Energy Research and Development Division

FINAL PROJECT REPORT

Santa Monica City Yards Advanced Energy District

California Energy Commission

Gavin Newsom, Governor

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PREFACE

The California Energy Commission's Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation and bring ideas from the lab to the marketplace. The California Energy Commission and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The Energy Commission is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Santa Monica City Yards Advanced Energy District is the final report for the Santa Monica City Yards project (Contract Number EPC-16-008) conducted by Arup North America, Ltd. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's research website (www.energy.ca.gov/research/) or contact the Energy Commission at 916-327-1551.

ABSTRACT

The Santa Monica City Yards Advanced Energy District project is a microgrid feasibility study evaluating the options for a renewable and self-sustaining microgrid for the redeveloped City Yards facility, which serves most of the city's public works operations. The microgrid is expected to be a state-of-the-art electric-power-generating storage and management system intended to satisfy the following goals:

- Approach zero net energy use during normal operation.
- Offer a low-carbon energy solution to the city.
- Be capable of continuing to operate during utility company power outages ("island mode").
- Allow for continuous operation for at least two days at full load in island mode.
- Be expandable.
- Achieve these goals in the most cost-effective way.

This project also considers two microgrid expansion scenarios to the adjacent future masterplan for Bergamot Station arts district and the existing Metro maintenance facilities.

The analysis conducted has determined solar photovoltaic and electrical energy storage to be the most suitable distributed energy resources. For the microgrid expansion scenarios, where the average load and energy consumption are substantially increased, biogas-fueled fuel cells were included to satisfy the aggregated demand.

For the base scenario, which integrates only the City Yards, the microgrid was optimized with 1.2 megawatts of solar photovoltaic and 7.2 megawatt hours of electrical energy storage. With this capacity, the system can provide almost 100 percent of the electrical demand, while satisfying the backup power requirements.

The project analyzed two cost tests to estimate the benefits for the City of Santa Monica (participant cost test) and the State of California (total resource cost test). The results indicate that more dynamic utility rates and incentives are required to bridge the gap between project costs and system benefits. The microgrid system provided $4.6 million net benefits in a 25-year period.

Keywords: Santa Monica, microgrid, advanced energy community, resilience, distributed energy resource

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EXECUTIVE SUMMARY

Introduction

In 2016, the City of Santa Monica received about $1,500,000 to develop innovative and replicable approaches for accelerating advanced energy communities. Advanced energy communities use an innovative power system, on a district-wide scale, to reduce operational costs while enhancing its ability to serve customers and lessen the need for capital investment into the existing utility network.

Santa Monica has a goal to become carbon neutral by 2050 and increasing localized renewable energy production is a key step to achieving that goal. Santa Monica will reduce emissions by using 100 percent renewable energy to meet its electricity needs, increasing local use of renewable energy, like solar, and switching from natural gas powered loads to electric. Recently, Santa Monica joined the Clean Power Alliance of Southern California, the largest community choice aggregator in California. Participation in a community choice aggregation program allows the city to buy and/or generate electricity for residents and businesses within their areas, which lowers rates and increases renewable energy use when compared to traditional utilities.

Microgrids

Local governments and communities must continue to expand the use of local energy resources.. Microgrids facilitate this expansion in valuable ways, by using renewable generation, storage and efficiency measures in a relatively small area to serve multiple users and provide electricity independent from the traditional electric grid. If necessary, they can operate disconnected from the larger electrical grid. This can provide additional resilience benefits to communities that are concerned about power outages due to climate related and natural disasters, such as heat waves, wildfires or earthquakes.

Microgrids traditionally serve only one entity and interconnect through one utility meter, however, local governments can play a role in expanding microgrids and their benefits to multiple beneficiaries. This expansion will aid in accomplishing local sustainability goals and prerogatives that serve and protect the community. Local governments also have jurisdiction in the public right of way and the authority to influence private development, making them a natural fit to implement and support the installation of microgrids. Additionally, local governments can partner with their community choice aggregation providers to develop local programs that lower rates and support community microgrids or other advanced energy projects.

By increasing local renewable generation of electricity, providing electric vehicle charging and decreasing the demand of electricity, microgrids can reduce the need for costly upgrades to the traditional electricity network. Existing microgrid installations in the United States are located at university campuses, military bases, and prisons, where the resilience requirements justify the cost of the installation. Lack of awareness, upfront costs, regulatory ambiguity, and a perception of risk are current barriers to the implementation of microgrids.

This report provides an overview of the Phase I project activities and results in planning and designing a microgrid that can transform the Santa Monica City Yards into an advanced energy community.

Project Purpose

The City Yards is a 14.7-acre site used as a base for the City of Santa Monica's maintenance operations, which includes 16 buildings and structures of various ages and conditions. The operations carried out at this facility include non-critical uses, such as fleet and street maintenance, as well as some essential city operations, such as traffic control and water/wastewater operations.

It is adjacent to Gandara Park, the privately-owned Mountain View Mobile Inn (mobile home park), the Metro facilities, and the city-owned Bergamot Arts Center, which is planned for private redevelopment. The City Yards site is scheduled to be fully redeveloped over the next 10 years to accommodate the incremental growth and changes of city services and operations. It is also important to note that the site is located partly over a former landfill, its methane emissions are monitored., and the methane is burned to limit health and environmental impacts.

The main objectives of this project are to:

- Provide a feasibility analysis for a modern, resilient, and economical source of electrical power that functions during man-made or natural disasters.
- Study incorporating renewable energy technologies in the City Yards to the greatest extent possible, with a potential goal of zero net energy consumption.
- Ensure that the proposed project implementation approach is consistent with prudent project-financing methods, reducing the financial burden for the city.
- Analyze potential benefits and value to the surrounding neighborhoods and citizens.

The activities carried out in the Santa Monica City Yards are common to most cities, which makes his project a relevant and replicable model for other California cities. The methods used to increase resilience while reducing greenhouse gas emissions showcase a variety of viable and attractive advanced energy community concepts, while reducing the environmental footprint of the state of California.

Project Process

First, the team developed the use case framework, which summarized the city's requirements for the project site. The project team then consolidated this input into the Owner's Project Requirements document, which defines the microgrid's functional, technical, and operational requirements.

The team analyzed potential renewable energy (such as solar) and electric energy storage technologies (such as batteries) to satisfy the electrical demand of the City Yards and adjacent sites, while optimizing the project’s overall cost for a 25-year timespan. The team created and simulated several models using a microgrid analysis and design software. The analysis assumed normal operation — when the microgrid is connected to the macro grid — as well as operation off the grid in islanding mode due to an outage.

The team examined the cost-effectiveness of the system under multiple rates, scales of implementation (such as a single user or multiuser), and other sensitivities, such as distribution voltage or electric vehicle growth scenarios.

The project team further analyzed the cost-effectiveness for each scenario from the perspective of the city, the State of California, and other utility ratepayers.

Project Results

While the technical analysis and experts recommended a smaller solar and battery system for an optimized microgrid, various city stakeholders found greater value in a larger system (the design scenario) that provided 100 percent resilience of all systems at a nominal cost compared to the overall project and microgrid investment. Through the stakeholder engagement activities, city participants voted for the following attributes for the City Yards microgrid:

1. Microgrid owned and operated by the City of Santa Monica.
2. Ability to switch off non-essential appliances (such as. air conditioning), to maintain other essential equipment (for example traffic signals) in case of emergency (also known as load shedding).
3. Increased resilience for essential equipment, such as traffic signaling or water operations.
4. Ability to operate off-grid for 2 to 10 days.
5. Showcase the benefits of the microgrid for the city, such as cost savings or greenhouse gas (GHG) emission reductions and enable transparency of the city’s operations to the public.

These attributes and others are included in the Owner’s Project Requirements, which has been used as a basis for the analysis of the City Yards microgrid.

The analysis of potential local energy resources indicated that, for a microgrid that just serves the City Yards, the only recommended energy resources were solar photovoltaic (PV), electric storage, and fuel cells. This analysis considered the expected electrical consumption of the site, the project location, and other project characteristics such as the thermal demand.

The project team optimized the microgrid design for three main scenarios:

- **Scenario 1** includes only the renovated City Yards. Within this scenario, additional subcases optimize seven levels of backup capacity.
- **Scenario 2** expands the microgrid to include the Bergamot Art District, accounting for likely development plans.
- **Scenario 3** expands the microgrid to include the redeveloped Bergamot Art District, and the Los Angeles Metro operation and maintenance facility.

Table 1 shows the selected and optimized technology sizes for each scenario.

Table 1: Optimal Distributed Energy Resource Systems, Scenarios 1 to 3

Scenarios for analysis		Scenario 1	Scenario 2	Scenario 3
Area covered	City Yards	●	●	●
	Bergamot District		●	●
	Metro			●
Solar PV (kW)*		1,200	1,200	1,200
Electrical storage (kWh)*		7,200	7,200	7,200
Fuel cell (kW)		Not adopted	400	800

Source: Arup North America Ltd

The project team then modeled the microgrid scenarios to evaluate their cost-effectiveness from the perspective of the city and the State of California.

Electric energy storage systems (for example, batteries) are very flexible and can provide more benefits to the system. However, more dynamic rates that reflect the benefits of these types of systems are necessary to unlock the full potential of energy storage When the cost-effectiveness calculations are performed assuming the microgrid can monetize all its services, the microgrid system provides $4.6 million net benefits under Scenario 1 over 25 years.

If City Yards is to electrify its commercial vehicle fleet, the most cost-effective charging technology to use is managed-charging, where the utility could remotely control vehicle charging to better correspond to the demands of the grid. The additional benefit provided by using the fleet batteries to power City Yards (vehicle to grid power) cannot be unlocked given the misalignment of the existing rate periods and the fleet driving patterns.

The microgrid is cost-effective when additional load from Bergamot Art District and the Metro maintenance facility is added.

In relation to the procurement options analyzed, third-party leasing was the most effective financing option compared to city debt financing and a hybrid option, which combines a power purchase agreement for the solar PV and city debt financing for the rest of the microgrid equipment. The city can obtain investment tax credit benefits only through a third-party financing or a power purchase agreement. Because these benefits outweigh the advantages provided by city self-financing (such as lower debt interest rate, no required return on equity), third-party leasing is the most cost-effective option.

Transferring Knowledge

The team developed a general stakeholder engagement plan to gain support, ensure stakeholders are effectively involved, and anticipate problems such as resistance, conflict, or competing goals. This stakeholder analysis includes identifying stakeholders and compiling relevant information on each, then analyzing all stakeholder expectations and potential impact on the project. The team then familiarized themselves with the stakeholders, collected their feedback, discussed it with all internal parties, and incorporated that feedback into the design wherever feasible.

Specific types of outreach and stakeholder communication varied depending on the type of stakeholder. For example, conferences were targeted towards local government staff, utilities, regulatory agency representatives, and other practitioners, whereas public outreach to residents has consisted of ongoing city documentation explaining the reasons for the project. This documentation is available on the Office of Sustainability and Environment website, with information detailing Santa Monica's other extensive sustainability plans and targets.

Additional knowledge transfer strategies center around direct community engagement, which is especially imperative at the City Yards given the damage caused by the open landfill previously on the site. Building trust and support between local government and the public is crucial and challenging for this kind of environmental justice site. The team is meeting this challenge by engaging with local organizations early and often, and educating local residents about how the project will benefit locals and correct past injustices. Furthermore, a planned community-benefit agreement between the city and the community will define the shared prosperity of the project and solidify local trust by including measures to prevent gentrification and displacement. These measures include:

- Reserving 30 percent of new and rehabilitated housing in the surrounding neighborhoods for low-income and working families
- Freezing property taxes for longtime residents
- Independently monitoring and assuring local hiring in and around center
- Requiring that a percentage of development costs in the area be set aside for affordable housing and employment programs
- Codifying housing and employment protections and preserving deed-restricted housing

Future public outreach plans include, but are not limited to staff reports, websites, videos, social media posts, interviews, press releases, community presentations, a documentary of microgrid construction to be uploaded to project website, and interactive educational displays showcasing the facility's sustainability implemented into the site upon completion.

Lessons Learned

Education: Microgrids are an abstract concept to non-technical stakeholders. An education plan is required to bring stakeholders up to speed so they can develop opinions on how the microgrid should function and what benefits the system should bring to Its users.

Financial: The use case survey and charrette with the stakeholders provided guidelines regarding project objectives, but much of the feedback was not grounded in representative costs for the project size. This created a mismatch between objectives and their associated cost. Providing information on economic trade-offs earlier in the process would have allowed stakeholders and the project team to make better-informed decisions.

Policy: The electrical market has traditionally been structured around a model where the utilities had the only rights to supply electricity to a defined geographic area. While this model is changing, there are still numerous legal aspects, such as rights-of-way or tariff structures, that need to be revised to facilitate the expansion of advanced energy communities. Liaising with the local utility, Southern California Edison, to define a project that benefits both entities could have resolved some of those legal complexities.

Social and political: Building advanced energy communities requires that public and private entities understand the technologies involved, as well as its benefits and constrains. However, the technical capacity of leaders and electors to understand, appreciate, and deliver this type of projects is still limited. Increasing market awareness can reduce some of the perceived risk to these technologies, enabling its implementation.

Technical: The microgrid concept was added to the renovation plan of the City Yards site, rather than incorporated in the beginning of the design process. As a result, the microgrid had to be designed around the City Yards renovation project, instead of being designed alongside the site. Earlier adoption of this project could have increased the technical resources associated to this feasibility analysis.

Benefits to California

Microgrids can provide increased system reliability, cost reductions, and renewable energy to California's electrical grid. As more distributed energy resources integrate into an aging grid, microgrids can help advance and coordinate local and regional goals with respect to renewable energy, electric vehicles, and greenhouse gas emissions. Furthermore, facilitating public and private partnerships and investment in multi-user microgrids will reduce risks and encourage competitive and cooperative market management. Multi-user microgrids will also offer added scale and a leveling of operational profiles, resulting in more economically viable microgrids.

The project team quantified the benefits to the State of California through the total resource cost test. The assessment resulted in a negative outcome due to the misalignment between the current electrical structure and the project characteristics. These results indicate that given the energy demand of the site, current technology costs, inability to quantify resiliency, and current rate structure and existing incentives, there would be a negative financial return for the City and California. Nonetheless, the development of advanced energy communities will play a major role to reach California's greenhouse gas emission goals, while maintaining a reliable and resilient grid to natural and man-made disasters. Once the capital cost associated with these technologies is reduced and the electrical tariffs are structured to unlock all their attributes, microgrids will produce significant cost savings to its users and the State of California and help advance resiliency and de-carbonization goals.

Chapter 1: Project Introduction

Project Objectives

The Santa Monica City Yards Advanced Energy District project is a microgrid feasibility study funded by the California Energy Commission under the Electric Program Investment Charge (EPIC). The project proposes to develop an Advanced Energy District based around a multiuser microgrid, built in the Santa Monica City Yards facility. The City Yards Advanced Energy District will act as a demonstration model that will lay a foundation for policy and financial frameworks to enable public and private investment in future district-scale systems.

The project offers a unique opportunity to develop an advanced energy community at an infill site. The goal of the City Yards microgrid is to develop a distributed renewable energy and storage system that achieves zero or near-zero-net energy (ZNE) status, lowers energy demand, and provides benefits to the Santa Monica City Yards, the Bergamot area, and Metro maintenance facilities.

- Provide several mission-critical services to citizens of Santa Monica. These services require a modern, resilient, and economical source of electrical power to function regardless of the occurrence of man-made or natural disasters, and the potential loss of power availability from the local grid.
- Incorporate renewable and sustainable energy technologies to the greatest extent possible, with ZNE or net power exporting as a goal. The city has established an extensive set of sustainability and low-carbon energy targets, and believes that site- based renewable energy is a viable and necessary solution to achieving these targets.
- Ensure a project delivery and implementation approach that is consistent with prudent project financing methods and allows for private sector involvement and investment. The project development and financing approach will seek to appropriately manage/mitigate project, technical, and financial risks to the city.
- Provide benefits and value to the surrounding neighborhoods and citizens, such as the Bergamot area, which consists of five acres of former industrial land that is planned to be transformed into a walkable, sustainable, and innovative neighborhood.
- Serve as a relevant and replicable model for most other cities in California, especially those with a dedicated city yard that serves and hosts several city departments and functions. The innovative energy-production technologies, energy-storage options, site vehicle and transportation integration, microgrid solutions, and benefits sharing with local community participants will showcase a variety of viable and attractive advanced energy community concepts to other cities.

Project Site

The proposed City Yards Advanced Energy District will be located at the City of Santa Monica City Yards facility at 2500 Michigan Avenue in Santa Monica, California.

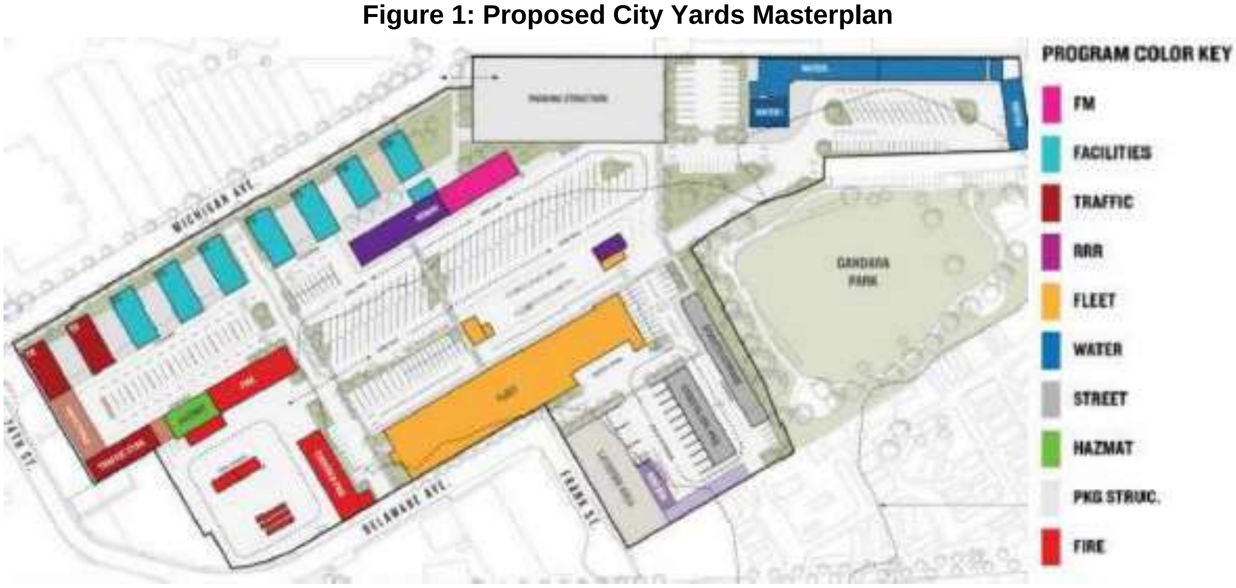
The City Yards is a 14.7-acre site, located partly over a former landfill. The site is scheduled for redevelopment to accommodate the incremental growth and changes of city services and operations (Figure 1). The City Yards is adjacent to Gandara Park, the privately owned Mountain View Mobile Inn, and the city-owned Bergamot Arts Center. Bergamot is also slated for redevelopment by a private firm, which will add commercial and residential uses to the 5-acre site.

There are also two nearby Los Angeles Metro properties linked with the Exposition Line, which runs between Santa Monica and downtown Los Angeles. The first is a large maintenance yard across Stewart Street. This site contains components to clean and maintain the trains used by Metro on this line. The second nearby Metro site is the 26th Street/Bergamot Station located on Olympic and 26th.

The public services currently based within the City Yards are:

- City facilities maintenance.
- Custodial services.
- Street maintenance.
- Fleet maintenance and fueling.
- Traffic operations.
- Resource recovery and recycling.
- Water and wastewater operations.
- Hazardous waste storage.
- Fire department training area.

Figure 1: Proposed City Yards Masterplan



Source: Miller Hull

A former waste landfill covers part of the site. Methane emissions from this landfill are being monitored and measured, and it is expected that this will continue.

When the initial EPIC grant application was developed for this project, one of the main goals was to develop a multiuser microgrid — an energy system with core components located at the main City Yards site but with the ability to interconnect with adjacent properties, such as the mobile home park, Bergamot Arts Center, or Metro's nearby properties. This could allow the sharing of energy resources across these sites and enable the microgrid to leverage the diversity of uses, increasing equipment utilization and generally allowing the microgrid to be modular and grow over time. Figure 2 shows the properties near City Yards as submitted during the grant application phase.

Figure 2: Bergamot Area Map

Source: Santa Monica Office of Sustainability and the Environment

Schedule and Budget

The City Yards modernization project has been divided into Packages A through D as shown in Figure 3, which are further subdivided into phases. Santa Monica has established a construction start date for Package A, Phase I of June 2019, with the intention to complete all Package A phases by 2024. Package A encompasses the construction of most of the buildings on the site and includes:

- Phase I
    - Fleet Maintenance
    - Sitework
    - Site Improvements
- Phase II

- Public Works Administration
- Crew Lunch Room
- New Fuel Island
- Sitework

- Phase III
    - Shops: Rosie’s Girls, Paint, Electrical
    - Sitework
    - Site Improvements

Figure 3: City Yards Construction Phases and Indicative Timeline

Source: Miller Hull

The cost for the full design and construction of Package A, which also includes demolition and temporary relocation of several operations, is estimated at $114 million. Santa Monica is committed to redevelop a City Yards that is ZNE, uses non-potable water for non-potable uses, and is microgrid-ready.

Out of the estimated construction budget of $114 million for the entire microgrid-ready project, the city has currently allocated $38.5 million in capital funding from the city's general fund for the initial project costs. This allocation was adopted by city council in the Capital Improvement Program Budget and fiscal year (FY)18/19 Budget on May 22, 2018.

The $38.5 million will be primarily dedicated to sitework and construction of buildings included in Package A. A portion of the funds will support the electrical sitework, distribution, and equipment necessary to support the future buildout of the microgrid’s energy systems. The roof structures of the buildings constructed would also support rooftop solar photovoltaic (PV) systems integrated into the microgrid. Beyond this, critical microgrid elements such as energy generation, energy storage, and control systems are currently not budgeted within this project.

Additionally, the City Yards project budget and scope do not include the extension of distribution infrastructure across the right-of-way into the Bergamot Arts Center, which is essential to integrate future non-city users.

The city is proposing a $5 million grant application to fund the construction of a microgrid within City Yards with 1.2 megawatts (MW) of solar and 7.2 megawatt hours (MWh) of energy storage. The City Yards microgrid will serve as the base of a future multiuser microgrid beyond City Yards. The City Yards microgrid will be modular and expandable, following the development stages of the City Yards modernization.

The city proposes to spend $4.8 million of the grant funding on microgrid equipment, including battery energy storage systems, inverter, microgrid controller, and advanced electric vehicle charging stations. The city will procure solar independently for the project either through a third-party agreement or using the city's general funds, if available. The remaining grant funds will be used to implement monitoring and verification, develop case studies, and analyze the costs and benefits of the project.

