,000**
Benefits		
Reduction in Generating Costs	$10,900,000	$960,000
Fuel Savings from CHP	$6,820	$601
Generation Capacity Cost Savings	$5,530,000	$488,000
Distribution Capacity Cost Savings	$16,700,000	$1,480,000
Reliability Improvements	$1,200,000	$106,000
Power Quality Improvements	$572,000	$50,500
Avoided Emissions Allowance Costs	$5,980	$527
Avoided Emissions Damages	$8,890,000	$580,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$43,800,000**	**$3,660,000**
Net Benefits	**-$7,450,000**	**-$710,000**
Benefit/Cost Ratio	**0.9**	
Internal Rate of Return	**3.5%**	

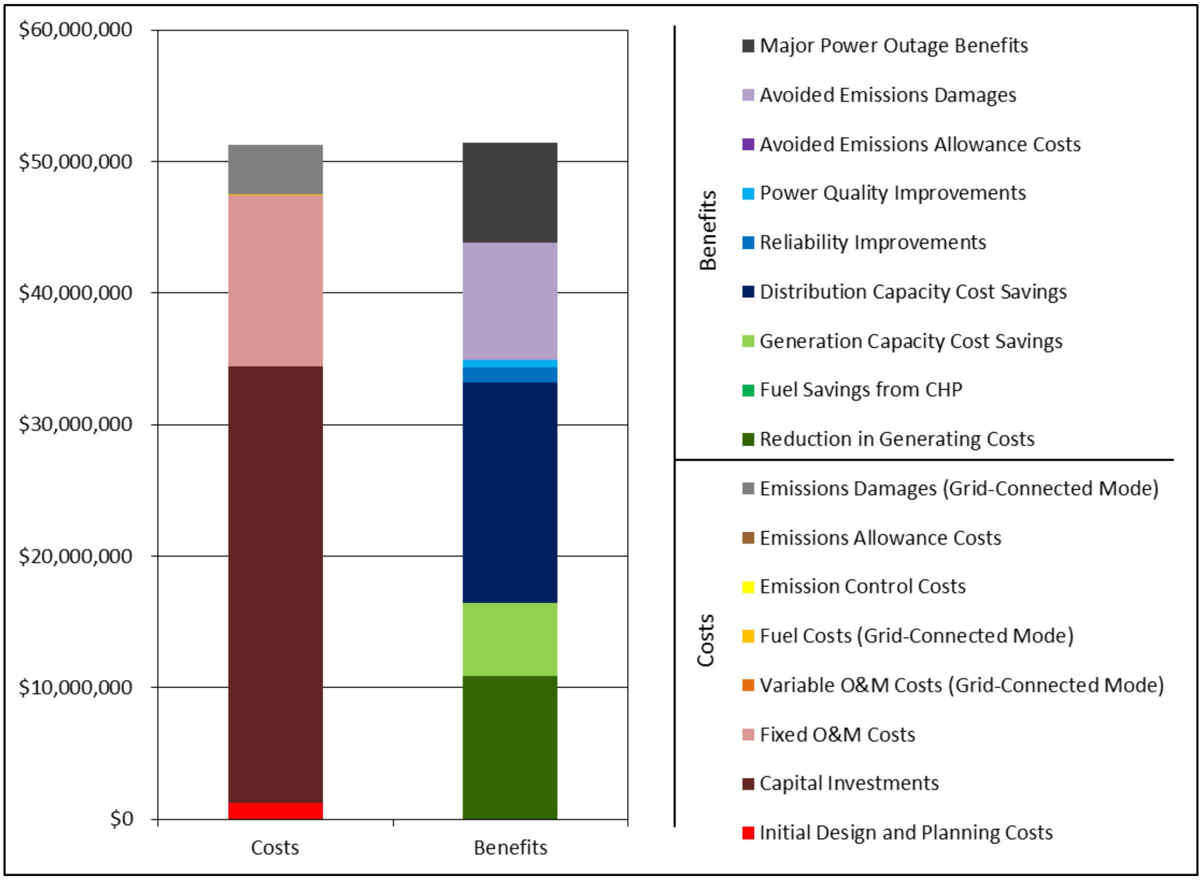

Figure 14: Present Value Results, Scenario 2 Secondary Network Grid (Major Power Outages Averaging 0.9 Days/Year; 7 Percent Discount Rate)

Table 8: Detailed BCA Results, Scenario 2 Secondary Network Grid (Major Power Outages Averaging 0.9 Days/Year; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$1,250,000	$110,000
Capital Investments	$33,200,000	$2,860,000
Fixed O&M	$13,000,000	$1,150,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$71,000	$6,260
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$3,760,000	$246,000
Total Costs	**$51,300,000**	**$4,370,000**
Benefits		
Reduction in Generating Costs	$10,900,000	$960,000
Fuel Savings from CHP	$6,820	$601
Generation Capacity Cost Savings	$5,530,000	$488,000
Distribution Capacity Cost Savings	$16,700,000	$1,480,000
Reliability Improvements	$1,200,000	$106,000
Power Quality Improvements	$572,000	$50,500
Avoided Emissions Allowance Costs	$5,980	$527
Avoided Emissions Damages	$8,890,000	$580,000
Major Power Outage Benefits	$7,620,000	$673,000
Total Benefits	**$51,500,000**	**$4,340,000**
Net Benefits	**$172,000**	**-$37,300**
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.5%**	