Project Team

The Santa Monica Advanced Energy District team consists of multiple entities and participants with proven practical experience in the technical and engineering aspects of the analysis, feasibility, design, construction, and operation of advanced microgrid technologies.

City of Santa Monica, Office of Sustainability and the Environment

The City of Santa Monica has been a leader in sustainability for more than two decades. The city adopted the Sustainable City Plan and 15x15 Climate Action Plan, establishing several ambitious goals and targets for energy efficiency, renewable energy, and electric vehicle use.

The relevant goals adopted by the city of Santa Monica that meet the State's goals are to:

- Reduce greenhouse gas emissions 80 percent by 2050.
- Reduce energy use at the community and municipal operations level by 10 percent by 2020.
- Install 7.5MW of solar within the community and 1MW of solar on municipal facilities by 2020.
- Achieve 80 percent of alternative fuel fleet vehicles by 2020.

The city's Office of Sustainability and the Environment develops and implements programs and policies to achieve the goals and targets established in the city's Sustainable City Plan, 15x15 Climate Action Plan, Water Self-Sufficiency Initiative, Zero Waste Strategic Plan, and other strategic initiatives. The office served as the grant administrator and main point of contact with the Energy Commission, various municipal departments, SCE, and other stakeholders.

Arup

Arup is an independent firm of designers, planners, engineers, consultants, and technical specialists offering a broad range of professional services. Arup's energy consultants provide specialist mechanical, electrical, technical, and project management skills to integrate energy systems. Arup acted as primary technical consultant and project coordinator for this report. Arup provided high-level planning, engineering, and energy analysis throughout the duration of the project, organizing all activities related to the Owner's Project Requirements, coordinating the development of the technical work, and compiling this report.

University of California, Irvine; Advanced Power and Energy Program

The Advanced Power and Energy Program at the University of California, Irvine (UCI) addresses the development and deployment of efficient, environmentally sensitive, sustainable power generation and energy conversion worldwide. For this project, UCI provided industry expertise and field research covering the use of energy resources from a systems perspective. They contributed their experience and expertise in modeling of advanced generation and microgrid resources. Their involvement in the Irvine Smart Grid Demonstration project and close coordination with Southern California Edison (SCE) — the utility company that services Santa Monica — brought essential expertise to the project. UCI analyzed the various distributed energy resources and microgrid scenarios considered on the project, including the preparation of load flow simulations and electric vehicle charging analysis.

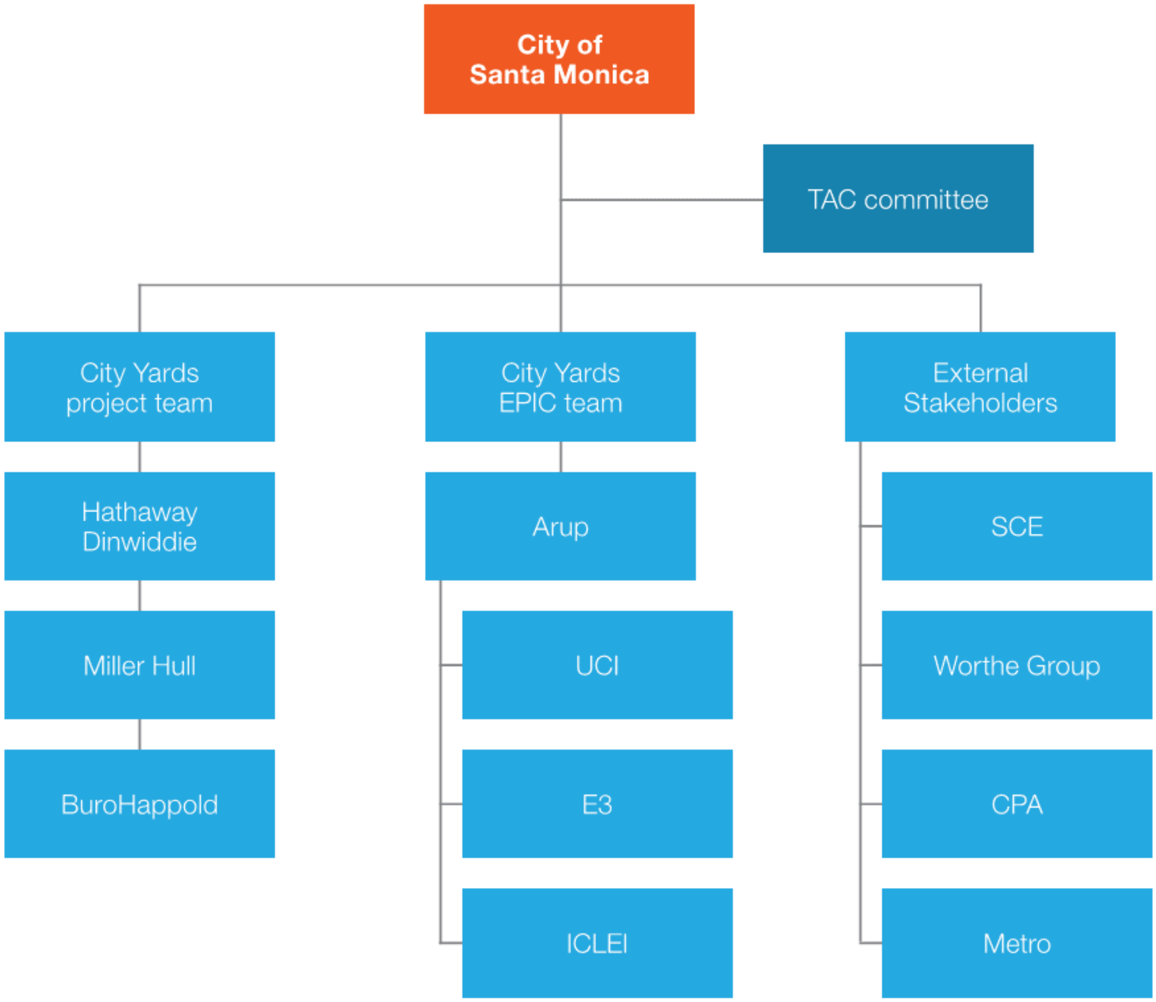
Energy + Environmental Economics

Energy + Environmental Economics (E3) has operated at the nexus of energy, environment, and economics since its inception in 1989. E3 analysis has informed debate on many of the key issues facing the electricity industry today. From regulated utilities to restructured markets, from distributed resources to high-voltage transmission, E3 understands electricity economics. For the Santa Monica Advanced Energy District project, E3 performed cost-benefit analysis for the various microgrid scenarios, in line with the California Standard Practice Manual for cost-effectiveness evaluation. Value implications focused on the participants of the microgrid, non-participating ratepayers, the utility, and California.

ICLEI – Local Governments for Sustainability

ICLEI – Local Governments for Sustainability is a membership association of more than 1,000 cities and countries around the world committed to sustainability, resilience, and climate solutions. ICLEI conducted a policy review of local, state, and federal codes that support multiuser microgrids. ICLEI also provided outreach strategies and materials, and used its networks to ensure dissemination of the project findings, benefits, and approaches.

Figure 4: Santa Monica Advanced Energy District Organizational Chart



Source: Arup North America Ltd

City Yards Design-Build Team

In 2015, the city initiated a contract with a design-build team to conduct a feasibility analysis for modernization of the City Yards site. The design-build team is currently developing the schematic design of the City Yards redevelopment. The design-build team consists of Hathaway Dinwiddie as the project manager, Miller Hull as the architect, and Buro Happold as the structural, mechanical, electrical, and plumbing engineer (Figure 4).

Project Tasks

The City Yards Advanced Energy District project investigates the energy supply and resilience requirements, technical feasibility, and economic potential of a microgrid that generates, stores, and distributes renewable energy within the city's redeveloped City Yards facility, as well as extended scenarios that incorporate multiple users.

The project is organized into the following tasks, which are discussed in more detail in the subsequent chapters of this report:

Task 1: General project tasks – This task describes some of the administrative activities to be completed throughout the project, such as reporting or invoicing. The information produced in this task is excluded from this report, as does not include relevant content.

Task 2: Use Case Framework – The development of a use case framework involved obtaining owner and stakeholder preferences, requirements, and perspectives. The project team then consolidated this input into the Owner's Project Requirements (OPR) document, which defines the microgrid's functional, technical, and operational requirements.

Task 2 also identifies the stakeholders and applicable regulations to understand the project's economic, regulatory, and social framework.

The policy and incentive matrix included under this task identifies the primary barriers to adoption of the microgrid, the potential policies and incentives to barrier removal, and the market impact.

Task 3: Distributed Energy Resources – Research and Selection – This task is to understand the electrical loads expected for the renovated City Yards and expanded scenarios. The project team then used this research to identify generation technologies suitable to satisfy the expected electrical loads. The project includes several mature technologies such as PV and microturbines, and newer technologies such as electrical energy storage, biogas generation, and electric-vehicle-to-grid applications.

Task 4: Microgrid Modeling and Optimization – With the loads and generation technologies identified, the team created several models using standard microgrid analysis and design software. The analysis assumed normal operation — when the microgrid is connected to the main grid — as well as operation during an outage in the main grid supply produced by a man-made or natural disaster.

The key microgrid elements, such as the PV array or energy storage, were sized to satisfy the energy demands and optimize the project's overall cost, considering design, construction, and operation of the microgrid.

Task 5: Business, Regulatory, and Financial Models, and Implementation Plan – This task examined the cost-effectiveness of the City Yards microgrid under multiple technology sizes, rates, and load scenarios, with three potential financing options. The project team analyzed the cost-effectiveness for each scenario from the perspective of the City, the State of California, and other utility ratepayers.

Task 5 also includes a microgrid implementation plan and potential governance structures.

Task 6: Case Study, Tools and Dissemination – This task required developing a case study that details how to encourage the expansion of advanced energy communities. It also involved developing a plan to disseminate the knowledge gained, results, tools and lessons learned to the public and key decision makers. These two documents were delivered separately from this report, and do not contain additional information.

Task 7, Project Benefits – Task 7 required to complete three project benefits questionnaires supplied by the Energy Commission. They correspond to three main intervals in the agreement: kick-off meeting, mid-term and final meeting. The questionnaires are for administrative purposes and are not included in this report.

Chapter 2: Use Case Framework

Owner's Project Requirements

Overview

The Owner's Project Requirements (OPR) is a condensed collection of vital owner and stakeholder information about the City Yards microgrid project. This section defines the expected outputs and characteristics desired from the microgrid, providing clear documentation and guidance. The OPR conveys information from the owner to the microgrid consultants, designers, contractors, operators, and maintenance staff.

This OPR provides a summary of the process followed to identify and quantify the most desired uses and elements of the microgrid. The project team used various techniques to develop this OPR, including surveys, polls, charrettes, and direct communications with City staff, managers, and other consultants and the City Yards design team. See Appendix A for polling/voting results from the use case studies.

The City Yards Microgrid Requirements section defines and comprises the current microgrid requirements. As this project progresses and the City Yards design team begins the design phases of the City Yards redevelopment, the OPR must be periodically updated and adjusted to incorporate additional information.

The OPR contains some programming information, such as functional, operational and performance requirements, as well as the owner's goals, expectations, performance criteria, and (if necessary) records of decisions and trade-offs made during design and construction.

The OPR document is intended for a wide audience, including the owner, design team, construction team, operations and maintenance staff, future renovation teams, and anyone who needs access to the original project information. This OPR will be used for many future activities, including the following:

- The sizing and modeling of the microgrid.
- Inputs to the basis of design for the schematic, design development, and final designs phases of the City Yards
- The eventual functional performance testing for the commissioning of the microgrid

Microgrid Use Case Study

Approach

To determine and prioritize the desired attributes of the microgrid, Arup led the development of a Use Case Study, which defined the OPR.

A Use Case Study process is typically used to solicit and receive tangible owner and stakeholder input — via preferences, attitudes, and perspectives — regarding the specific desired functional uses of the microgrid. These use-case characteristics are then consolidated into an OPR document that then informs the microgrid design and operations criteria. Generally, the influence/importance of one criteria over another depends on the specific microgrid application. For example, a rural microgrid in a developing country has a strong societal impact compared with the technical element. On the other hand, the focus of a private/commercial microgrid could be on economics, resilience, or green generation credentials.

An example of the possible range of microgrid operational functions and capabilities is shown in Figure 5. Each of these capabilities requires a specific set of design criteria — and likely incremental costs — to achieve functionality and must be included in the OPR. While many of these capabilities may be desirable, stakeholders will typically need to prioritize certain features for the final OPR.

Figure 5: Examples of Microgrid Use Case Features

Source: Arup

Presenting the Use Case Study

On August 28, 2017, Arup presented an introduction and generic overview on the technical, economic, and social aspects of typical microgrids to a broad group of the City Yards stakeholders, including the City Yards design team, City department managers, and selected attendees. The aim of this presentation was to communicate the key elements and define the attributes of the microgrid system, informing future decision making.

Together with the overview of microgrids, Arup also discussed the Use Case Study process and the OPR document.

Use Case Study

In early October 2017, Arup subsequently managed an online survey with the Santa Monica city staff. The survey was designed to narrow down the potential use cases for the microgrid to a reasonable number (typically less than 10). The survey asked the stakeholders to rank in order of importance (1 to 5) the provided use-case attributes for the City Yards microgrid.

The initial list of potential use-case attributes was as follows:

- Prioritization of areas to be served by microgrid
    - City Yards
    - Arts district
    - Bergamot Transit Village
    - Maintenance yard
    - Mixed-use creative
    - Creative sector
    - Expo station
    - Mountain View Mobile Inn
- Economics
    - Capital cost of energy systems and distribution infrastructure ($)
    - Payback period of energy systems and distribution infrastructure (years)
    - Reduced cost of electricity for customers ($/kWh)
    - Increased electricity rate flexibility (such as dynamic pricing)
    - Reduced cost of maintenance
    - Reduced cost of operations (for example staffing, fuel price)
    - Grants, third-party financing, tax-credit equity
- Reliability
    - High availability
    - Power quality
    - Reduced frequency of short-term interruptions (<5 min)
    - Reduced frequency and duration of long-term outages (>5 min)
- Resilience
    - Ability to operate autonomously (islanding)
    - Black-start[1] capability
    - Ability to operate during city-wide blackout from 0 to 4 hours
    - Ability to operate during city-wide blackout from 5 to 12 hours
    - Ability to operate during city-wide blackout from 2 to 10 days (major event)
- Environment / sustainability
    - Greenhouse gas (GHG) emissions reduction
    - Percentage of fuel mix from renewables
    - Diversity of renewable energy sources (such as solar, wind, combined heat and power)
    - Energy efficiency of systems
    - Water use and waste generation

[1] Capacity to restore electricity to the microgrid without relying on the external electric network.

    - Performance Excellence in Electricity Renewal (PEER) or other certifications
- Customer engagement
    - Customer engagement and awareness
    - Real-time data available to public
    - Demand response participation from customers
    - National media attention (for example success story)
    - Energy production from rooftop solar photovoltaics
    - Stakeholder support
- Social equity
    - Environmental justice
    - Enhanced quality of life for residents
    - Air quality (reduction in particulates, nitrogen oxide, sulfur oxide) Some key results from the online survey include the following:
- The abilities of the microgrid to increase energy resilience, reduce the frequency and duration of outages, and lower operational costs are more highly valued than its capacity to reduce GHG emissions or improve local air quality.
- First cost is not deemed as critical as lower lifecycle costs.
- The City is willing to increase the capital cost of the microgrid to reduce the frequency and duration of electrical outages.
- Beyond providing benefits to the City Yards, this project should provide financial benefits to the city of Santa Monica as a whole. These extended benefits are perceived as necessary to maintain positive public relations with City Yards neighbors.

The survey results can be found in Appendix A.

Use Case Charrette

Arup and project partner ICLEI met with the City Yards stakeholders to provide further background on microgrids and to determine and prioritize the desired future attributes of the microgrid using a use-case charrette. Based on the results of the online survey, charrette discussions focused on the following seven use cases:

1. Education and research and development (R&D)
2. Economics and cost-effectiveness
3. Advanced Energy District participants
4. Resilience
5. Sustainability
6. Ownership and operations (who owns/operates the microgrid?)
7. Reliability

Use Case 1: Education and R&D

Constructing the microgrid in the city-owned and operated City Yards will provide a framework to inform the R&D of future city projects.

The real data gathered from the project could be used to showcase Santa Monica's efforts to reduce its environmental impact and provide awareness and education to the city inhabitants.

The following attributes were discussed within this topic:

- **R&D engagement with University of California, Los Angeles; and Santa Monica College** – UCLA is one of the top public research universities in the United States, and more locally, Santa Monica college is a well-recognized community college within the city. There are opportunities for engagement with these institutions through the operational phases of the microgrid.
- **Real-time data output to the public** – One of the barriers for new technologies, such as microgrids, is the lack of information on operating performance. By providing real-time data output to the public, it will be possible to objectively evaluate the performance of the system, while providing awareness to the public on energy matters.
- **User engagement and awareness** – Increasing user engagement and awareness on energy matters can be one of the most cost-efficient methods to reduce energy consumption, as this is generally relatively tied to human behavior (such as switching off equipment that is not in use). There are also opportunities to use the microgrid to help make the City Yards project more transparent and accessible to the public — one of the key design drivers for the new masterplan project.
- **Public access, tours and schools** – Once the microgrid system is operational, it will be possible to provide on-site tours to schools and any other interested public, strengthening the image of Santa Monica as a leading city in the fight against climate change. While raising the public perception of the city, public access will encourage other institutions to follow Santa Monica's path.

Use Case 2: Economics and Cost-Effectiveness

Economic viability is one of the main pillars of sustainability. An initiative cannot be deemed sustainable if cannot sustain its economics throughout its lifetime. Most existing microgrids have been designed to promote other attributes, such as resilience or capacity to work in remote areas with no access to the grid. However, the broader commercialization of microgrid systems and the introduction of new revenue streams (time-of-use, peak load reduction, net metering) is leading to an increased focus on the economic benefits of microgrids.

The following attributes were discussed within this topic:

- **Lowest initial system capital cost** – When there is not enough support from stakeholders, a low initial capital cost may increase the likelihood of implementation of a microgrid system. In general terms, a smaller investment will provide fewer benefits, though it could still be a catalyst that transforms the market.

- **Lowest system lifecycle costs or payback** – Commercial institutions are generally driven by profitability, looking for investments that provide fast payback periods. Governmental institutions, with assets not expected to be sold, may prefer to consider lifecycle costs, which will optimize the primary and operational costs.

- **Use of private sector financing** – Given the high capital costs of microgrid systems, in some cases public institutions may not want to pay upfront for the high capital costs. They may instead arrange other types of procurement that displace most of the risk to the private sector, such as private-public partnerships or energy performance contracts. In addition, the private sector may be able to benefit from incentives and rebates not available to public institutions, which can be passed on to the system owners.
- **Lowest user energy cost** – A microgrid system can be designed to reduce the cost of energy. To do this, the microgrid will reduce the energy consumed during the high peak periods, increasing consumption when the energy is cheaper. Reducing demand consumption at peak periods will also reduce the cost of energy. The microgrid can also provide benefits to the existing utility electrical network by increasing the robustness of local supply. This may be difficult to monetize based on current utility structures, but there may be opportunities to monetize these benefits in the future.
- **Lowest operations and maintenance costs** – The operating costs include all costs incurred to run a system, including energy, fuel, staff, and maintenance costs. In some cases, the initial cost of the project may be defrayed by a grant, reducing the importance of the capital costs but maintaining the need for low operational costs to reduce the burden on the municipal budget.
- **Lowest staffing/operator costs** – This system attribute will aim to account for the experience and specialization of the staff required to run the microgrid system. Although some systems may have lower initial costs or simplified designs, designers must also consider the cost for manual operation and/or the requirements for additional operator training expenses that result from new/sophisticated technology.

Use Case 3: Advanced Energy District Participants

City Yards is surrounded by publicly and privately-owned developments. Although the microgrid system will be initiated in the City Yards, owned and controlled by the City of Santa Monica, the project aim is to look for opportunities to develop a multiuser microgrid that connects to diverse users and optimizes energy supply for all participants, leveraging operational synergies (Figure 6).

Figure 6: City Yards and Surrounding Areas Aerial View

Source: Arup

Stakeholders discussed the following potential users during the charrette and voted on which should be prioritized as part of the microgrid:

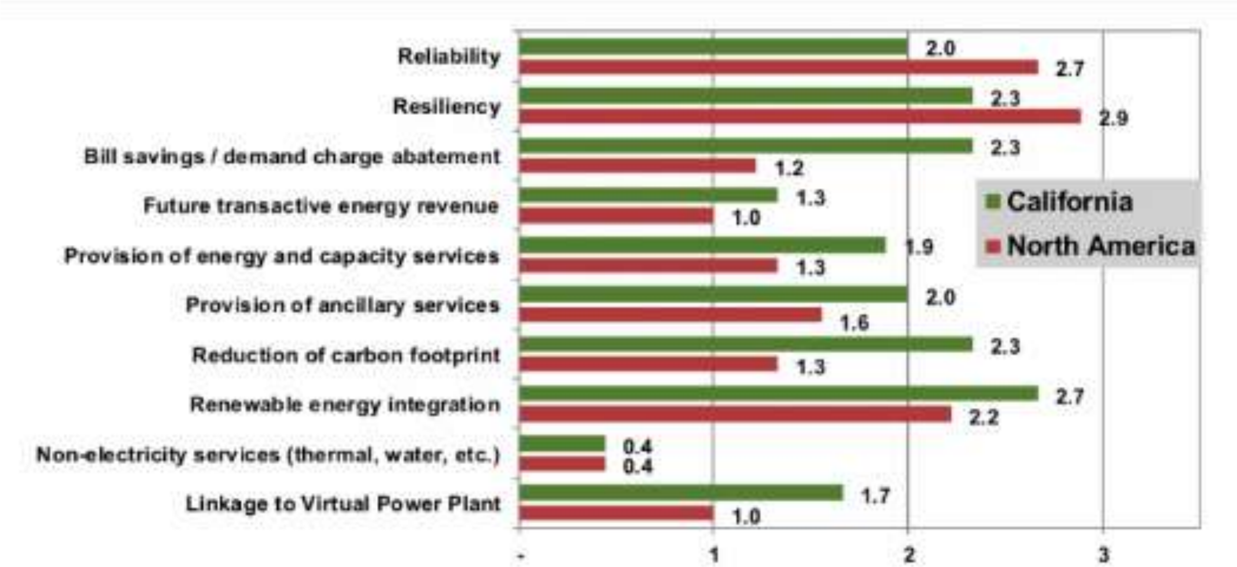
- City Yards
- Arts district
- Bergamot Transit Village
- Maintenance yard
- Mixed-use creative
- Creative sector
- Expo Station
- Mountain View Mobile Inn
- Park tie-in for disaster response equipment

Use Case 4: Resilience

For energy systems, resilience is defined as the ability of an electric power system to withstand and recover from extreme, damaging conditions, including weather and other natural disasters, as well as cyber and physical attacks. Resilience has generally been one of the most sought-after attributes for microgrids in North America.

Figure 7 shows which attributes were considered of most importance for many existing microgrid projects in North America. Resilience is considered the most important attribute.

Figure 7: Average Importance of Value Proposition, Studied Microgrids



(0= not important; 3 essential)

Source: Navigant Research

The following attributes were discussed within this topic:

- **Ability to operate autonomously from grid (island mode)** – This is the ability to operate in island mode is essential for the critical loads included within the City Yards.
- **Black-start capability** – A black start is the process of restoring an electric power source or a part of an electric grid to operation without relying on the external electric power network. This capability can be used to start emergency generators or a cogeneration engine if the external network fails.
- **Operate 0 to 4 hours** – This the capacity to operate in island mode for an interval of 0 to 4 hours upon external electrical grid failure.
- **Operate 5 to 12 hours** – This the capacity to operate in island mode for an interval of 5 to 12 hours upon external electrical grid failure.
- **Operate 2 to 10 days** – This the capacity to operate in island mode for an interval of 2 to 10 days upon external electrical grid failure.

Use Case 5: Sustainability

The following attributes were discussed within this topic:

- **GHG/carbon reductions** – The City Yards' carbon dioxide emissions can be reduced with the implementation of a photovoltaic (PV) plant or other renewable energy system. The battery system may also be used to store electricity when the PV generation is higher than the energy consumption.
- **100 percent renewables** – Santa Monica aims to increase its share of renewable energies up to 100 percent. With the implementation of batteries and the solar PV

plant, the City Yards will increase the use of energy generated from renewable sources.

- **Diversity of fuel mix** – Diversification of the primary sources of energy reduces the dependency of a system/state/country on external energy sources. The 2016 power mix for SCE (estimated by the Energy Commission [2017]) is 25 percent renewable, 4 percent coal, 10 percent large hydroelectric, 37 percent natural gas, 9 percent nuclear, and 15 percent unspecified. Increasing the share of renewable energies reduces dependency on natural gas, coal, or nuclear fuel.
- **Low water/waste** – The City Yards masterplan project includes a reduction in potable water use and wastewater generation within the project. This will need to be a consideration of the microgrid project when selecting systems, and the trade-off between water use and energy use will need to be part of the assessment criteria.
- **Sustainability certification** – As part of its sustainability plan, Santa Monica aims to increase the number of buildings within the city that achieve the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification. The City Yards masterplan also aims for certification under the Institute for Sustainable Infrastructure's Envision system, which includes considerations for energy performance. There is also the option to certify the microgrid itself under the Green Business Certification Inc.'s PEER certification system.

Use Case 6: Ownership and Operations

The Santa Monica City Yards microgrid project was initially conceived as a multiuser microgrid, with several different entities and some non-city users interconnected. Given the current political, technical, and regulatory constraints, the project team and the city determined that the city should own and operate the microgrid.

City ownership of the microgrid provides several substantial benefits for the project, including simplified decision-making, improved "bankability" (the ability to finance the microgrid using the city's strong credit rating), better coordination with the City Yards design team, and the ability to move ahead quickly with any implementation.

Load management controls may be implemented to allow for SCE's demand response programs.

Use Case 7: Reliability

Electricity reliability is the ability of the electric power system to consistently deliver electricity in the quantity — and with the quality — demanded by end users. Together with resilience, this is also one of the most sought-after attributes for microgrid systems. Resilience directly impacts reliability.

The following attributes were discussed within this topic:

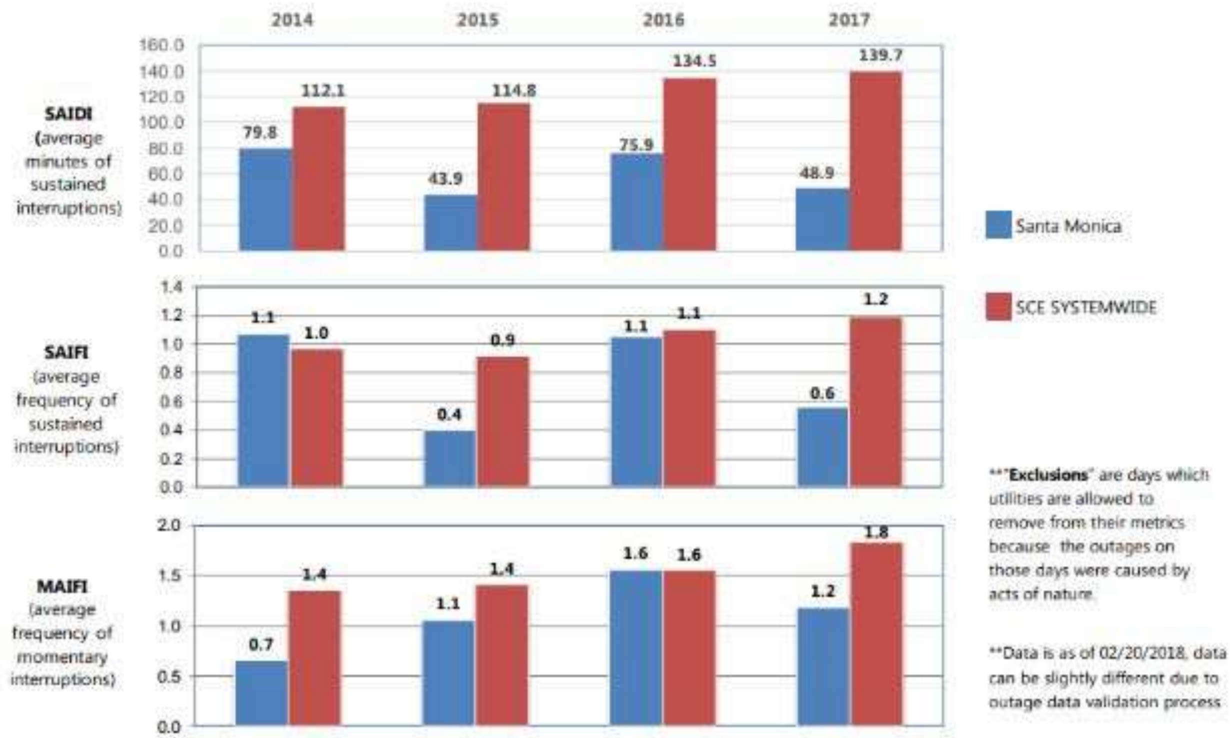
- **Improved power quality** – This generally involves voltage, frequency, and waveform. The incidents that occur outside the City Yards can influence the quality of the electricity supplied to the development, potentially impacting sensitive equipment, such as computers or cogeneration engines.

Upon large variations of voltage, frequency, or waveform, the microgrid controls may switch the electricity supply from the grid to batteries, ensuring that all critical equipment remains operational. The microgrid can also be used like an uninterruptible power supply or power filter — importing the low-quality grid power and cleaning it up using the batteries and inverters. The microgrid can also increase the quality of local grid power by acting as a frequency regulator by injecting reactive power, which may also provide an economic benefit.

- **High "nines" availability (such as 99.99 percent)** – The city has designated City Yards as an "Essential Services Facility" and therefore, it is essential to provide high availability to critical loads, such as traffic controls or potable and sewage water pumps.
- **Reduced frequency of outages** – This is defined by the System Average Interruption Frequency Index (SAIFI) for outages lasting more than five minutes and the Momentary Average Interruption Frequency Index (MAIFI) for outages lasting less than 5 minutes. The reported value is the average number of outages per customer per year.
- **Reduced duration of outages** – This is defined by the System Average Interruption Duration Index (SAIDI), which is the cumulative amount of time the average customer is interrupted by sustained outages (more than five minutes) each year.

Figure 8 presents the availability indexes from Southern California Edison (SCE) for Santa Monica for the years 2013 to 2016.

Figure 8: SCE Reliability History (with No Exclusions) for Santa Monica



Source: SCE 2018

Table 2 compares the SAIDI and SAIFI indexes for the top largest US utilities, showing SCE with some of the best reliability indexes among the utilities surveyed.

Table 2: 2015 Reliability for Top 10 Largest Utilities

Utility Name	State	Number of Customers (meters)	SAIDI with major events (minutes)	SAIFI with major events (# events)
Pacific Gas & Electric Co	CA	5,446,629	147.200	1.052
Southern California Edison Co	CA	5,033,330	114.827	0.916
Florida Power & Light Co	FL	4,796,829	65.080	0.820
Commonwealth Edison Co	IL	3,853,843	109.000	0.970
Consolidated Edison Co Inc*	NY	3,385,176	21.100	0.112
Oncor Electric Delivery Co LLC	TX	3,321,366	267.300	1.880
Virginia Electric & Power Co*	VA	2,420,939	183.103	1.381
CenterPoint Energy	TX	2,394,231	258.840	1.980
Georgia Power Co	GA	2,366,621	175.100	1.500
Public Service Elec & Gas Co	NJ	2,278,286	81.330	0.687

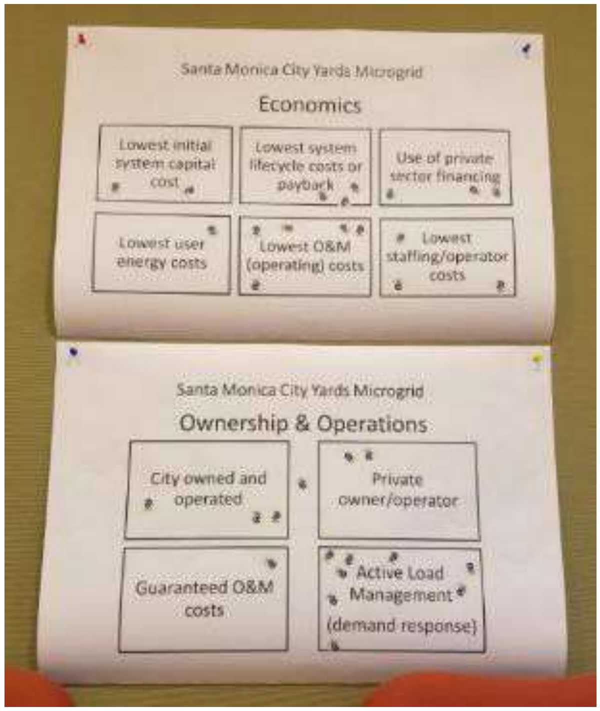
Source: EIA 2015

Use Case Voting Process and Results

Immediately after the definition and discussion of the use cases, the stakeholders were asked to vote on each of the seven use cases. The voting process followed the following rules and guidelines:

- Each stakeholder was provided with 20 small stickers,
- They were directed to place the stickers on the large posters on the conference room walls (Figure 9).
- The stakeholders could vote for as many use-case attributes as they preferred.
- If a preferred use case was not present, participants could write in a selection.

Figure 9: Sample Voting Posters with Use Case Details



Source: Arup North America Ltd

Table 3 lists the use cases most voted.

Table 3: Most Voted Attributes for the Microgrid

#	Use Case Ranking	Desired Attribute	Votes
1	Advanced Energy District Participants	City Yards is the primary user	12
2	Ownership and Operations	Active load management (demand response)	8
	Resilience	Operate 2 to 10 days	
3	Education and R&D	Real-time data output to the public	6
	Reliability	High "nines" availability (e.g., 99.99%)	
	Resilience	Ability to operate autonomously from grid	
	Resilience	Black-start capability	

Source: Arup North America Ltd

The following sections provide a more detailed description of the voting results and stakeholder comments on the use cases.

Advanced Energy District Participants

The results from the survey indicate that the microgrid will be initially developed primarily for the City Yards. Connection to the LA Metro maintenance yard was second in priority but with only four votes, compared to the 12 votes received for the City Yards.

Ownership and Operations

The survey results indicate a preference for the microgrid system to be owned and operated by the city of Santa Monica rather than a private third party (four votes to be publicly owned to three votes to be privately owned).

There were 8 votes for active load management, the capacity to actively manage the microgrid loads through a demand–response system. This system provides an opportunity for the City Yards to reduce or shift its electricity usage during peak periods in response to time-based rates or other forms of financial incentives.

Resilience

The topic of resilience was one of the most frequently voted. This is likely to be related to the critical operations carried out in the City Yards (traffic light controls and potable and wastewater pumps).

There is a high interest in the microgrid's capability to operate autonomously from grid, in case of grid failure. An autonomy of 2 to 10 days is initially desired.

Reliability

In line with the previous topic, a high reliability (99.99 percent) of the electrical supply has been selected as a highly desired attribute.

Education and R&D

In addition to the technical capabilities desired in the microgrid, stakeholders also expressed an interest in showcasing the benefits of the microgrid system through real-time data output to public. This will be used to increase awareness and user engagement.

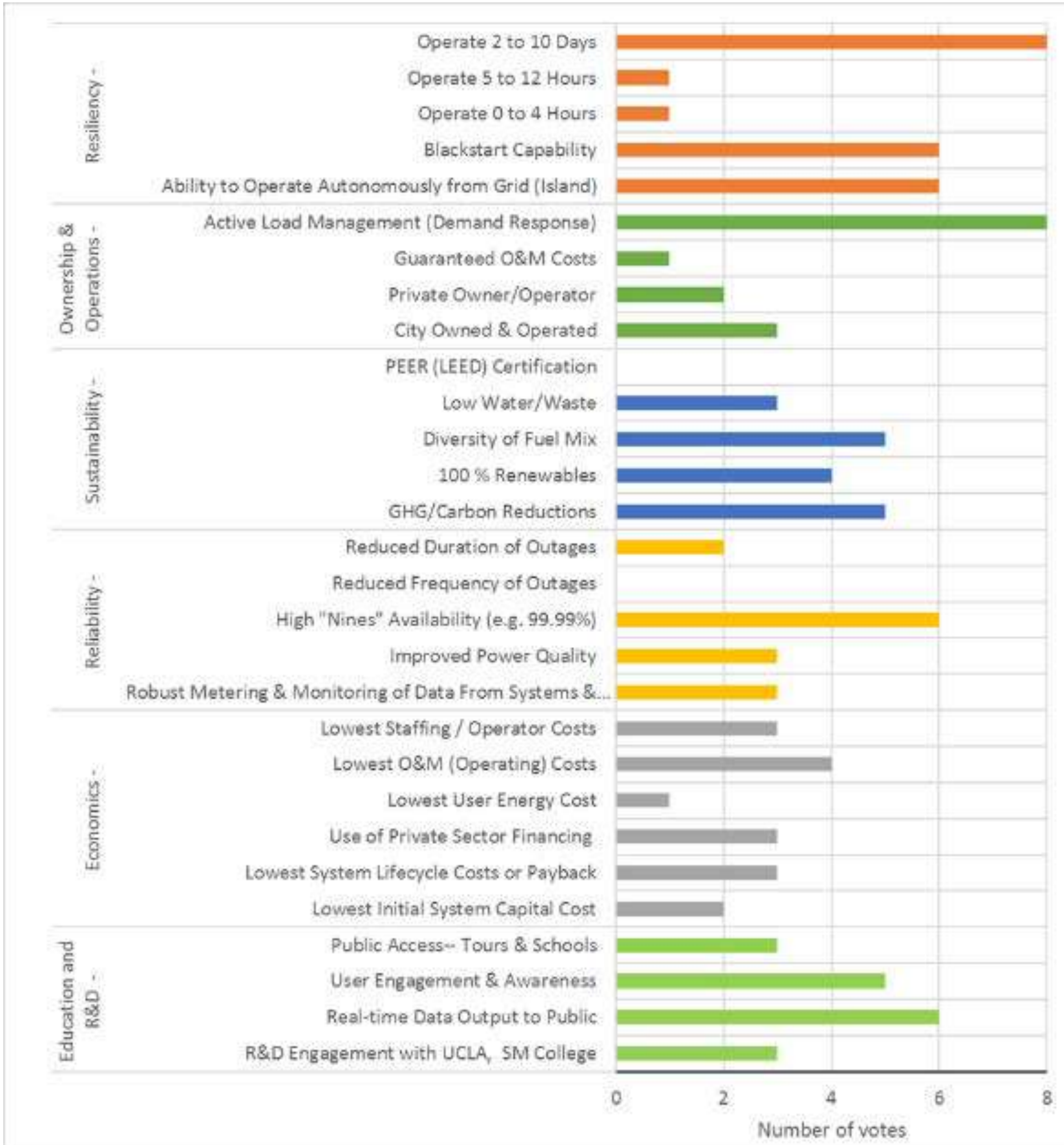
Other Results

Although not listed as the most voted attributes, stakeholders were interested in increasing renewable energy generation and reducing the carbon emissions associated with the city of Santa Monica operations.

The topics related to the economic aspect of the microgrid obtained fewer votes, indicating a strong will to proceed with the project. Within the economic aspect, low operational and maintenance costs received more votes than first-time costs.

Figure 10 provides a summary of the stakeholders' votes on the attributes provided.

Figure 10: Desired Attributes of the Microgrid System



Source: Arup North America Ltd

Emergency Power Survey

On December 14, 2016, Santa Monica's Office of Sustainability and the Environment completed a survey of city of Santa Monica department managers and staff to determine the desired emergency power requirements for the City Yards buildings and operational areas. The following buildings and operations were included in the survey:

- Water Resources Division
- Data (servers, internet)
- Traffic Controls

- Fleet Division
- Radio Shop
- Facilities Maintenance
- Public Works/CY Administration
- HVAC Shop
- Fire Department
- Paint Shop
- Fueling Stations
- Electrical Shop
- Resource Recovery & Recycling
- Information Systems Department
- Household Hazardous Waste Center/Storage
- Carpentry Shop
- Streets Division
- Plumbing Shop

The survey questions and responses are provided below:

Question #1

In a disaster or emergency response situation, what buildings and operations would be the most important to ensure power is sustained on standby power?

The buildings/operations that received a highest priority rating are as follows:

	No. of times voted as priority #1	No. of times voted as priority #2	No. of times voted as priority #3
Fire Department	4	0	0
Fueling Stations	0	1	3
Data (servers, internet)	1	1	0
Fleet Division	1	1	0

Question #2

To the best of your ability, please describe the types of "powered" functions that would be essential during a disaster or emergency situation within each building or operation.

For the four buildings/operations with highest priority, the power functions identified as essential are as follows:

Fire Department	All functions required for community and fire support
Fueling Stations	Fueling stations required for fueling of emergency vehicles
Data (servers, internet)	Required for communication to other cities and departments
Fleet Division	All systems needed to repair emergency vehicles

Question #3

Of the powered functions described above, what bare minimum of operating capacity would be acceptable during a disaster or emergency situation?

For the four buildings/operations with highest priority, the minimum operating capacity identified is as follows:

Votes	Percentage of power required				
	0%	**25%**	**50%**	**75%**	**100%**
Fire Department					5
Fueling Stations			2	2	2
Data (servers, internet)			2	2	2
Fleet Division	Results unreliable due to a clerical error.				

For additional information on the City Yards Emergency Power survey, please see Owner's Project Requirements.

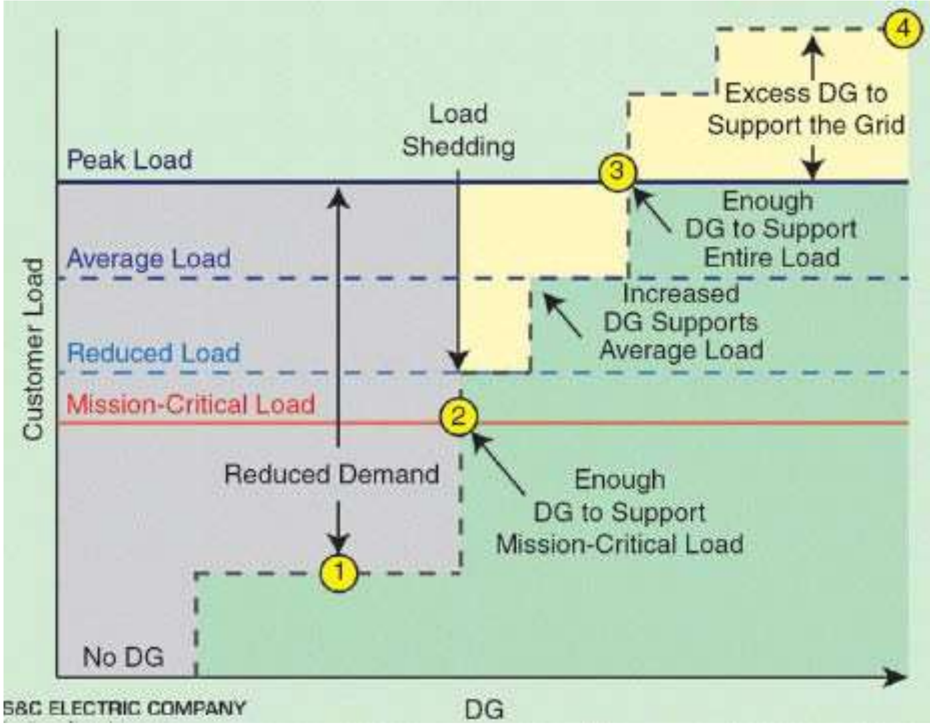
City Yards Microgrid Requirements

Based on the surveys, polls, charrettes, and direct input from city staff and project stakeholders, the following performance goals and technical/operational objectives shall be incorporated into the City Yards Advanced Energy District microgrid design/specifications, construction, and commissioning. Together these requirements form the initial OPR for this project.

Functional Requirements

- The new and remaining buildings, systems, and energy requirements/loads within the City Yards site shall define the initial sizing and capacity of the microgrid. As shown in Figure 11, the microgrid shall be designed for Operational Point #3 for Normal Power conditions. During extended SCE system outages (i.e., island mode greater than 1 hour), Operational Point #2 shall be required. No net export power (Operational Point #4) is expected, unless power wheeling to other city-owned facilities is agreed to with SCE. Based on the availability and attractiveness of SCE and California ISO demand response programs, Operating Point #1 shall be achieved for short-duration (<4 hour) demand response operation.

Figure 11: Microgrid Design Capacity



Source: S&C Electric Company

- The microgrid shall be designed to allow for future integration of additional energy generation, energy storage, and loads that may be incorporated from adjacent entities and desired microgrid participants. These integrations are expected to modify the loads and operational points initially designed, and therefore, the microgrid's MCC setpoints shall be adjustable.
- Resilience targets for the microgrid are for up to 10 days of extended operation after the failure or loss of normal power from SCE. However, not all areas of the City Yards site will require extended emergency power for the 10 days.
- Enhanced reliability of the microgrid shall be achieved through a combination of redundant systems and appropriate design considerations to achieve 99.99 percent annual availability — or a maximum total annual outage duration of less than 53 minutes per year. This improves reliability compared to the recent 4-year average SCE outages of 75.8 minutes per year.
- The microgrid shall be able to operate in island mode, independently and separate from the SCE distribution system.
- The microgrid shall have the ability to blackstart while in island mode.
- Low-carbon on-site generating systems are preferred to fossil-fuel-based systems. Generation technologies such as solar PV, solar thermal, biofuels, and heat recovery shall be incorporated in the microgrid to the maximum extent possible. Secondary preferences for generation will include high-efficiency systems such as cogeneration / combined heat and power, and trigeneration.

- The microgrid is expected to provide emergency, critical, and backup power services for the City Yards site; therefore, any separate emergency generators anticipated for the City Yards buildings should not be necessary.

Design and Technical Requirements

- The City Yards design team shall determine a single point of common coupling (PCC) between the microgrid and the SCE distribution systems. The PCC location and capacity shall be based on accepted engineering design and application electrical codes, as well as through discussions and direction from SCE.
- A digital, motorized circuit breaker shall be provided at the PCC. SCE's Rule 21 interconnection process shall determine the breaker operations, set points, and tolerances (SCE, n.d.). Rule 21 shall be adopted and used for the PCC design, metering, breaker settings, and other relevant coordination.
- The microgrid shall be able to seamlessly connect and disconnect from the SCE system, using a closed-transition, synchronous process, to maintain power quality and facilitate continuous City Yards operation.
- The 10-day resilience requirements for the microgrid will require one or more forms of on-site energy storage. These may be a combination of batteries, fossil-fuel generators, and other appropriate energy storage systems. As part of the project pre-design process, the design team shall determine the type and quantity of on-site energy storage. The physical location and civil, mechanical, and electrical design of the on-site energy storage systems shall be determined during the schematic through construction document phases of the City Yards design.
- Sufficient autonomous, on-site electrical energy storage shall be provided and available at all times to allow the microgrid to operate at full load, independently of the utility service, for at least 2 days.
- The microgrid shall respond to a loss of utility power (while in paralleling mode) within 15 cycles to immediately transfer to island mode and provide all required power. If available generation cannot support all loads, non-critical loads shall be shed to maintain service for all critical and emergency loads.
- If the microgrid is in island mode and without available generation operating, the MCC shall immediately begin a black-start sequence.
- The selection and sizing of on-site generation resources and energy storage systems shall be performed during subsequent phases of this project.
- The MCC shall provide comprehensive control of the microgrid, including the following key capabilities:
    - Selection, dispatch, and curtailment of the on-site generation assets in an optimal manner to achieve energy balance and minimize export of power
    - Selection, dispatch, and curtailment of the on-site generation and SCE imports to achieve the lowest cost of hourly and monthly operation
    - Coordination of the generation of on-site energy with SCE purchases to optimize the rate of charging and quantity of energy stored in batteries for both reliability and economic criteria

    - Determination of the dispatch timing and rate of discharge of the battery system to achieve operational and economic requirements, black start, and other needed performance
    - Recording and storing of operational data for all controlled devices and meters on the microgrid; data points and frequency of measurements to be determined during the microgrid design phases
    - Load shedding, with a prioritization of circuits
    - Local alarming, annunciation, and external notification for any faults, failures, and predetermined conditions
- The microgrid MCC and supervisory control and data acquisition systems shall be either open-source or allow for full data export capabilities to communicate near-real-time microgrid performance information to appropriate (i.e., as determined by the City) stakeholders, SCE, and/or third parties.
- The microgrid design and MCC shall consider and incorporate appropriate cybersecurity controls, firewalls, secure access, and safety features as deemed prudent and reasonable by the City Yards design team and the City.

Operational Requirements

- The City of Santa Monica shall be responsible for the microgrid operation, maintenance, and management.
- The City may decide to contract (outsource) the performance of the operations and/or maintenance of the microgrid to a qualified third-party contractor.
- The design of the microgrid shall allow for suitable access to the components and primary system assets by the operators and City-approved vendors, researchers, consultants, and SCE to conduct research and training functions.
- The City should consider having the microgrid participate in the Los Angeles County's Community Choice Aggregator, the Clean Power Alliance, for any net electrical requirements. This participation could provide the microgrid with a greater percentage of renewable, low-carbon energy content than is currently available from SCE. Clean Power Alliance currently offers three rates with different renewable content: 36 percent, 50 percent, and generation from 100 percent green power. However, it is likely that the 100 percent renewable energy costs could be as much as 6.3 percent higher than forecasted SCE commercial rates.

As additional microgrid users and participants are added to the system in the future, the City shall determine contractual terms and conditions, and financial compensation methods among the parties, along with rates. As the microgrid owner, the city of Santa Monica shall be responsible for creating and negotiating these agreements.

Potential Barriers to Microgrid Implementation

California regulatory structure is built around the historical model of the electric utility as a "natural monopoly." Typically, the utility natural monopoly has been vertically integrated, owning generation, transmission, and distribution systems that serve all electric customers in a geographic service territory. More recently, with restructuring, electricity is now treated as a commodity, centrally produced by large generation facilities owned by utilities or independent power producers. These utilities/producers then sell the electricity in a market to utilities that provide electricity to retail customers.

Existing laws and rules limit the ability of a customer to purchase electricity from any provider other than the incumbent utility. With the enacting of Assembly Bill 117 (Migden, Chapter 838, Statutes of 2002), this barrier was partially overcome for California cities and counties, which can become now community choice aggregators (CCA). A community choice aggregation is a program that allows cities to buy and/or generate electricity for residents and businesses within their areas, as an alternative to traditional utilities. Community choice aggregators often provide residents with lower rates and higher percentages of renewable energy than the traditional utilities. For Santa Monica, the Clean Power Alliance of Southern California (CPA) was created and is expected to begin the formal supply of power to the City's residential customers in January 2019.

Table 4 identifies the top 10 barriers to microgrid commercialization, according to a survey carried out for the Energy Commission.

Table 4: Top 10 Barriers to Microgrid Commercialization

Barrier	Rank	Average Score (5 highest, 1 lowest)
Lack of policies or regulations that enable microgrids	1	4.1
Interconnection rules impose limitations on microgrids	2	4.0
Utility franchise rights inhibit microgrid deployment	3	4.0
Existing retail tariffs do not allow all microgrid benefits to be monetized	4	3.9
High cost of meeting interconnection requirements	5	3.8
Lack of direct access to wholesale markets do not allow all microgrid benefits to be monetized	6	3.7
Lack of utility understanding of the impacts of end- user microgrids to the utility	7	3.6
Adequacy of IEEE* technical standards to address integration and operation of microgrids	8	3.5
Lack of clearly defined roles and responsibilities between utility and microgrids	9	3.5
Lack of standardized method to establish cost and value of microgrids to various stakeholders	10	3.5

***Institute of Electrical and Electronics Engineers**

Source: California Energy Commission, 2015.

Current barriers to microgrid systems have been grouped under four aspects: Technical, financial, regulatory and social.

Technical Barriers

A survey prepared for the California Energy Commission (2015) indicated that technical barriers represent the least concern to microgrid developers, designers, and manufacturers.

Microgrids are created by integrating multiple components into a single system. Failure of a component can undermine the successful operation of the entire microgrid system. Challenges can also be associated with communication and control software, which can reduce the utilization factor for renewables, or underuse of energy storage systems, such as batteries. This is especially relevant due to the lack of technical standards to address integration and operation of microgrids.

Obvious solutions to avoid these issues are to incorporate multiples technologies and communication/control software that are proven and cost-effective.

The main technical barriers to microgrids are identified in the following sections.

Dual-Mode Operation

The core of the microgrid concept is its ability to transition from grid-connected mode to island mode, either intentionally to reduce energy purchases or due to a fault event. This conversion to island mode can take two forms: black start, which allows a short period of outage before reenergizing the system in island mode, or seamless transition within a very short time (microseconds) after disconnecting from the main grid, which generally requires upgraded (i.e., closed-transition) switchgear.

Reconnecting the microgrid to the main grid also poses challenges. Resynchronizing the two grids after the fault event has been resolved requires carefully choosing the moment to close the switch between them and requires further voltage and/or frequency controls while in the islanded microgrid to synchronize and avoid mismatches between both grids.

The ability to support the transition between on- and off-grid modes lies at the individual component level, particularly the inverters and converters needed for distributed energy resources (DER) since the conversions need to occur in a short period of time.

Power and Frequency Control

Operators of the main grid (SCE and the California Independent System Operator [CAISO]) must maintain specified frequency and voltage quality to ensure stable power flow to all consumers. This poses certain requirements for grid-connected microgrids due to the potential for fluctuating power, frequency, and phasing generated at the microgrid.

Difficulties also arise in the coordinated control of harmonic currents and voltage between many DER with often-conflicting requirements. Therefore, power-quality issues should be carefully dealt with and matched to network standards, which can be a challenge to identify due to the limited direct transparency, accuracy, and availability of network running states.

The power and frequency control problem ultimately lies at the component level, either from intermittent generation like PV and wind, or when there is frequent load switching.

Protection and Safety

Short-circuit faults, which can harm components, consumer equipment, and personnel, are common events in the power system. Therefore, just like the traditional power system, microgrids need protection schemes against not only external faults, but also internal faults. To prevent the microgrid from being exposed to high voltages during external faults, protective relays should be installed to automatically detect abnormal conditions and initiate circuit breakers to isolate the fault.

In grid-connected mode, this protection can normally be achieved with a switch at the connecting point. However, the major issue arises in island operation with inverter-based generation resources, such as PV or wind. This is because fault currents in inverter-based microgrids may not have sufficient current rates to use traditional over-current protection techniques that rely on high fault currents for detection.

While many safety solutions have been researched and presented, more research needs to be done on differential protection or voltage-based protection mechanisms to complement the current safety proposals.

Regulatory Barriers

Proper regulatory support is a critical foundation to smooth microgrid implementation, providing guidance and allowing for distributed generation (DG) penetration, integration, and main network connection. Many aspects of current legislation limit and prevent the use of microgrids.

Current regulations undermine one of the key benefits of microgrids to integrate and control DER to optimize the end users' power consumption. This leads to issues with interconnection rules and bidirectional power flow and, thus, the inability to trade locally produced power.

The main regulatory barriers to microgrids are identified in the following sections.

Interconnection Rules

When DG integration into the main power grid began, network operators created interconnection guidelines and codes to standardize the process and manage the impacts of DG integration without disturbing the functionality and safety of the main grid. For the California investor-owned utilities, these interconnection protocols are called Rule 21 (CPUC 2018a).

While some of the Rule 21 guidelines do not directly apply to the microgrid concept, anti-islanding and fault regulations do affect microgrid design because they effectively treat distributed energy sources as a potential source of disturbance to the grid. Therefore, these interconnection rules force immediate disconnection during blackout to avoid operation/protection complexities and prevent potential safety threats to network users and utility field crews. The anti-islanding capability comes with passive protection schemes, using voltage and frequency relays at the installed generator, or active protection schemes in inverter-connected generators (PV or wind). These use sophisticated algorithms for detecting loss of grid conditions. Anti-islanding protection schemes may ultimately interfere with the microgrid's ability to seamlessly transition to island mode and continue functioning locally.

This barrier is overcome with the installation of a control switch at the point of connection to the grid, called the point of common coupling (PCC), where the microgrid connects to the distribution grid, combined with a microgrid master controller (MCC) global control system. The MCC system automatically monitors and detects faults so that microgrids can disconnect from the grid before anti-islanding mechanisms are activated. This PCC switch and control system allows generators to continue producing power without feeding it back into grid, thereby preventing potential safety hazards.

Bidirectional Flow of Reactive Power

Once the PCC is established to switch the microgrid on and off from the distribution grid and the network starts to view the microgrid as one functioning entity rather than a bunch of individual generating and load units, another problem arises — microgrid control of bidirectional flow of reactive power at the PCC.

Ideally, the microgrid should be able to participate in the electricity market by buying and selling active and reactive powers to/from the grid. However, under current regulatory and market frameworks, microgrids may import but cannot export active power, unless specifically designed and permitted by the utility interconnection agreements and tariffs. This is because the grid operators can stipulate that there is no export of power (except momentary inadvertent power) from microgrids if no agreements are in place for who will buy back the electricity produced from renewable energy sources.

If microgrids cannot export the power produced by their generation units, this has implications for their ability to trade with local consumers via the distribution network. This type of local trading mechanism is a concern for local energy suppliers and grid operators since local trading would take away from the energy suppliers' daily income and reduce the use of system fees charged by the system operator.

Therefore, microgrids are impacted by regulatory and market conditions that abolish any economic gains that would incentivize and push microgrid implementation forward. If grid feedback or net metering for systems above 1MW was allowed, opening the gates for local trading, a common stakeholder sharing platform would need to be created to resolve the power trading between the grid operator (SCE) or energy supplier, and the user. To provide sufficient incentives for both existing and new players in the energy retail chain, such a platform would need to transfer some of the benefits of local retail market to SCE and energy suppliers.

However, this would require a complicated market-clearing mechanism to properly allocate net values created within this business model.

Relationship with Incumbent Distribution Utility and Ability to Export Locally

In Santa Monica, as in most of the United States, the existing distribution system is owned and operated by the distribution system operator, usually under a local franchise agreement. This was essential in the early days of electrification to reduce the amount of redundant infrastructure. The monopoly ownership and control of the existing distribution infrastructure creates a problem for independent microgrid development because SCE is responsible for safety, cost, and operational stability.

Selling electricity to other entities or installing wires over/under public streets can trigger franchise-rights litigation. A non-utility installing facilities and distributing electricity over public streets will get the attention of the local utility that has a franchise to build power lines. Not only does a microgrid need to avoid infringing on a utility's franchise rights, but it also needs to work with the utility to avoid having to go through lengthy and expensive litigation just to prove that it is not doing so. This may require contracting with the utility to pay a rate for using the wires that cross public streets to avoid franchise issues. Local governments may need to modify the franchise agreement or make other considerations for microgrid developers for microgrids to be developed in certain municipalities.

Regulators have many ways to address the utility control of the distribution system. With a comprehensive site survey to determine optimal sites for microgrids, the distribution grid characteristics in the optimal sites can be modeled using automated grid-simulation and power-flow-modeling tools. This approach streamlines the engineering effort required to address the impact of modifications that may be required for microgrid development. A comprehensive model of the distribution grid that enables simulation and modeling will be required in any case to streamline any DG implementation. Expanding the simulation capability to include microgrid modeling would give greater flexibility from a policy standpoint.

Current SCE Renewable Energy Self-Generation Bill Credit Transfer (RES-BCT) tariffs allow local governments with one or more eligible renewable-generating facilities to export energy to the grid and receive generation credits that benefit other local energy accounts. The following criteria are required:

- The customer must be a city, county, special district, school district, university, political subdivision, or other local public agency.
- The maximum generator size is 5MW, and multiple arrangements are allowed.
- The benefiting account may be at remote locations within the same city or county.
- Generating and benefiting accounts in the arrangement must be on a time-of-use rate schedule.

Financial Barriers

Commercialization of the microgrid concept heavily depends on the reduction of production costs of renewable energy generation, storage technologies, and energy management systems. While some technologies have already become cost-effective (e.g., PV), many important technologies like fuel cells and storage technologies remain expensive without some sort of financial support.

In addition to the capital cost of microgrids, the main financial barriers to microgrids are identified in the following sections.

Standby Charges and Departing Load Charges

Departing load charges apply to California investor-owned utilities customers who generate a significant amount or all of their own power. These charges cover forward power procured on behalf of these customers. However, if the generation is "clean," the customer may be exempt from these charges. These charges apply to any customer that no longer receives power from the incumbent utility (SCE). In California, new Direct Access customers must pay these charges, as well as customers who shift to a community choice aggregator (CCA). These charges are "vintaged" because the amount of forward power purchases that these customers are responsible for declines over time, and eventually goes to zero.

Standby charges apply to self-generation customers who remain connected to the grid, regardless of whether they receive power from the incumbent utility. The customer pays these charges because the utility is required by law to deliver energy automatically if the customer's generator is not working. Standby charges are assessed to cover the cost of providing this service. These costs are assessed based on the size of the customer's generator (e.g., PV plant size) and load. These charges are meant to reflect the share of the customer's cost of operating and maintaining the infrastructure to provide them with reliable power.

In the case of microgrids, if a microgrid can supply most or all of its own electricity needs and can island but remain connected to the grid, standby charges may also apply, increasing the cost of the electricity and reducing the competitiveness of the microgrid. For microgrid-based electric supply to be cost-competitive, the nature and amount of the standby charges need to be revaluated by the regulator.

A major consideration that distinguishes microgrids from other types of customer generation is its capacity to provide services back to the grid. In other words, the microgrid can "net out" the benefits. It is no longer the case with a microgrid that the grid connection exists solely for the benefit of the microgrid owner. The grid connection can also benefit the system more broadly to the extent the microgrid can provide operational services to the grid, such as ancillary services or frequency regulation.

Cost and Cost Recovery

In California, the "bundled" customer (specifically where generation procurement, transmission, and distribution services are all provided by the incumbent utility to the customer) pays the generation charge as a "pass through" — the utility is required to charge for generation of power consumed by the customer at cost. How the generation charge is set depends on the customer tariff, but ultimately the total retail cost of generation paid by all customers is the actual total cost of the electricity that is contracted for by the utility.

Transmission and distribution, on the other hand, are the revenue base on which the utility can collect a rate of return. The rate of return is guaranteed by the California Public Utilities Commission (CPUC). Rates for transmission and distribution are set based on operating costs and a return on equity. Normally, the transmission and distribution costs represent about 40 percent of the total cost a bundled customer pays for electricity.

For microgrids, the cost of electricity paid by the customer will depend on the following factors:

- The cost of the electricity produced by the microgrid
- The cost of distribution services set by the distribution operator
- Any additional costs associated with interconnection to the grid
- Any additional revenues associated with services that the microgrid can supply to the SCE utility grid
- Profit for the microgrid owner/operator/developer.

Rationalizing these factors with the existing tariff and billing structures of the incumbent utility is a key challenge.

To the extent that microgrids can be located where they can provide benefits to the grid, such as relieving congestion, current mandates suggest that the costs of grid upgrades to support DER may be included in the utility's general rate case. This approach would take the burden of grid modernization costs off the developer (and its customers) and allocate it toward all ratepayers who benefit from the presence of the microgrid.

Social and Political Barriers

While there are potentially many social and political challenges with microgrids, Santa Monica is generally viewed as having a favorable setting for low-carbon and renewable energy projects. It is expected that the City Yards modernization, together with the implementation of the microgrid, will be well received by the surrounding neighbors and city occupants.

Managing Operations

The day-to-day operations can still be challenging since microgrids are new systems and stakeholders may not always be familiar with operating the system components. This is especially the case for abnormal operating conditions or emergencies where impacts are greater than anticipated.

Comprehensive microgrid operator training, contingency planning, and user-friendly interfaces are important components to easily and consistently maintain the microgrid's normal operation particularly during unforeseen events, like earthquakes or other natural disasters.

Lack of Stakeholder Trust, Knowledge, or Buy-In

The lack of stakeholder understanding in the microgrid system can make buy-in for the project operations difficult. This trend has occurred in previous California microgrid pilot projects.

Early Stakeholder involvement in decision-making can foster trust and cohesiveness among all parties. Building a cooperative relationship between the utility and the microgrid system is especially important if the microgrid is to be connected to the grid.

Stakeholder Identification and Engagement

A Stakeholder Engagement Plan is essential for the construction and operation of a multiuser microgrid. The plan must include the people, groups, and organizations that could affect or be affected by the operation of the City Yards microgrid. Plan development includes analysis of stakeholder expectations and their potential impact on the operation. This document may be created from the owner's project requirements, including the design project requirements, and then evolve with the operation.

The consultant team has identified a preliminary list of internal and external stakeholder groups that will affect or be affected by the City Yards microgrid project (Figure 12). When implementing this microgrid project, the city should perform a detailed stakeholder analysis in which potential stakeholders and relevant information (interests, involvement, interdependencies, influence, and potential impact on project success) are gathered, documented, and analyzed. Some preliminary community outreach has already been done as part of the environmental impact report.

Once this information has been collected, the city should develop appropriate strategies and tactics for effectively engaging internal and external stakeholders in a manner appropriate to the stakeholders' interest and involvement in City operations. The Stakeholder Engagement Plan helps to:

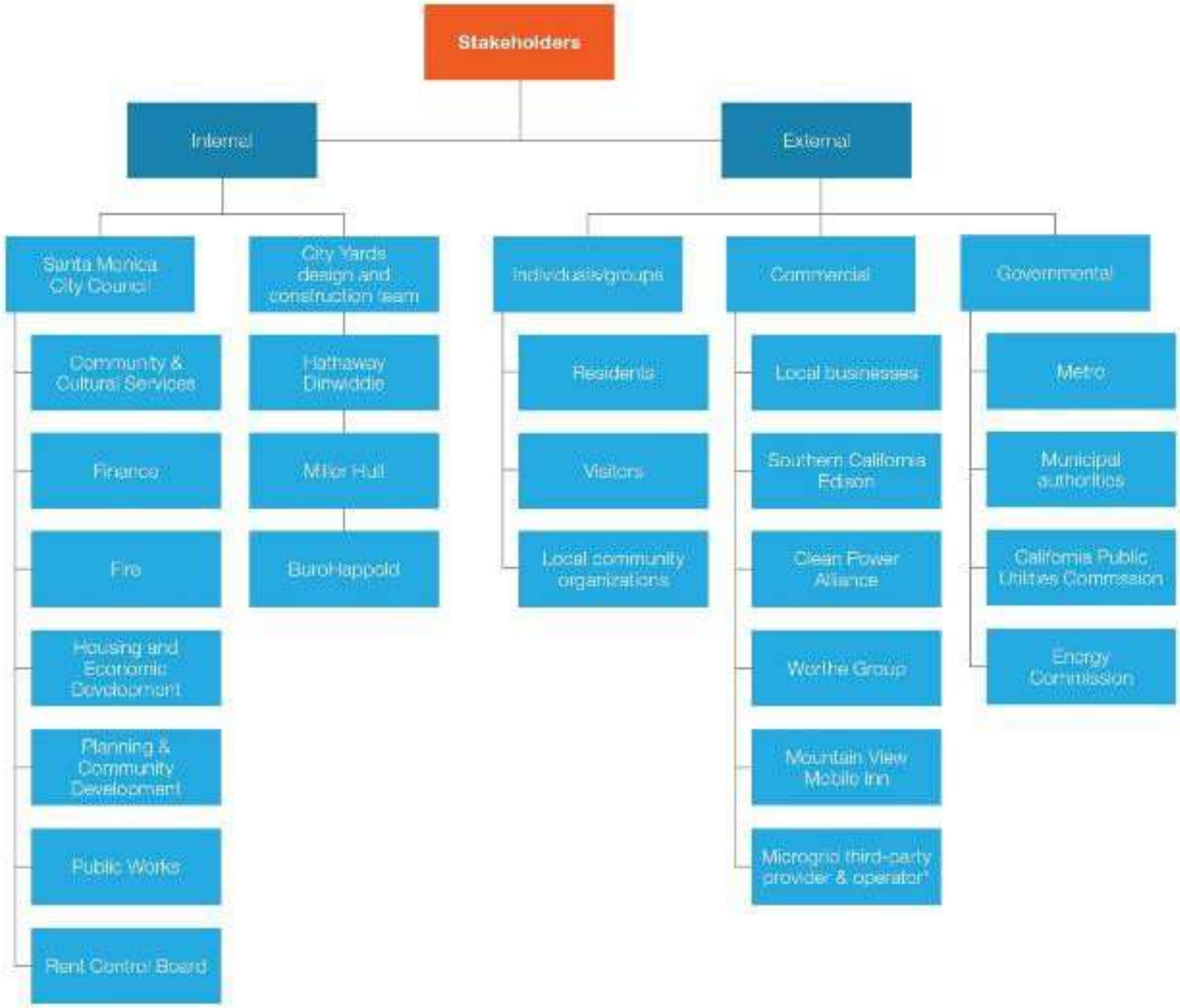
- Ensure that stakeholders are effectively involved in project decisions and execution throughout the lifecycle of the project.
- Gain support for the project.
- Anticipate resistance, conflict, or competing goals among the project's stakeholders.

Best practices from similar public projects indicate that the microgrid development team must conduct a consensus exercise with most, if not all, external and internal actors affected by the project.

Stakeholder engagement is divided into these stages:

1. Familiarize external actors with the project and city goals
2. Present the general vision and objectives established by the City of Santa Monica
3. Collect comments and suggestions to enhance the project
4. Discuss feedback with the design team and city internal stakeholders.
5. Integrate into the design when feasible.

Figure 12: Preliminary Stakeholder Groups



*** Depending on the microgrid procurement process and governance model**

Source: Arup North America Ltd

Community Benefits for Project Success

An important first step is for the city to engage with established local community organizations early and often. Community organizations are instrumental in building trust between local governments and the public. Trust and transparency is key to project success and ongoing support, particularly because the project site is an environmental justice site where there used to be an open landfill near residents. Stakeholders will need to know precisely how the project can benefit them and correct the injustices that have happened in the past. Equitable planning and holistic stakeholder engagement through thorough community outreach can help to achieve this. A community-benefit agreement can be written between the community and the city to define the "shared prosperity" of the project.

Other community benefits fall into three main piles: energy rates, housing, and employment. Once the microgrid is up and running, equitable affordable energy rate structures should be developed. These should consider socioeconomic conditions, medical conditions, and other factors to accurate reflect the community.

Since one of the unintended consequences of Bergamot redevelopment may be gentrification and displacement of low income residents and businesses, it is important to help retain those communities through promotion of transit-oriented affordable housing. The housing and employment protections for residents of the center's surrounding neighborhoods should be codified and deed-restricted housing preserved. This is supported by the passage of Proposition R in 1990 to ensure at least 30 percent of new housing is affordable and expansion of affordable housing options and programs such as the family self-sufficiency and housing choice voucher programs. A community-benefits agreement can be written to include reserving 30 percent of new and rehabilitated housing in the neighborhoods surrounding the center for low-income and working families, freezing property taxes for longtime residents, independently monitoring and assuring local hiring in and around the center, and requiring that a percentage of development costs in the area be set aside for affordable housing and employment programs.

Local employment is another approach that will help prevent displacement and retain local wealth. During the microgrid construction process, there can be stipulations for a certain percentage of the workers to be hired from local businesses.

Policy and Incentive Matrix

The project team developed the following policy and incentive matrix, which identifies relevant stakeholders, primary barriers to adoption, potential policies and incentives to barrier removal, and market impact. The matrix (Tables 5, 6, 7 and 8) was developed for four aspects: social and political, financial and economic, technical, and regulatory.

Table 5: Policy and Incentive Matrix – Social and Political

Barrier >	Public perception regarding project cost	Environmental injustice
Scenario	All scenarios	City Yards Design Baseline
Involved Stakeholder	City of Santa Monica, local communities, public	Disadvantaged/low income communities near Santa Monica City Yards
Policies Oriented to Remove Barrier	**Communications policy** that understands community concerns and seeks to address them. **Public procurement policies** that ensure transparency and require a certain percentage of work to be completed by local contractors, disadvantaged businesses, or mission-drive organizations. **Lifecycle Cost Assessment Policy** to assess and communicate the project social, economic, and environmental costs and benefits over the life of the project.	**Equity in Climate Action Policies**. Follow the Community Driven Climate Resilience Planning Framework (https://www.nacrp.org/) other environmental justice principles. City of Santa Monica Council's stated goal: Provide presentations and outreach targeting at engaging vulnerable populations.
Incentives to Overcome Barrier	Improved trust between City and the public, City of Santa Monica Council goal: provide transparency in planning procedures	Equitable planning and community belonging, stakeholder engagement through community outreach
Market Impact		Community-benefits agreement (CBA). Include reserving 30% of new and rehabilitated housing in the neighborhoods surrounding the center for low-income and working families, freezing property taxes for longtime residents, independently monitoring and assuring local hiring in and around the center, and requiring that a percentage of development costs in the area be set aside for affordable housing and employment programs
Notes	Santa Monica's attempt to implement a Living Building Challenge project had similar public outcry, despite payback over time.	Site has history of dirty operations (trash/recycling, fueling station, former landfill) and environmental injustice.

Barrier >	Affordability concerns	Gentrification
Scenario	All scenarios	All scenarios
Involved Stakeholder	Frontline communities near microgrid, City of Santa Monica	Frontline communities near microgrid, City of Santa Monica
Policies Oriented to Remove Barrier	Equitable affordable energy rate structures that take into account socioeconomic conditions, race, medical conditions, and other factors. The passage of Proposition R in 1990 to ensure at least 30% of new housing is affordable. Expansion of affordable housing options and programs-- including the family self-sufficiency and housing choice voucher programs. Community Benefit Agreements: create a written agreement between the community and the City to defines the "shared prosperity" of the project. Affordable Housing Policies. Require that a percentage of the developments costs be set aside for affordable housing and employment programs. Local property tax policies to freeze property taxes for longtime residents. Local hiring polices to assure local hiring in and around the development.	Transit oriented affordable housing policy combined with continuous relationship building with local community groups. Codify housing and employment protections for residents of the center's surrounding neighborhoods. Preserve deed-restricted housing.

Barrier >	Affordability concerns	Gentrification
Incentives to Overcome Barrier	Equitable and affordable energy access for all. Energy resilience for low income residents/small businesses. Energy programs centered around helping low income households, energy rebates.	Preventing displacement of vulnerable residents and small businesses, incorporating diversity of all kinds into new development, community events and city-wide programming
Market Impact		Working alongside Metro to determine opportunities for shared and common-use resources between these adjacent sites.
Notes		

Barrier >	Lack of stakeholder trust/knowledge and buy in	Lack of stakeholder trust/knowledge and buy in	New and unknown business model for decision makers
Scenario	All scenarios	Add Ons: Clean Power Alliance	All scenarios
Involved Stakeholder	City of Santa Monica, Worthe (Bergamot), Metro, SCE	City of Santa Monica, CPA, SCE	City of Santa Monica, EPIC team
Policies Oriented to Remove Barrier	Entitlement process: legal review, architecture review board for project components be confirmed and accepted by public. Any issues that need mitigating would be resolved there and is more intensive than the EIR.	The CPA may be involved in the EPIC Project Phase 2 to get a further insight of the market and develop policies/incentives with the City and SCE.	Process guidelines for microgrid planning including operations, maintenance, and ongoing financial obligations
Incentives to Overcome Barrier	Smoother operations, communications, and investment. Lower energy cost or higher reliability. Public perception that Santa Monica as a sustainable community, project would be in the ethos of Santa Monica business.	Smoother operations, communications, and investment. Lower energy cost or higher reliability	Clearer understanding and buy-in from all decision makers
Market Impact		Incentive rates may lead to more revenue for Santa Monica and greater solar energy sold back to the grid when the City Yards are not able to absorb the excess production, With current rates, the cost of energy will raise approx. 16%, compared to SCE standard rate.	Provide a successful example of developing an "Owners Project Requirements" using a Use Case Analysis for a Multi-User Microgrid.
Notes			Information is very technical, based on models and assumptions, and difficult for decision makers to get behind. Phase II will need to expand on financial obligation and operations perspective.

Table 6: Policy and Incentive Matrix – Financial and Economic

Barrier >	Grid Connection Costs	Standby charges and departing load charges
Scenario	Scenarios #1-3	Scenario #1-3
Involved Stakeholder	City of Santa Monica, SCE	City of Santa Monica, SCE
Policies Oriented to Remove Barrier	CPUC Interconnection Proceeding (R.17-07-007) and Rule 21, CPUC Energy Storage Proceeding (R.15-03-011)	CPUC's Renewable Energy Market Adjusting Tariff (note Dec 2017 CPUC put hold on approving new ReMAT contracts) CPUC Energy Storage Proceeding (R.15-03-011)
Incentives to Overcome Barrier	Combining all meters into a single Point of Common Coupling (PCC) will reduce the demand charges	Facilities with net energy metering do not have to pay for standby charges.
Market Impact		Departing load charges apply to all customers and are calculated by how much load is taken away from SCE for another source.
Notes		Standby charges are rates applied to self-generation customers who remain connected to the grid as SCE acts as a backup energy source. Departing load charges are calculated by how much load is discontinued from SCE for other sources. For microgrid-based electric supply to be cost-competitive, the nature and amount of the standby charges need to be revaluated by the regulator. Participating in ancillary energy services may lower energy costs, as it allows the microgrid to be paid for its potential benefit to the grid.

Barrier >	Currently there are no microgrid specific rates.	High capital cost and long payback periods for batteries
Scenario	Microgrid Scenario #1-3	Microgrid Scenario #1-3
Involved Stakeholder	City of Santa Monica, SCE, CPA	City of Santa Monica
Policies Oriented to Remove Barrier	CPUC Energy Storage Proceeding (R.15-03-011). New rates structures specifically for microgrids should be developed to help promote more microgrid development and reach the State's goals on community resilience, energy affordability, and emissions reduction.	The following law/regulations promote the use of EES, which would reduce the cost of its components. · Assembly Bill (AB) 327 (Distributed resource planning requirements - 2013) · Assembly Bill (AB) 2514
Incentives to Overcome Barrier	The 2018 General Rate Case will create new TOU periods that may promote the use of EES tied to solar PV.	Existing EPIC grant, ITC tax credit, SGIP Recognizing the benefits that microgrid can bring to the macrogrid may reduce payback periods Ability for generators >500kW to participate in the ancillary services market to provide income streams

Barrier >	Currently there are no microgrid specific rates.	High capital cost and long payback periods for batteries
Market Impact	The new TOU periods may increase the electricity cost of PV owners, as part of the time when PV produces its electricity will go from on-peak to off-peak.	While the batteries are expensive, increasing the battery use will increase its cost-effectiveness. For microgrids, the cost of electricity paid by the customer will depend on the following factors: · The cost of the electricity produced by the microgrid. · The cost of distribution services set by the distribution operator · Any additional costs associated with interconnection to the grid · Any additional revenues associated with services that the microgrid can supply to the macro-grid; and, Profit for the
Notes		

Barrier >	Determining organizational structure (governance) for payback with multiple entities under one meter	Complex interactions between demand and generation by multiple partners
Scenario	Microgrid Scenario #2-3	Microgrid Scenario #2-3
Involved Stakeholder	City of Santa Monica, SCE, Worthe (Bergamot)	City of Santa Monica, hotel/restaurants in area, Worthe (Bergamot), Metro, SCE
Policies Oriented to Remove Barrier	SCE tariff RES-BCT for local governments may simplify these interactions by allowing Virtual Net metering between different governmental facilities.	It will be required to create mechanisms to account for energy transactions between stakeholders
Incentives to Overcome Barrier	New and innovative solutions such as blockchain technology and peer-to-peer energy resource sharing may be options for owners and users of the microgrid	Ease of determining demand and generation, and assigning credit/debt as needed by all stakeholders
Market Impact		There will be a substantial market impact once it is possible to buy energy from local DERs
Notes		

Barrier >	Right of way and franchise rights	Separate SCE account and meter required for selling excess energy to grid
Scenario	Microgrid Scenario #3	Add Ons: Clean Power Alliance
Involved Stakeholder	City of Santa Monica, Metro, SCE	CPA, City of Santa Monica, SCE
Policies Oriented to Remove Barrier	Clarification of Rule 218(b) or a new CPUC Rule: If the CPUC were to allow commonly owned buildings participating in a microgrid to aggregate power across the public right-of-way, this would eliminate the barriers caused by CPUC Rule 218(b) and allow cities to develop microgrids without having to become a municipal utility.	CPA can work collaboratively with City to develop best project rates.
Incentives to Overcome Barrier		There will be net metering. Surplus power is bought by CPA at 0.06 $/kWh
Market Impact	Current alternative for crossing public right of way is to build a new inter-facility distribution line owned and operated by the IOU. However, there are large capital costs, a substantial utility transfer fee, and operational costs.	
Notes		

Table 7: Policy and Incentive Matrix – Technical

Barrier >	Microgrid controls: cost and complexity of the required control systems.	Lack of data for modification of existing systems and new (greenfield) systems: This lack of data can result in oversized (overly expensive) microgrids.
Scenario	Microgrid Scenario #1-3	Microgrid Scenario #1-3
Involved Stakeholder	City of Santa Monica, SCE	City of Santa Monica, microgrid operators, SCE, ISOs/RTOs
Policies Oriented to Remove Barrier	· Any policy prioritizing solar and storage over solar by itself · Assembly Bill (AB) 327 (Distributed resource planning requirements - 2013) · CPUC Energy Storage Proceeding (R.15-03-011) · Assembly Bill (AB) 2514	No policies are oriented to address this barrier at this time
Incentives to Overcome Barrier	Existing EPIC grant, ITC tax credit, CPUC's Self Generation Incentive Program for existing, new, or emerging distributed energy sources	No financial incentives are set up to overcome this barrier
Market Impact	Finding and hiring qualified and capable technical staff to operate and maintain the microgrid could be a challenge.	Increase in energy costs for the microgrid
Notes		Operation of the microgrid will be semi-automatic, and will react to specific grid events in a prescribed manner. Most 'operations' by the operator will be maintenance related. Most of the day to day switching and control is automatic.

Table 8: Policy and Incentive Matrix – Regulatory

Barrier >	CPUC's Interconnection Proceeding R.17 07 007 / Rule 21: Anti islanding protection schemes force immediate disconnection during blackout to avoid operation complexities and prevent potential safety threats to network users and utility field crews.	Local wheeling capability: local power sharing for incorporating neighboring properties (Bergemot & Metro) into the City Yards microgrid.
Scenario	Microgrid Scenario #1-3	Microgrid Scenario #2-3
Involved Stakeholder	SCE, City of Santa Monica, CPUC, Federal Energy Regulatory Commission (FERC)	SCE, City of Santa Monica, CPUC, Bergamot, Metro
Policies Oriented to Remove Barrier	Clarification of Rule 21 interconnection and tariff rules for the islanded operation of systems: None of the existing tariffs under Rule 21 clarify the governance of microgrid operation in islanded mode. While backup generation may be allowed to operate during a grid outage, there is no guidance to support a utility tariff for microgrid-generated power during the outage or regarding nonutility operation of inter-facility distribution lines during the outage. This limits the ability of multi-facility microgrids to recover project costs and/or distribute power to third-party customers. Clarification of this rule would help to advance microgrids.	A single meter (master meter) or virtual single meter tariff structures would allow for renewable energy resources and storage to offset coincident peak demand at multiple facilities, even if solar and storage are not co-located, and could be key for maximizing the potential energy savings for any microgrid Currently there are no tariffs that would allow a microgrid to incorporate multiple facilities owned by different parties to share power or credits. If such a tariff were to exist, it could provide some cost benefits for these types of systems. However, there is currently limited CPUC guidance related to this, and it may be solely at the utility's discretion to allow for a more favorable metering arrangement.
Incentives to Overcome Barrier	Certain regions have expanded interconnection rules to allow for economic payback on services offered by microgrids	Aggregating projects together will allow for sites where it is difficult to have standalone renewable energy generation to share in locally generated energy.
Market Impact	Microgrid exceptions to SCE's anti-islanding protection schemes could be expanded to other scenarios.	Being able to aggregate projects together can increase the revenue potential and create a more attractive portfolio of assets with a larger scale. The aggregated scale of the assets' value may then be sufficient to justify a financiers' consideration through reducing transaction costs, diversifying cash flows, and standardizing collateral. This method has proven successful in a number of industries.
Notes	Install a control switch at the point of connection to the grid, called the Point of Common Coupling (PCC) where the microgrid connects to the distribution grid, combined with a Microgrid Master Controller (MCC) global control system. The MCC system automatically monitors and detects faults so that microgrids can disconnect from the grid before anti-islanding mechanisms are activated. This PCC switch and control system allows generators to continue producing power without feeding it back into grid, and thereby preventing potential safety hazards.	

Barrier >	Bi directional flow of reactive power: Microgrids may import but cannot export active power, unless specifically designed and permitted by the utility's Interconnection Agreements and tariffs.	A non utility facility distributing electricity over public streets need to get approval from the local utility that has a franchise to build power lines.
Scenario	Microgrid Scenario #1-3	Microgrid Scenario #1-3
Involved Stakeholder	SCE, City of Santa Monica, CPUC	SCE, City of Santa Monica, CPUC
Policies Oriented to Remove Barrier	Current SCE RES-BCT tariffs allow local governments with one or more eligible renewable generating facilities to export energy to the grid and receive generation credits to benefitting other accounts of the same local government, however the following criteria is required: • The customer must be a city, county, special district, school district, university, political subdivision or other local public agency. • The maximum generator size is 5MW, and multiple arrangements are allowed. • The benefiting account may be at remote locations within the same city or county. • Generating and benefiting accounts in the "arrangement" must be on a time-of-use rate schedule. The CPUC should amend the IOUs' Interconnection Agreements and tariffs to allow for greater flexibility to export active power beyond internal facilities.	CPUC Rule 218(b) regulates the right of way and franchise agreement. If the CPUC were to allow commonly owned buildings participating in a microgrid to aggregate power across the public right of-way, this would eliminate the barriers caused by CPUC Rule 218(b) and allow cities to develop microgrids without having to become a municipal utility.
Incentives to Overcome Barrier	The current regulatory and market conditions make microgrids outside of campuses very difficult to sustain economically. Allowing for more flexibility in the regulatory landscape will allow for more economic benefits and sustainable business models.	Enabling more microgrids with multiple facilities owned by different entities without any entity needing to build expensive distribution lines.
Market Impact	Microgrids are impacted by regulatory and market conditions that abolish most economic gains that would really incentivize and push microgrid implementation forward. If grid-feedback or net-metering for systems above 1-MW was allowed, opening the gates for local trading, a common stakeholder interest sharing platform would need to be created to resolve the power trading class between the grid operator (SCE) or energy supplier and distributed generators (DG) owners. To provide sufficient incentives for both existing and new players in the energy retail chain, such a platform would need to transfer some of the local benefits of local retail market to SCE and energy suppliers. However, this would require a complicated market clearing mechanism to properly allocate net values created within this business model. FERC Docket ER16-1085-000 would allow microgrids to participate in ancillary service markets if they have a minimum of 500kW of controllable dispatch in California (under CAISO)	
Notes		

Regulatory Framework

In accordance with Chapter 8.24 of Santa Monica Municipal Code, the electrical code applicable for the City of Santa Monica is the "2016 California electrical code" which adopts by reference the National Electrical Code, 2014 edition, with some local amendments (City of Santa Monica 2018c).

Effective since May 2017, Santa Monica City Council adopted the newly proposed Santa Monica Reach Code (City of Santa Monica 2018b). All new non-residential buildings shall be designed to use 10 percent less energy than the allowed energy budget established by the 2016 California Energy Code.

In addition, California has a series of regulations that pertain to microgrid development, and broader policy infrastructure around advanced energy communities. In addition to statewide policies, the federal government also has several existing incentive programs for renewables and energy efficiency.

The following are several of the more significant legislative, regulatory and policy drivers related to microgrids and advanced energy communities in California.

California Public Utilities Commission (CPUC) Interconnection Proceeding (R.17-07-007) and Rule 21

The application, technical review, and interconnection processes for a microgrid are the same as those for typical distributed generation interconnections under Rule 21 (CPUC 2018a). The smart inverter requirements from Rule 21 allow for greater hosting capacity, with minimal infrastructure upgrades. The goal is to allow the adoption of new technologies quickly and cost-effectively and to provide a stable path for distributed energy resources growth while decreasing dependency on fossil fuels.

CPUC Energy Storage Proceeding (R.15-03-011)

Decision D.18-01-003 in Rulemaking R.15-03-011 considered new rules to address the ways microgrids should connect to the existing grid. In mid-January 2018, the CPUC issued revenue stacking rules for energy storage projects which will permit 'revenue stacking', enabling storage projects to quantify and 'stack' multiple energy market benefits, making the installation of energy storage more cost-effective. This allows for smoother transition to islanded operation and provides greater renewable energy supply to microgrids.

The CPUC sees energy storage as a ground-breaking technology to enhance the integration of DERs in the grid. Given the nature of the electricity, that must be used the instant it is generated, the City Yards' battery storage will be central to maximizing the renewable electricity generated onsite. The City Yards are planning to install a 1.2 MW solar array, that at peak generation conditions will generate a significant excess of instant electricity. With the use of battery storage and the current Net Energy Metering schemes, the City Yards plan to be reduce significantly its net energy consumption from the incumbent utility, Southern California Edison (SCE).

Distributed Resources Plans Proceeding (R.14-08-013)

The goal of the Distribution Resource Plans (DRP) proceeding is to move the State towards a high-penetration DER future that accomplishes the goals of making the grid greener and producing ratepayer benefits. The DRP Proceeding has authorized two microgrid projects. The goal is to develop a demonstration project where the utility would serve as a distribution system operator of a microgrid where DERs serve a significant portion of customer load and reliability services. These are the Borrego Springs microgrid in the SDG&E territory and a microgrid in the northern area of Mono County in SCE's territory.

The City Yards project aligns with the state Distribution Resource Plans to increase the penetration of renewable Distributed Energy Resources within California electrical grid.

CPUC's Self-Generation Incentive Program (SGIP)

The Self-Generation Incentive Program (SGIP) provides financial incentives for the installation of new qualifying technologies that are installed to meet all or a portion of the electric energy needs of a facility. The SGIP contributes to GHG emission reductions, demand reductions, and reduced customer electricity purchases, resulting in the electric system reliability through improved transmission and distribution system use; and market transformation for distributed energy resource (DER) technologies (Center for Sustainable Energy 2017). CPUC Decision 17-10-004 created the SGIP Equity Budget, which will be implemented beginning with Step 3. This Equity Budget will be allocated 25 percent of SGIP funds already allocated for energy storage projects, and will provide incentives for customer-sited energy storage in disadvantaged communities and low-income communities in California (CPUC 2018b).

SMCY's is eligible to apply for the SGIP program as a client of SCE. The city will apply for the category "Large Storage Claiming ITC." For the given microgrid project, it is expected that this program could fund the City Yards microgrid with $882,000 if awarded.

Title 24 Building Code

Established in 1977, the California Energy Commission Building Energy Efficiency Standards for Residential and Non-residential Buildings (Title 24, Part 6 of the California Code of Regulations) set building standards that are cost-effective for homeowners over the 30-year lifespan of a building and have been successful at maintaining per capita electricity use, despite a growing economy and population. The Energy Commission is required to update standards every three years and the most recent 2019 update will include requirements for solar on new homes. This raises the question of whether these new buildings will contribute their solar generation to an expanded version of the microgrid system.

Santa Monica Building Code exceeds the state requirements. The City Yards new buildings will need to be at least 10 percent better than 2016 Energy Code (2016 T-24), and include 2 watts of solar PV per square feet of footprint.

CPUC Long-Term Energy Efficiency Strategic Plan

The CPUC Long-Term Energy Efficiency Strategic Plan (adopted in 2008 and updated in 2011) establishes the following goals for ZNE buildings:

- All new residential construction by 2020
- All new commercial construction by 2030
- All new state buildings and major renovations by 2025
- 50 percent of existing commercial buildings retrofitted to ZNE by 2030 (CPUC 2018c)

This would impact new construction near the microgrid site - if the buildings themselves cannot generate enough energy, the microgrid may be a clean energy source for them.

In addition to the more stringent Building Energy code, the City of Santa Monica is evaluating to design the City Yards as zero-net energy, as defined by the International Living Future Institute. This would be achieved by a combination of Energy Efficiency Measures (EEMs) with solar PV and electric batteries. Achieving zero-net energy also requires removing all fossil-fuel combusting devices from the design.

Community Choice Aggregation

Created under AB117 and governed by the CPUC, CCAs allows cities and counties to aggregate their purchasing power in the procurement of renewable energy -for those customers served by regulated utilities (investor-owned utilities), such as SCE, in Los Angeles County.

The cumulative share of CCA load in California is currently about 10 percent of the total state electricity consumption and is expected to rise to 16 percent by 2020 (Julien Gattaciecca, Dr. DeShazo and Kelly Trumbull, The growth in community choice aggregation).

The City of Santa Monica is currently member of a CCA called Clean Power Alliance (CPA). This was created in December 2017 when cities in Los Angeles and Ventura County voted to form a Joint Powers Authority to administer the program. CPA is a public, locally-controlled electricity provider that gives SCE customers such as City of Santa Monica the choice of having 36 percent, 50 percent (ECOplus) or 100 percent (ECO100) of their electricity supplied from clean, renewable sources. While the residential customers can already join the CCA, its commercial customers will need to wait until 2019.

California Renewables Portfolio Standard Program

AB327 promotes small-scale distributed renewable energy by removing the cap on renewable energy in the Renewable Portfolio Standard (RPS). The RPS sets renewable energy targets of 33 percent by 2020 and 50 percent by 2030. According to the Energy Commission's July 2018 update, 32 percent of 2017 retail electricity sales in California were served by renewable energy facilities. While the 2020 target is within reach, the establishment of new CCAs across the state means there will be opportunity for new renewable energy facilities to help these new CCAs meet the procurement requirements of the RPS.

The City Yards project aligns with the state program to increase the penetration of renewable energies. The 1.2 MW solar PV plant is expected to generate approximately 2,000 MWh per year. Integration of adjacent areas, such as the Bergamot Arts Center or Metro Division 14 could increase the energy yielded to 3,500 MWh.

Business Energy Investment Tax Credit

This federal tax credit program gives incentives for different types of energy technology, including solar. The incentives for solar will be scaled back from 30 percent in 2019 to 10 percent in 2022.

In addition to these existing bills, Senate Bill 1339 recently passed the Senate and went under revision in Assembly Appropriations Committee on July 5, 2018. This bill, if passed, would prohibit utilities from issuing permits for any microgrids that use diesel backup or gas combustion, while boosting clean energy microgrids via utility tariffs and streamlined interconnection and permitting.

Santa Monica City Yards project could benefit from the Business Energy Investment Tax Credit if procures the PV array through a private third-party financer.

Chapter 3: Distributed Energy Resources – Research and Selection

Introduction

The objectives of the City Yards microgrid are to:

- Achieve zero-net energy (ZNE) during typical operation.
- Be capable of operating in island mode (disconnected from the grid) during power outages.
- Allow for continuous operation for at least two days in island mode.
- Be able of integrating additional distributed energy resources (DER) in the future.
- Provide energy savings and local GHG emissions reductions.
- Achieve these goals at minimum capital and operational cost.

Currently, the City Yards consists of a set of buildings that support municipal operations. The microgrid design is projected to be able to expand to include the adjacent Bergamot Arts Center, including a planned hotel, and nearby local Metro operation and maintenance facilities. While the current plan is to develop the microgrid design based on the City Yards requirements, it is critical to develop a design that can be scaled as other buildings and electrical loads are added.

The design process occurred in four separate steps:

- **Development of load profiles** for the three potential areas included within the microgrid. The consumption profile for the City Yards buildings was developed using the utility data from City Yards current electrical meters. This data was collected and analyzed for reductions through implementation of energy efficiency (EE) measures. These will be implemented in the City Yards renovation works following current California Building Standards (Title 24 – 2016) and Santa Monica's Reach code.

  Data from DOE's Commercial Reference Building Models were used to estimate the energy consumption and load profile for the Bergamot Arts Center, which will include a hotel, commercial and residential developments.

  Finally, since it has not been possible to access the Metro facility metered data, Metro energy use was estimated using metered data from another similar-in-size and function Metro facility.

- **Selection of eligible distributed energy resource (DER) technologies** for analysis. The DER technologies were evaluated on the potential of successful integration with the microgrid, and ability to support the other Advanced Energy District design objectives, such as net-zero energy consumption.

- **Use of software package HOMER** for selection and optimization of DER technologies. During this design phase, the resilience, reliability, and ZNE requirements were used as the defining DER selection criteria. The analysis has been carried out including the following operation modes: when the microgrid is operating in parallel to the grid, when is operating independently of the grid (island mode), and in island mode during an adverse event (such as consistently cloudy weather).

  The conversion of the City Yards vehicle fleet from fossil fuels to electric has also been included in the analysis to determine how potential DER system operation is affected by the increase in electrical consumption.

  HOMER software was also used to evaluate the electrical topology and optimal distribution voltage for the City Yards microgrid.

- **Design for expansion of City Yards microgrid to Bergamot Art Center and Metro facilities.** The expansion of the microgrid shall not affect the resilience and reliability requirements for the City Yards. The results provide a trajectory of technology adoption that will provide resilience and reliability at the City Yards and adjacent structures while supporting the ZNE and environmental goals.

Microgrid Growth Scenarios

As included in Table 9, this project considers three growth scenarios for the microgrid design. Scenario 1 includes only the load of the City Yards renovated facilities. Scenario 2 adds the electrical loads of the adjacent Bergamot Arts Center. Scenario 3 adds the local Metro facilities to the City Yards and Bergamot electrical load.

Table 9: Growth Scenarios Analyzed

Scenarios for Analysis		CY Design Baseline	Scenario 1	Scenario 2	Scenario 3
Features of each scenario	**Area Served**	City Yards	City Yards	City Yards + Bergamot art district	City Yards + Bergamot art district + Metro
	Energy Efficiency Level	10% better than T-24 (per city ordinance)	10% better than T-24 Microgrid Controller	50% better than T-24 Microgrid Controller	50% better than T-24 Micro grid Controller
	PV Plant	1.4 MW*	1.4 MW	1.4 MW City Yards' PV on Bergamot (as per City Ordinance)	1.4 MW City Yards' PV on Bergamot (as per City Ordinance) PV on Metro facilities
	Electrical Topology	Multiple SCE services @ 480V	Medium Voltage (5kV) with single point of common coupling (PCC)	Medium Voltage (5kV) with PCC + Bergamot	Medium Voltage (5kV) with PCC + Bergamot + Metro
	Resilience	Onsite DERs • Gensets	Onsite DERs • Solar PV • Electric Energy Storage • Gensets	Onsite DERs • Solar PV • Electric Energy Storage • Gensets • Fuel Cells • Bergamot PV	Onsite DERs • Solar PV • Electric Energy Storage • Gensets • Fuel Cells • Bergamot & Metro PV
Alternatives / Add-ons		• Conventional SCE • CCA w/ 100% green power	• Conventional SCE • CCA w/ 100% green power • Demand Response • Vehicle to grid	• Conventional SCE • CCA w/ 100% green power • Demand Response • Vehicle to grid	• Conventional SCE • CCA w/ 100% green power • Demand Response • Vehicle to grid

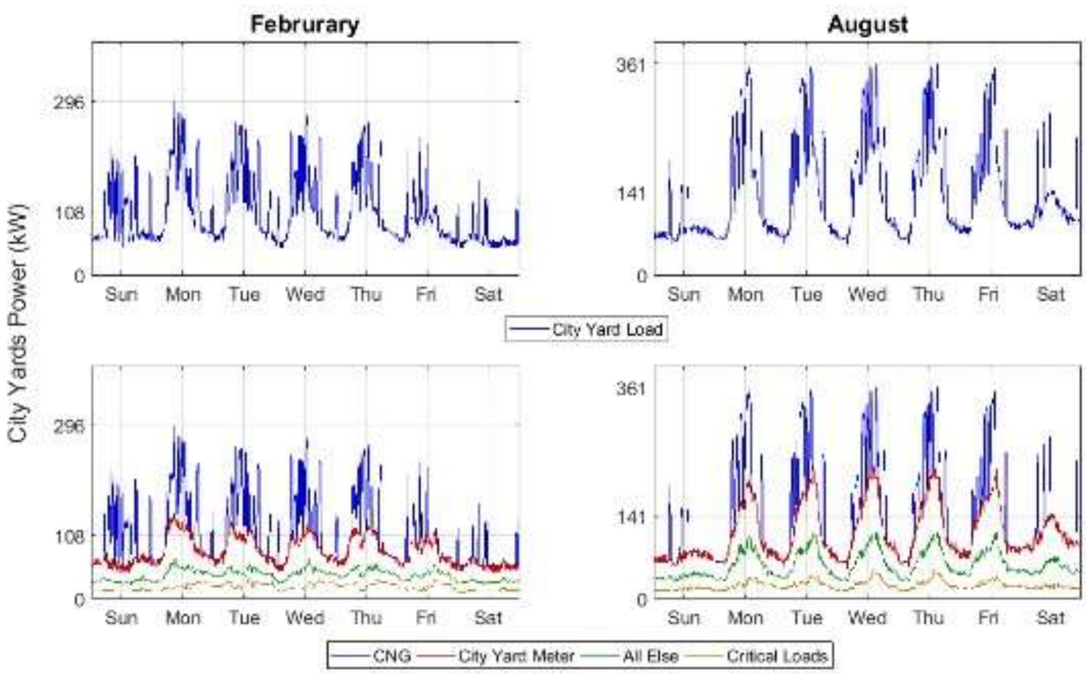
* PV size estimated by Buro Happold in NZE note from April 2018.

City Yards Energy Demand

An energy audit at the current City Yards revealed that the principal energy source in buildings is electricity. Since many of the City Yards work areas consist of workshops that are generally open to the ambient environment, heating and cooling demand is relatively small compared to the electrical demand. Currently, the electrical demand is served through 14 individual meters, which receive service from the local utility, Southern California Edison (SCE). Of these 14 meters, meters serving the Sewer and Water Division, Traffic Signal Operations, and the Fire Station are considered critical loads. Of the remaining loads, the most significant are a meter that aggregates different City Yards loads, and the compressed natural gas (CNG) station, that is used to fuel the fleet of NG garbage trucks. When combined, the 14 meters produce a 116kW average load with a 410kW peak demand.

Figure 13 shows an example of the estimated summer and winter load for the City Yards. The top row of subfigures shows the total City Yards load (blue), while the bottom subfigures shows individual end-uses within the City Yard. Note that only the CNG Station and main meter loads are shown separately, while critical and all other loads are combined into load subsets. The second row of figures shows that the demand peaks present in the total load can be traced back to CNG Station operation. In addition, most loads are increased during City Yards' operating hours, further contributing towards a high peak demand in the middle of the day.

Figure 13: Santa Monica City Yards Winter and Summer Loads



Source: Arup North America Ltd

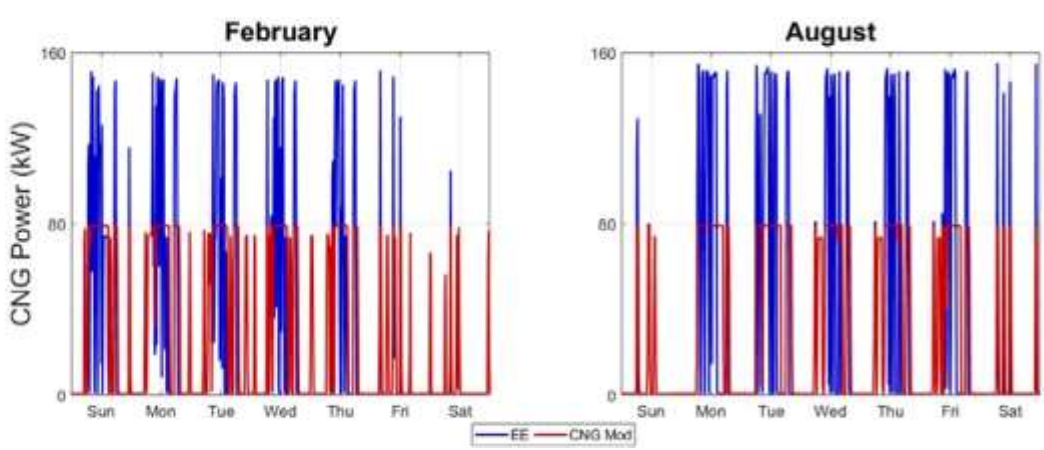
It is assumed that during City Yards renovation works, energy efficiency measures will be implemented such that the entire City Yards experiences a 10 percent improvement beyond Title 24 energy efficiency standards, as required by Santa Monica City Reach code. The projected improvements are estimated to reduce the average load down to 101kW (-13 percent) with a peak demand of 344kW (-16 percent). The scenario in which these energy efficiency measures are implemented is considered the design-base scenario.

Seven microgrid load scenarios have been generated to allow for different backup levels and DER sizes. Table 10 describes the load scenarios considered. Note that in load scenario "CNG Modification," the modification pertains to the CNG operation, which consists of two separate compressor systems that each create an 80kW electrical load. When both are in operation, the CNG load is approximately 160kW. In this work, the load is modified by staggering compressor operation such that only one compressor can operate at any time. This modification only reduces peak demand, not energy use. An example of the original and modified operation is shown in Figure 14.

Table 10: Description of Modified City Yards Microgrid Loads

Load Scenario	Annual Hourly Average Load (kW)	Maximum Annual Load (kw)	Load Notes
Design (EE)	101	344	City Yards load after energy efficiency measures
CNG Modification	101	278	Design load after CNG operation modification (staggering of compressors)
Necessary Loads	90.6	247	CNG modification load without fire tower, solid waste admin, fire training center, and streets conference road loads
Reduce Maintenance	73.4	200	Necessary loads with 50% reduction to City Yards load
No Maintenance	56.3	154	Necessary loads without City Yards load
No CNG/ Maintenance	27.6	74.6	No maintenance load without CNG load
Critical Loads	16.5	41.7	Critical loads only

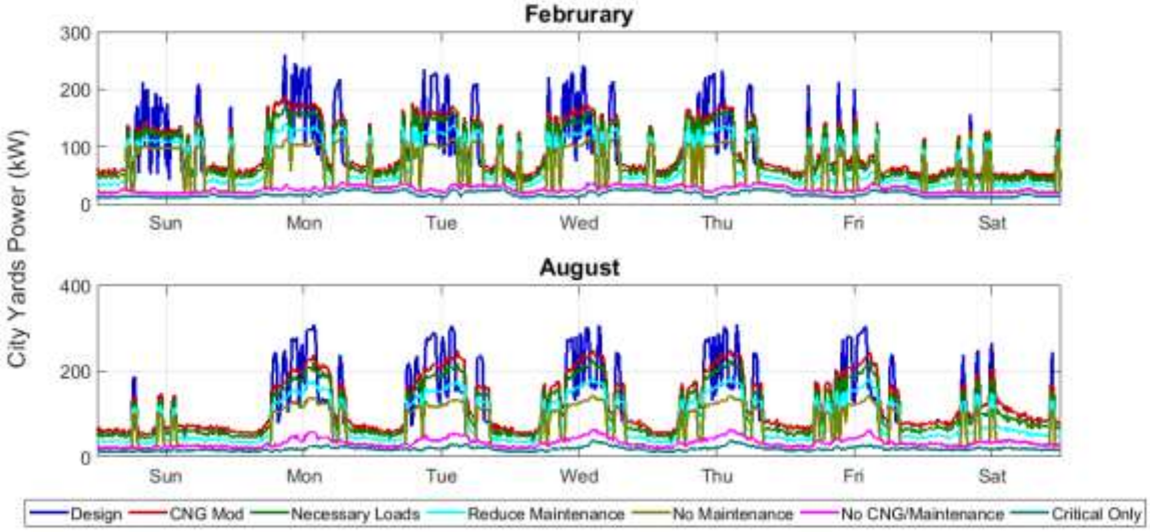
Figure 14: CNG Operation under Design and Modified Scenarios



Source: Arup North America Ltd

Figure 15 shows two weeks of the microgrid loads as described in Table 9.

Figure 15: Modified Microgrid Loads

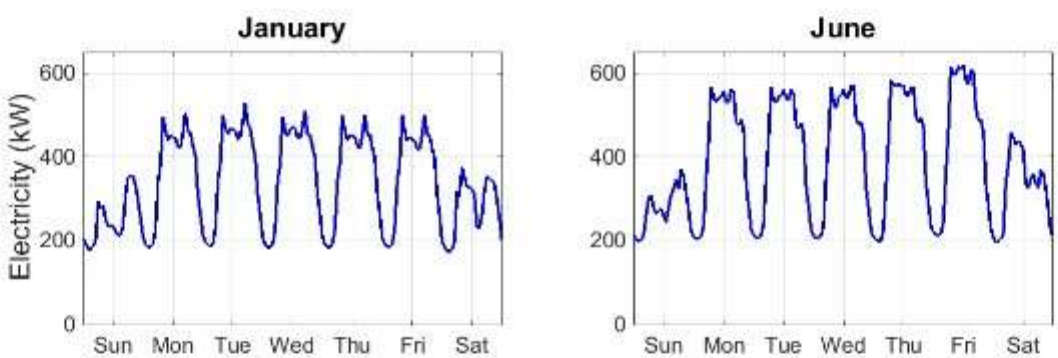


Source: Arup North America Ltd

Bergamot Arts District

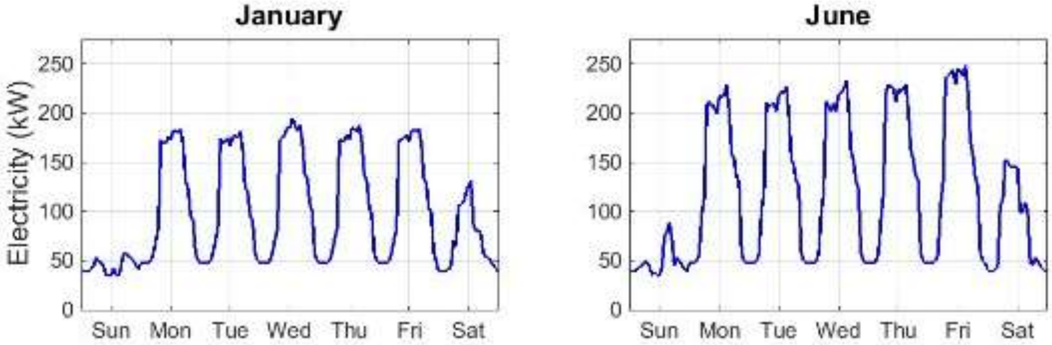
The consultant proprietary tool "DEF_v3" was used to develop the electrical and thermal demand for the Bergamot Station Art Center. DEFv_3 tool uses a database with information from the US Department of Energy Commercial Reference Building Models to estimate the energy demand. This group of buildings are projected to have an area of approximately 220,000 ft^2, with a hotel that adds approximately 82,600 ft^2. The projected energy load profiles for the Bergamot Station Arts District and the hotel are shown in Figures 16 and 17, respectively. Both figures show load profiles for a week in January and June.

Figure 16: Projected Energy Load Profiles for the Bergamot Arts Center



Source: Arup North America Ltd

Figure 17: Projected Energy Load Profiles for the Hotel



Source: Arup North America Ltd

The projected average and maximum electrical demand for the Bergamot Arts Center is 373kW and 711kW, respectively. The projected average and maximum electrical demand for the hotel is 110kW and 288kW, respectively.

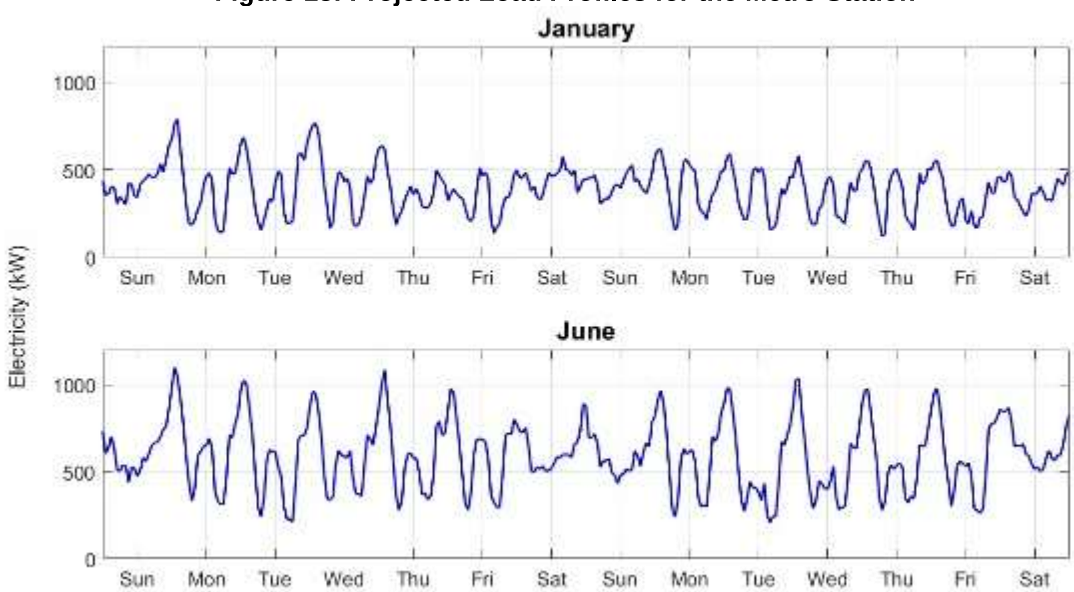
When the loads for the Bergamot art center are combined with the hotel and City Yards loads, the resulting electrical load averages 588kW with a 1,128kW peak.

Metro Division 14

Due to difficulties to collect the metered electrical data of this facility, the load profile has been estimated based on the electrical profile of a similar-in-size metro facility with similar operations. The electrical load is projected to average 500kW with a peak of 1,140kW. A winter and summer example of the electrical load profiles used in this work is shown in Figure 18.

When the Metro electrical profile is added to City Yards and Bergamot area loads, the electrical load average is projected to be 1,082kW with a peak of 1,816kW.

Figure 18: Projected Load Profiles for the Metro Station



Source: Arup North America Ltd

Available DER Technologies

This section describes the technologies and assumptions included in the Santa Monica City Yards microgrid design. A critical component of the City Yards microgrid design is the environmental impact of the proposed system. Solar PV is generally considered to be a viable renewable option in Southern California. Other renewable technologies, such as wind or geothermal power, are viable within California, but are a poor renewable resource in the Yards inner-city location (NREL, n.d.). The City Yards are built over a landfill which has the potential to produce biogas. In addition, there is the option to purchase biogas credits to offset the environmental impact of natural gas. Other natural gas technologies, such as a gas turbine or steam turbine, are excluded from the current work due to a mismatch between the project load and minimum generator size.

In addition to the DERs, electrical energy storage (EES) was also considered for resilience purposes and to increase the renewable fraction, defined as the amount of energy provided by renewable sources divided by the total energy consumed. For Scenarios #2 and #3, with higher electrical load, fuel cells and microturbines have also been considered as DERs.

The assumptions made when modeling these systems are presented in project technology assumptions. In addition to electric energy storage, compressed air, flywheel, and thermal energy storage technologies were also preliminary considered, although were discarded given the demand characteristics of the City Yards.

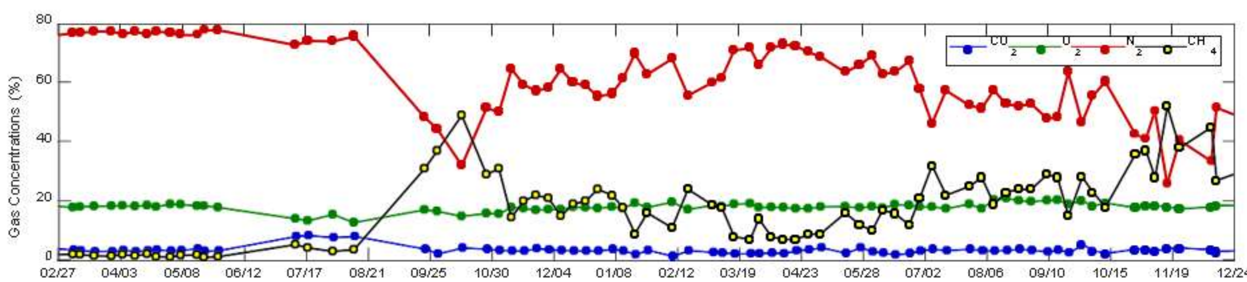
DER Evaluation

Prior to DER system optimization, an analysis should be performed to evaluate the initial feasibility of the considered technologies. This includes an evaluation of renewable energy generation, and storage potential.

Renewable Energy Potential

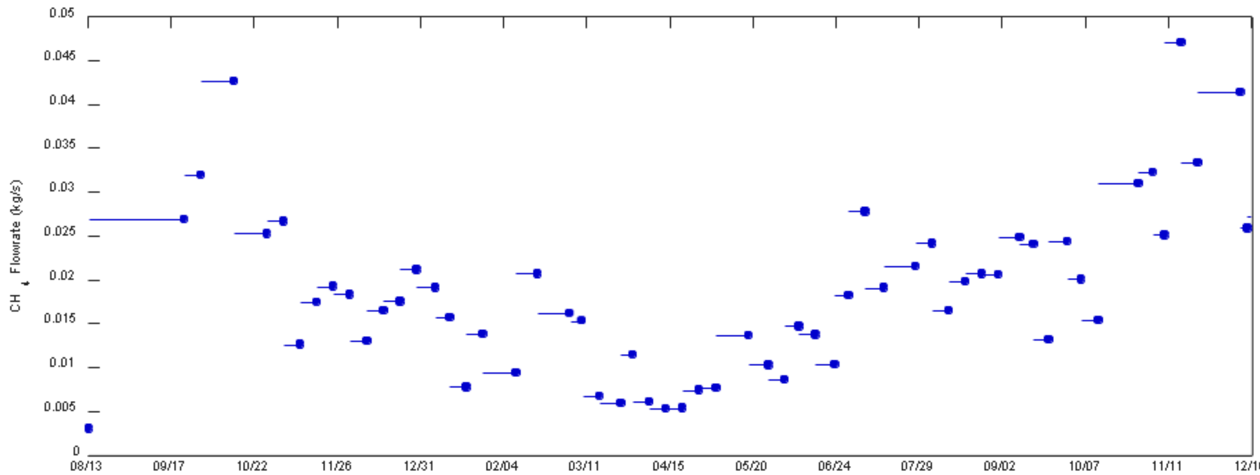
As previously stated, the City Yards are placed in a prime location for solar PV, but given its inner-city location lacks both wind and geothermal resources. The Yards are, however, built over an old landfill that produces methane. Recent emissions analysis from the landfill gas has yielded the following gas concentration measurements shown in Figure 19. Using volumetric flow rates, the mass flowrate of methane was calculated, and is shown in Figure 20.

Figure 19: Gas Concentration Measurements from the Landfill Located at City Yards



Source: Arup North America Ltd

Figure 20: Methane Flow Rates from the Landfill



Source: Arup North America Ltd

Currently, the time varying methane content and gas composition of the landfill effluent creates challenges for its use in the electricity generation technologies considered, microturbines and fuel cells:

- The fluctuating methane content requires the use of supplemental non-renewable natural gas to maintain a consistent fuel flow rate
- Additional engineering and controls implementation is required to sense the biogas methane content to compensate with nonrenewable natural gas when fuel content is too low.
- The presence of oxygen makes the methane stream unsuitable for use in a fuel cell
- The landfill is relatively old, resulting in the possibility of severely degraded biogas potential in the near future.

For the long-term economic and environmental value expected from this process, flaring of the biogas is likely to provide the best option.

Renewable biogas could also be purchased from biogas producer, and distributed to the City Yards through Southern California Gas company to fuel microturbines or fuel cells.

Evaluation Criteria

The criteria considered when selecting the optimal set of DERs has been:

1. Capital and operational cost
2. Environmental impact
3. Capacity to ramp up and down to follow load, and
4. Constructability.

All the considered generation technologies are currently available in the market, and can be installed within the time frame assigned to the renovation of the City Yards. The first three factors listed above are impacted not only by the DER own characteristics, but also DER integration in the microgrid system. Prior to DER design, cursory analysis has been performed to gauge the costs and capabilities of each DER. The results of this analysis are shown in Table 11. The values presented in this table are a mixture of the assumptions presented in Project Technology Assumptions and qualitative information (EPA 2018). Note that the cost calculations required an assumed capacity factor for each generator type. Actual capacity factor will depend on optimal microgrid design. For this current analysis, a capacity factor of 18 percent was assumed for solar PV, and 80 percent for all other technologies. In addition, it was assumed that any capital expenditures would be made with an 8 percent discount rate, and that capital costs would be recouped in 10 years. Finally, gas-fired technologies were tested for operation using nonrenewable natural gas at $0.50 per therm and biogas at $1 per therm.

Table 11: Generator Operating Characteristics

Parameter	Solar PV	200kW Fuel Cell	200kW Fuel Cell on Biogas	65kW Micro-turbine	200kW Micro-turbine	200kW Micro-turbine on Biogas
Capital Cost ($/kW)	2800	4400	3800	3000	2800	2800
O&M ($/kW/hr)	0.0017	0.01	0.01	0.01	0.01	0.01
Electrical Efficiency (%)	18	60	60	25	28	28
Overall CHP Efficiency (%)	n/a	60	60	70	70	70
Minimum Load Ratio (%)	n/a	90	90	25	25	25
Load Follow/ Base Load	n/a	Base Load	Base Load	Load Follow	Load Follow	Load Follow
Startup time	0 sec w/ sunlight	1 - 2 days	1 - 2 days	60 sec	60 sec	60 sec
CO2 Emission Rate (lbs/MWh)	0	883	0	1680	1497	0
NOx Emission Rate (lbs/MWh)	0	< 0.01	< 0.01	0.17	0.14	0.14
Cost of Electricity ($/kWh)	0.268	0.131	0.153	0.151	0.138	0.210

Source: Arup North America Ltd

The preliminary analysis indicates that the fuel cell system can provide the lowest electricity cost when operated on nonrenewable natural gas. When compared to solar PV, the high capacity factor associated with the fuel cell allows for the generation of more than four times more electricity, resulting in a lower cost per kWh produced. Compared to the microturbine, the fuel cell has a much higher electrical efficiency. Despite having a higher capital cost, the reduced fuel use makes up for this cost difference, resulting in a lower overall cost of operation.

Operationally, the microturbine is the most flexible generator. A combination of a fast startup time and load following capability allow for the widest range of operation between all generators. The considered fuel cell system is limited to base load operation only. Finally, the solar PV system is only capable of producing electricity when the sun is available. The system can be paired with storage, but this increases costs by up to $0.14 per kWh when pairing with a 2-h battery that is eligible for the maximum SGIP incentive.

Environmentally, the solar PV system provides the greatest benefit due to producing no emissions during operation. When powered by nonrenewable natural gas, the fuel cell produced less emissions than either microturbine model. However, the fuel cell emissions rate is higher than the SCE emissions rate of 0.24 metric ton CO_{2e} MWh. This rate is reduced to zero when using renewable fuel. Both the fuel cell and microturbines produce NO_x emissions regardless of fuel type.

Storage Evaluation

The energy storage systems considered in the initial study include conventional Li-ion batteries, flow batteries, compressed air, liquid air, flywheel, and thermal energy storage. These technologies exist between commercially available to being tested with pilot systems. Initial qualitative analysis on storage feasibility reduces the set of feasible storage technologies down to Li-ion batteries only.

Flow batteries, or redox batteries, are an emerging electrochemical technology that operates similarly to conventional batteries. In both, the separation of positive and negatively charged particles creates a chemical potential that can be used to store and release electricity. Unlike traditional batteries, which depend on ions suspended in a solid structure, flow batteries use charged particles dissolved in fluid held in tanks that are connected through a membrane or electrolyte. Flow batteries are excluded due to the relatively low energy density but similar cost when compared to Li-ion batteries.

Compressed air energy storage consists of using an air compressor to compress air using excess renewable electricity. When energy is required, the compressed air is heated and expanded through a turbine. Traditional compressed air energy storage systems add natural gas to the compressed air to achieve the temperatures required for expansion through a turbine. Liquid air energy storage consists of using a chiller and compression system to liquefy air using excess renewable electricity. When energy is needed, the liquid air is vaporized, and this expansion process is used to drive a generator. Traditionally, liquid air energy storage systems are only used at large scales. Compressed air and liquid air energy storage are excluded due to a low round-trip efficiency at small scale, and lack of viable systems at the City Yards scale.

Flywheel energy storage consists of accelerating a flywheel to high speeds, storing energy in the form of rotational energy. An electric motor is operated to accelerate the flywheel. The storage is then discharged by operating the electric motor in reverse, as a generator. Flywheel energy storage is only adequate for short term energy storage (seconds). While the storage duration of the City Yards project is not expected to exceed one to two days, it is anticipated that the optimal microgrid system will be able to provide continuous power for multiple hours to days. Due to this requirement, flywheel energy storage does not pair well with the City Yards microgrid design.

Thermal energy storage can consist of both hot and cold storage. Hot thermal storage typically consists of the storage of a hot liquid, such as hot water. This type of storage can use a phase change material that turns from solid to liquid as the system heats, allowing for latent energy storage. Likewise, cold thermal energy storage typically consists of a cold-water tank. This form of storage can also be combined with a phase change process, such as formation ice, but can also be paired with other materials. Considering the potential for these loads to be electrified in support of renewable energy, and the current lack of thermal load across the City Yards, there is little to no opportunity for thermal energy storage.

Chapter 4: Microgrid Modeling and Optimization

Introduction

To model and optimize the microgrid, the load profiles and DER properties described in Project Technology Assumptions were input into the HOMER tool along with TMY3 weather data for the Santa Monica Airport (Wilcox and Marion 2008). Using this data, a variety of simulations were run with and without grid connectivity. When the grid was considered, both the Southern California Edison (SCE) TOU-8 rate and the equivalent Community Choice Aggregation (CCA) rate with a 100 percent renewable adder were considered.

HOMER is a software application developed by the National Renewable Energy Laboratory. This software was created to design and evaluate technically and financially the options for off-grid and on-grid power systems. It allows the user to consider many technology options to account for energy resource availability and other variables. HOMER examines all different possible technology combinations to determine the lowest cost option for the given project constrains. The software also allows sensitivity analyses to model the effect of variables that are beyond the designer's control, such as electricity or fuel prices.

Although the design criteria required the adoption of 1.4 MW of solar PV (Buro Happold 2018), PV design was allowed to deviate from this point to determine optimal PV size under the specified constraints and technology options.

When the microgrid was simulated disconnected from the grid, DER optimization occurred using the technologies suggested during the grid-connected scenario. Finally, to predict the size of any backup DER, the optimal microgrid DER adoption was derated to predict the impact of adverse conditions on the ability of adopted DER technologies to meet the microgrid load. For solar PV, the most common reason for a derate is cloudy weather. This work assumes that cloudy weather would result in a reduction in solar PV production of 85 percent. The simulations for the islanding mode occurred using both the "Design" and the "CNG modification" scenarios described in Table 13.

The only DER types considered in the design-base scenario (Excludes Bergamot and Metro areas) were solar PV and EES. Due to an average electrical demand of 101kW, the current City Yards load is too small to receive electrical service from the considered 200kW fuel cell and microturbine. The 65kW microturbine was initially considered in the design, but the low thermal demand, high cost of renewable fuel, and lack of supporting incentives resulted in this technology never being adopted by the software.

Grid-Connected Design

Using the DER parameters outlined in project technology assumptions, current electricity rates, and the design-base scenario, the DER were optimized for the microgrid. The results for optimizing these technologies under the TOU-8-B rates are shown in Table 12. This table shows results when the local renewable energy requirement is increased from 0 percent (No renewables in City Yards) to 100 percent (optimized for cost when all energy is sourced from renewable resources). This table also shows cost of electricity and net present cost, as calculated through HOMER. A constraint in the renewable energy fraction was implemented since initial optimization results, with no renewable energy constraints, yielded a solar PV system of 87.4kW. Although the 95 percent and 100 percent renewable fraction scenarios were considered, the consultant found these scenarios to be infeasible.

Table 12: Optimization Results for a Grid-Tied Microgrid Under SCE TOU-8-B Rates

Renewable fraction (%)	PV Size (kW)	EES Size (kWh)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)
0	87	0	0.168	0.24
10	87	0	0.168	0.24
20	120	0	0.168	0.34
30	181	0	0.168	0.51
40	250	0	0.169	0.70
50	334	0	0.166	0.94
60	455	0	0.158	1.27
70	661	0	0.147	1.85
80	1,042	0	0.133	2.92
85	1,423	0	0.126	3.98
90	2,621	0	0.150	7.34

Source: Arup North America Ltd

According to these results, the adoption of a 1.4 MW solar PV system would provide nearly 85 percent of the City Yards load with renewable energy. None of these cases resulted in the adoption of an energy storage system. The results are nearly identical when using either the CCA or TOU-8-A rates. In all cases, excess electricity was exported back to the grid.

The effect of the Self-Generation Incentive Program was also investigated in the optimization process. The results assume a two-hour duration EES system is used. Increasing system duration further results in a decrease in the SGIP incentive by 50 percent, as shown in Table 13. When optimizing solar PV and EES under this lower incentive rate, the HOMER DER system optimization is identical to when no SGIP incentive is offered.

Table 13: Optimization Results for a Grid Tied City Yards Under SCE TOU-8-B Rates With SGIP Inventive for a 2-Hour Duration EES System

Renewable Requirement (%)	PV size (kW)	EES size (kWh)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)
0	87	0	0.168	1.70
10	120	0	0.168	1.70
20	181	0	0.168	1.73
30	250	0	0.169	1.79
40	334	1	0.166	1.89
50	399	374	0.182	2.04
60	589	218	0.156	2.22
70	736	577	0.161	2.49
80	624	1,216	0.205	2.48
85	724	1,341	0.199	2.66

Island Mode Design

All the microgrid designs proposed in the previous section consist of adopting sufficient solar PV to meet the renewable fraction. Unless EES is adopted, the systems proposed for grid connection operation will not be capable of supporting island operation due to a lack of storage used to bridge the gap between time of solar resource availability and City Yards loads. To evaluate what assets are necessary to enable island operation, the utility connection was removed in the HOMER model, and the DER system was optimized such that the City Yards load is always met. It is assumed some level of demand-response control during island mode to enable better matching between energy generation, storage, and demand. The level of modification is dependent between the available DER technologies and DER load following capabilities, and which City Yards loads are viewed as necessary for continual City Yards operation.

To capture these factors, the DER system was optimized for the seven scenarios described in Table 14. Table 13 shows optimization results when solar PV size is undetermined, while Table 15 shows results when solar PV capacity is fixed at 1.4 MW. Both tables show the initial net present cost.

If ITC is claimed for the PV system, then the initial investment can be reduced by $0.68 million when the solar PV size is approximately 1.2 MW, and $0.56 million when PV size is set to 1.4 MW. Use of SGIP funds for the EES system would decrease the initial cost by $1 million for the “Design” and “CNG Modification” load scenarios, and $280,000 for the “Critical Only“ load scenario.

Table 14: Optimal DER Systems for Island Operation

Load Scenario	PV size (kW)	EES size (kWh)	Cost of Electricity ($/kWh)	Initial Investment ($Mil)
Design	1,198	7,204	0.925	7.68
CNG Modification	1,209	7,226	0.925	7.72
Necessary Loads	1,087	6,623	0.932	7.02
Reduce Vehicle Maintenance	881	5,235	0.917	5.61
No Maintenance	1,268	1,797	0.873	4.63
No Vehicle Operation	658	834	0.895	2.34
Critical Only	360	790	0.985	1.48

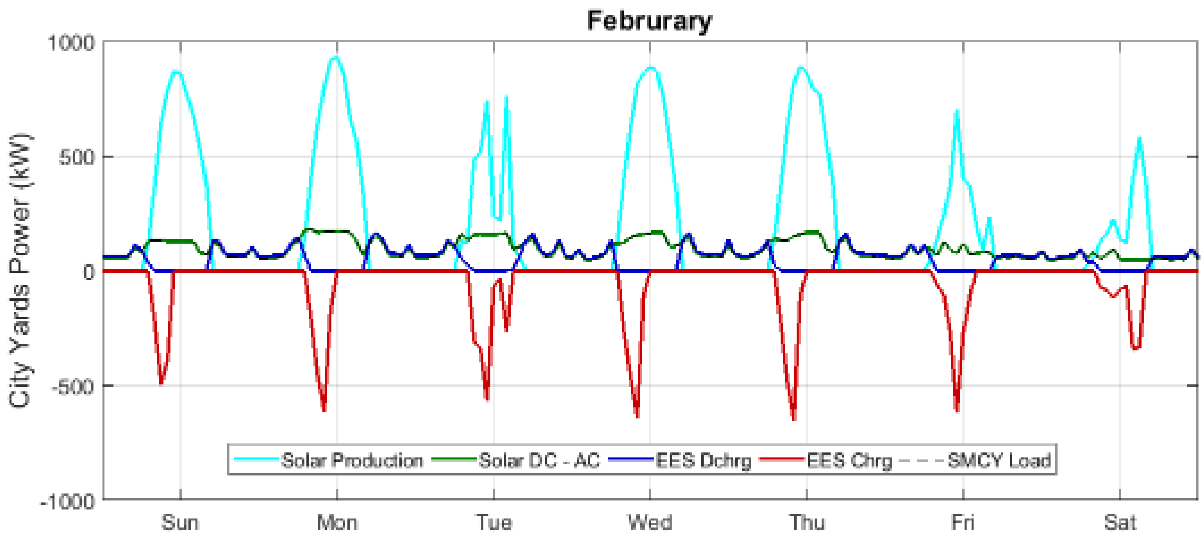
Table 15: Optimal DER System Design for Island Operation When Solar PV Is Fixed at 1.4MW

Load Scenario	PV size (kW)	EES size (kWh)	Cost of Electricity ($/kWh)	Initial Investment ($Mil)
Design	1,400	6,526	0.913	7.84
CNG Modification	1,400	6,526	0.913	7.84
Necessary Loads	1,400	5,392	0.913	7.16
Reduce Vehicle Maintenance	1,400	3,266	0.885	5.88
No Maintenance	1,400	1,506	0.894	4.82
No Vehicle Operation	1,400	790	1.61	4.39
Critical Only	1,400	458	2.56	4.19

Capital costs discussed are required to meet City Yards loads during island mode decreases as the load is reduced to critical loads only, and that the cost between the optimal and fixed PV scenarios are similar until the City Yard, CNG Station, and non-critical loads have been removed. Reducing the load beyond these levels requires much less solar PV than 1.4 MW, resulting in a significant decrease in the capital cost. Note that the energy storage requirements are reduced when fixing solar PV at 1.4 MW.

Operation of the DER systems presented follow similar profiles, where solar production is used first to meet the City Yards load, with excess production being stored in the EES. As solar production wanes, the stored energy is discharged to meet the evening and night time load. An example of this operation is shown in Figure 21.

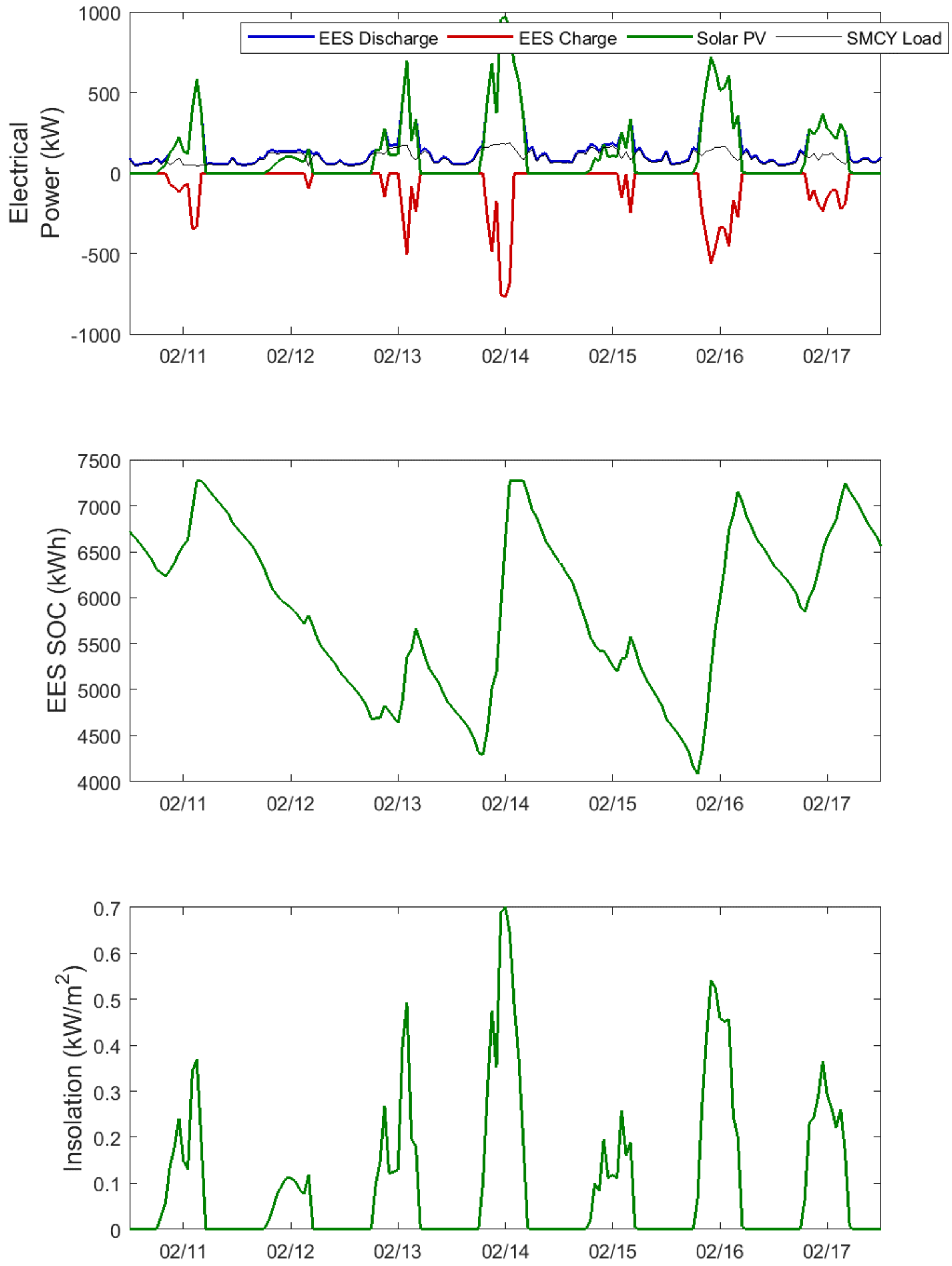
Figure 21: Example Operation of City Yards During Island Mode



The available solar resource follows the typical diurnal curve associated with solar energy during four of the seven days. The other three days experience reduced solar PV production, likely due to adverse weather conditions. In the case of the "Design" or "CNG Modification" scenarios, the size of the EES system is larger than what would typically be paired with the same solar PV system. This mismatch is driven by the possibility of experiencing poor solar PV production multiple days in a row. An example of this occurs in February and is shown in Figure 22. This figure shows solar PV and EES operation to meet the "CNG Modification" scenario in the top subplot, the EES state of charge (SOC) in the middle subplot, and the available solar insolation in the bottom subplot. In this example, solar insolation is significantly reduced throughout the entire week. Solar insolation is particularly low on 2/12 and 2/15.

During these days, the EES system is almost continually discharged from the evening of the prior day through to the morning of the following day.

Figure 22: Example of Solar PV and EES Operation to Meet the "CNG Modification" Island Load During a Week with Poor Solar Resource



The island mode optimization used typically available solar data, and does not capture operation during continual adverse events. To allow for continual adverse events it is recommended the use of a backup diesel/NG generator.

Consolidation of Grid-Connected and Island-Mode Results

The results presented in previous sections provide different DER options that must be reconciled to design an optimal advanced energy community. To determine the DER system that minimizes cost, while also allows for microgrid islanding operation, the financial performance of the systems sizes presented in Table 16 must be calculated when operating in parallel with the grid. To accomplish this, the grid-connected HOMER model was modified to force the adoption of each set of DER systems, resulting in operation that attempts to minimize net present value when utility import and export is possible.

The systems from Table 16 were selected for further analysis over the fixed solar PV scenario (1.4 MW PV) because of the overall lower cost to adopt and operate the microgrid. The results from this analysis are shown in Table 18. Note that additional information is included in this table, including the net present cost of the DER system and the annual operating cost: The reduction in utility grid purchases, renewable fraction, percent of solar generation that cannot be instantly used onsite, and number of times the EES is cycled per year. EES cycles per year is roughly defined as the quantity of electricity discharged from the battery divided by the capacity of the battery. The final two columns show the CO_{2e} emissions associated with utility imports and the potential avoided emissions created through the export of excess solar energy. Note that the avoided emissions use the average SCE emissions factor. These results assume 2018 prices and SGIP incentives for a two-hour duration EES system.

Table 16: Summary of Results When the Optimal Islanding Systems Are Operated in Parallel with the Grid

Load Scenario	Grid Purchase Reduction (%)	Renewable Fraction (%)	Excess Solar (%)	EES Cycles per Year	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)	Operating Cost ($/Year)	CO_{2e} Emissions from Import (Metric ton/Year)	Offset CO_{2e} Emissions from Export (Metric ton/Year)
Design	99.97	100.0	48.0	55.6	0.309	6.58	10650	0.06	217.6
CNG Modification	99.97	100.0	48.0	55.6	0.309	6.58	10650	0.06	219.6
Necessary Loads	99.93	99.9	43.3	61.2	0.312	5.98	16573	0.15	178.1
Reduce Vehicle Maint.	99.60	99.6	31.5	78.8	0.311	4.82	31783	0.85	105.0
No Maintenance	98.80	98.7	52.0	206.8	0.161	3.66	-29143	2.55	249.5
No Vehicle Operation	83.60	82.6	30.8	259.2	0.177	2.49	38305	34.80	76.7
Critical Only	62.00	60.3	4.6	155.0	0.207	2.18	83924	80.70	6.3

These results show that all DER systems except for the "No Vehicle Operation" and "Critical Only" scenarios are capable of meeting nearly the entire City Yards load (>98 percent). At the same time, the cost of electricity is highest for these scenarios, except for the "No Maintenance" scenario. The "No Vehicle Operation" case also has a relatively low electricity cost, and can reduce utility imports by nearly 84 percent. Cost of electricity increases when shifting to the "Critical Only" scenario due to the existence of a relatively large EES system. These results also indicate the costs imposed on normal operation due to the requirement to provide islanding service.

Recommended Scenario 1 DER System

Considering the City Yards microgrid requirements, it is recommended that 1.2 MW of solar PV and 7.2 MWh of EES be adopted at the City Yards. The adoption of these technologies would enable island operation, allow City Yards operation to continue for two days at full load during a power outage, and achieve lowest net present cost.

Considering the ability of the system to operate in island mode indefinitely using only a solar PV – EES system, the City Yards will likely approach ZNE. In addition, the adoption of the EES of 7.2 MWh will create flexibility to add new renewable or sustainable generation in the future. For example, if loads from adjacent buildings are served by the City Yards microgrid, such as the Bergamot Arts Center or Metro facilities, then the EES system will allow for technologies like high-temperature fuel cells to be adopted.

Electric Vehicle Charging

This section addresses the electrification of the existing vehicle fleet at City Yards. A summary of the total miles traveled per day by each vehicle type, the mean vehicle type efficiency, number of vehicles, and the assumed battery size is shown in Table 17. The number of Level 2 electric vehicle supply equipment (EVSE) required can be calculated by assuming a charging time and a power consumption. Two charging time periods were chosen given that the dwell period for these vehicles was assumed to be between 6pm and 6am. One charging time would extend for the entire duration of the dwell period, specifically 12 hours, while the other would extend for only half of the dwell period.

Table 17: Summary of City Yards Fleet Vehicle Electrification

	Van/Pickup	Sedan/SUV	Truck	Truck / Garbage
Miles per Day	604	185	113	317
Vehicles in Fleet	48	21	12	26
Mean Vehicle Eff [mi/kWh]	2	3.5	1.3	0.6
Mean Batt Storage per Vehicle [kWh]	80	80	300	200
Mean Range [mi]	160	280	390	120
Required charge kWh/day	302	53	87	528
Level 2 EVSE (12 hr charge time)	4	1	2	7
Level 2 EVSE (6 hr charge time)	7	2	3	13

The average vehicle miles traveled per day is about 12 miles across the entire fleet for all vehicle types. The Level 2 EVSE power consumption is assumed to be 7.2kW. Based on this assumption the number of chargers required varies between 14 and 25 depending on the duration of charging desired. When the garbage fleet is electrified, it is recommended the use of DC fast chargers that can be connected to the microgrid's DC bus. This will reduce system losses increasing efficiency.

Three levels of charge duration (6, 9 and 12 h) were assumed and added to the City Yards Scenario 1 CNG Mod load profile (Figure 23). The total energy consumed and peak load of the aggregated profiles remain the same across the three cases of EV charging (3,193kWh/day average consumption and 335kW peak demand).

Figure 23: EV Load Profiles Added to the City Yards Scenario 1 CNG Mod Load Profile for Three Different Charge Durations

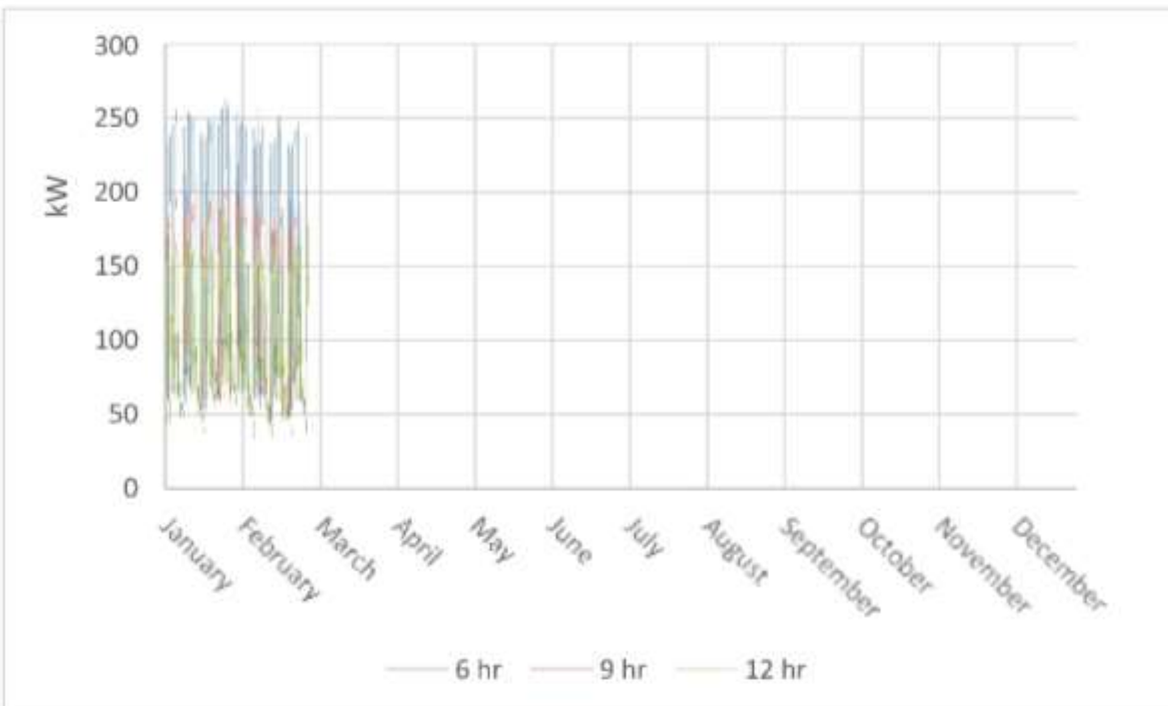


Table 18 shows the HOMER results for the "No Vehicle Operation" DER case with EV loads added. As the EV load is added, additional grid energy purchases must be made at night to serve the EV charging load that cannot be satisfied with the electrical batteries. The renewable fraction is also reduced.

Table 18: HOMER Results for a Grid-Tied City Yards Under “No Vehicle Operation” Scenario

Charge duration	PV (kW)	Battery (kWh)	Renewable Fraction (%)	Grid Purchase Reduction (%)
No EV load	658	834	83.0	83.6
6 hr	658	834	71.9	68.7
9 hr	658	834	71.9	68.7
12 hr	658	834	72.0	68.7

Includes an electrified fleet under SCE TOU-8-B rates with various nighttime charging durations.

Table 19 shows the HOMER results for the design-base scenario with EV loads added. For this case of DER sizing, a full transition of the City Yards fleet to electric will not impact the grid energy purchases or the renewable fraction because the size of these DER are sufficient to meet the additional EV charging load.

Table 19: HOMER Results for a Grid-Tied City Yards With “Design” DER

Charge duration	PV (kW)	Battery (kWh)	Renewable Fraction (%)	Grid Purchase Reduction (%)
No EV load	1,198	7,204	100	99.97
6 hr	1,198	7,204	100	99.97
9 hr	1,198	7,204	100	99.96
12 hr	1,198	7,204	100	99.95

With an Electrified Fleet under SCE TOU-8-B Rates with Various Nighttime Charging Durations.

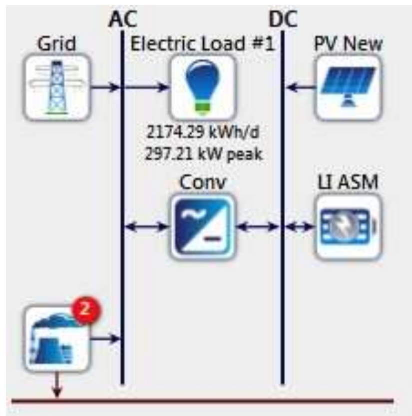
Microgrid Electrical Topology

Currently, the City Yards receives electrical service through 14 electrical supplies. The microgrid upgrade will result in the adoption of additional electrical infrastructure that will reduce the 14 points to a single point of connection, known as point of common coupling (PCC). The incumbent utility, Southern California Edison, also expressed in a meeting with Santa Monica delegates and the design team their interest in combining all their electrical supplies associated with the City Yards into a single connection. This upgrade will be required for connections between all current loads, and the points of future connection to the Bergamot Arts Center and Metro.

To economically provide sufficient capacity, flexibility, and to minimize resistive losses within the microgrid, the local electrical topology and voltage levels must be optimized. The first steps towards accomplishing this requires for the development of an electrical topology and the evaluation of operating the new electrical infrastructure at different voltage levels.

Figure 24 shows the proposed microgrid connection diagram, as depicted in HOMER software. Solar PV and EES are tied to the direct current (DC) bus, while the grid and the City Yards loads are connected to the alternating current (AC) bus. Both busses are connected through a DC-AC inverter. If a fuel cell system is considered to supply the load of adjacent areas, this would also be tied to the AC bus. A backup diesel generator would usually be connected to the AC bus, as indicated in the schematic.

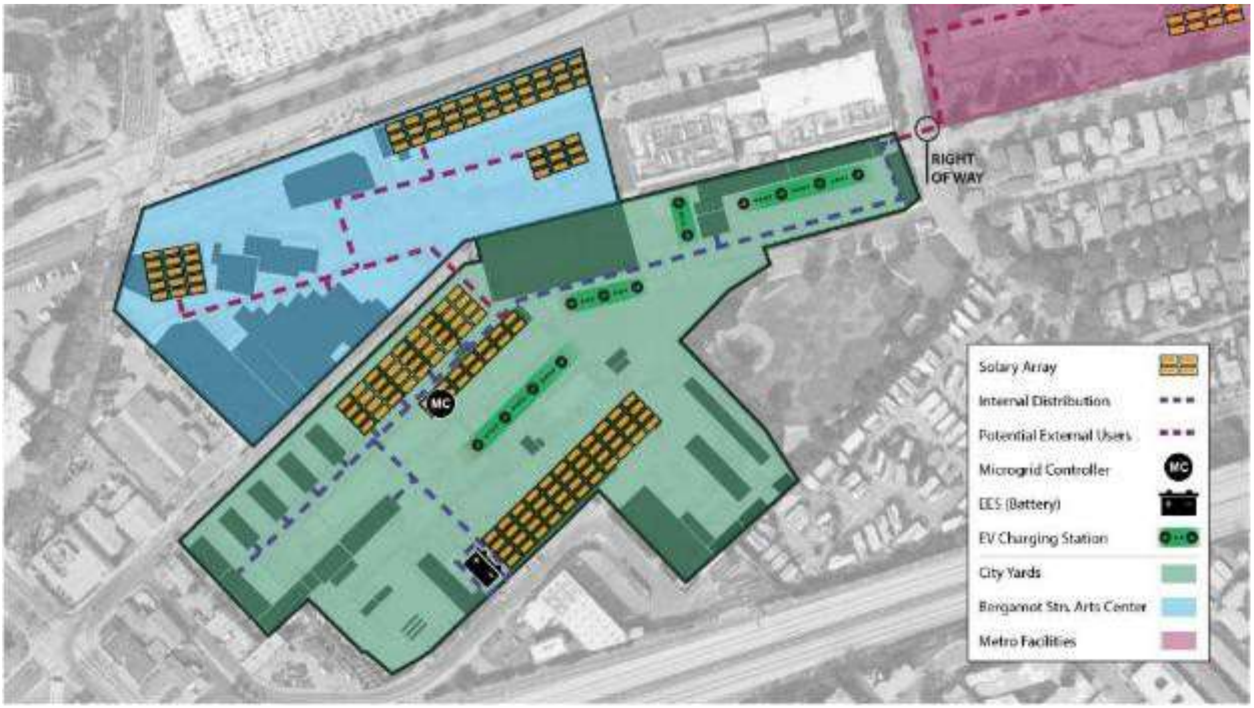
Figure 24: Microgrid Schematic by Homer Software



This work considers three separate voltage levels: 480 V, 4.8 kV, and 12 kV. The electrical utility data described in project technology assumptions was used to develop power flows through the proposed topology. In addition to the three main scenarios (480 V, 4.8 kV and 12 kV), additional sub-scenarios considered the possibility of having different wire segments operating at different voltage levels. These scenarios were based on a) the installing transformers along lines that have higher ampacity, and b) entire wire runs of the City Yards electrical topology will be converted all at once. The analysis indicates that the 12 kV scenario seems the most cost-effective, as the reduced cost of wiring and conduits will offset the additional cost of the 12 kV electrical gear.

Figure 25 shows preliminary locations for the solar PV and electrical energy storage equipment. These locations shall be confirmed by the City Yards redevelopment design team.

Figure 25: Potential Location for Microgrid Equipment and Distribution Routes



City Yards Microgrid Expansion Scenarios

Scenario 2 Optimization Results

The DER system for Scenario 2 was designed using the load profiles described in Project Technology Assumptions. The Homer model developed for Scenario 1 was modified to include the electrical load profile of the Bergamot Arts Center development. The same utility rates used for Scenario 1 were used to analyze Scenario 2. Due to the larger average electrical demand, the 200kW fuel cell and microturbine, and 65kW microturbine were included in the analysis. The solar PV and EES technologies considered in Scenario 1 were also included.

The following DER adoption scenarios were considered:

- The solar PV and EES system proposed for Scenario 1 was assumed to be present and available to support the additional Bergamot Arts Center development. In this scenario, it was possible to adopt additional solar PV and EES beyond the Scenario 1 design, but not less than the Scenario 1 proposed DER systems.
- The DER technology scenario ignores the Scenario 1 results, optimizing solar PV and EES for the Scenario 2 loads independently of the initial results for Scenario 1.
- The DER technology scenario is the same as the previous case, but using the 2021 capital costs discussed in the Island Mode Infrastructure and Interconnection Costs section of Appendix B.
- The final DER technology scenario excludes the fuel cell and microturbine technologies, only allowing for the adoption of solar PV and EES technologies at the currently assumed capital costs.

It is important to consider the requirements of the microgrid under Scenario 2. Since the City Yards is considered a critical load, it is imperative to ensure that City Yards operations can operate unimpeded during any adverse events. Although it is important to continue to provide electrical power to the Bergamot Arts Center, its resilience requirements are not as stringent as those for the City Yards. As a result, the primary determining factor for Scenario 2 is the renewable fraction, or the percent of the load that is met through local renewable means. As a result, the HOMER model was run for a renewable fraction ranging from 0 percent (or when cost is the only design factor) to 100 percent in 10 percent increments.

In all technology scenarios, HOMER found that 100 percent renewable fraction was impossible to achieve. Note that the results do present the portion of the total load met by the utility for each renewable fraction scenario. This value represents the portion of the Scenario 2 load that would either go unmet during an islanding event, or would necessitate the purchase of additional energy storage to bridge the gap between excess renewable generation and time of energy demand. The decision to pursue the necessary energy storage resources would need to be evaluated by the Bergamot developers by weighing the benefit of the energy load versus the cost of storage to support the unmet load.

Results for the systems selected by HOMER in Scenario 1 are considered in Table 20. Results for when solar PV and EES are optimized for Scenario 2 are shown in Table 21. The results show that the 1.2 MW solar PV and 7.2 MWh EES system proposed through Scenario 1 is sufficient to achieve a renewable fraction of over 40 percent. Beyond this renewable fraction, fuel cell systems operated using biogas are adopted to meet the increasingly stringent renewable fraction requirement. When solar PV and EES size are both being determined by the HOMER tool, and not fixed by Scenario 1 results, the solar PV system sizes increases until fuel cell adoption occurs, at which point the solar PV system decreases in size. Note that the cost to adopt the Scenario 1 system increases the net present cost of the overall system by approximately $5 million for all renewable fractions. In both cases, the system designed for a renewable fraction of 80 percent meets more than 90 percent of the Scenario 2 electrical demand.

Table 22 and Table 23 show results when solar PV and EES costs are reduced to the projected 2021 values, and when only solar PV and EES technologies are considered at current capital costs.

Table 24 shows that the reduced solar PV capital cost results in a larger solar PV system being adopted when only cost is considered. If 2021 capital costs are available, the DER system includes more solar PV at higher renewable fraction requirements, and less fuel cell capacity. When limiting technology to only solar PV and EES, the maximum renewable fraction is reduced from 90 percent to 60 percent, and results in the adoption of the largest solar PV system observed in this study.

Table 20: HOMER Results for Scenario 2 Assuming the Recommended Scenario 1 System Is Adopted

% Renewable Requirement	Solar PV (kW)	Fuel Cell (kW)	EES (kWh)	Micro turbine (kW)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)	Operating Cost ($100k/year)	Initial Investment ($Mil)	Renewable Fraction	Utility Fraction (%)	Export Fraction (%)	CO_{2e} Emissions (Metric Tons/year)
0	1,200	0	7,200	0	0.204	12.81	5.48	6.46	1.1	67.4	3.7	1,022
10	1,200	0	7,200	0	0.204	12.81	5.48	6.46	10.0	67.4	3.7	1,022
20	1,200	0	7,200	0	0.204	12.81	5.48	6.46	29.3	67.4	3.7	1,022
30	1,300	0	7,200	0	0.203	12.93	5.35	6.74	30.4	65.7	5.0	985
40	1,200	0	7,200	0	0.205	13.50	5.22	7.46	40.1	38.7	9.0	605
50	1,200	200	7,200	0	0.205	13.50	5.22	7.46	56.5	38.7	9.0	605
60	1,700	200	7,200	0	0.195	14.20	4.61	8.86	60.5	35.2	20.5	421
70	1,200	400	7,200	0	0.198	14.22	4.98	8.46	70.2	14.6	18.9	188
80	1,200	400	7,200	0	0.175	14.97	4.76	9.46	80.1	3.5	41.6	-226
90	1,200	1,000	7,200	0	0.141	17.29	5.04	11.46	90.0	0.0	102.6	-1,017

Table 21: HOMER Results for Scenario 2 Optimized for Grid Connected Operation

% Renewable Requirement	Solar PV (kW)	Fuel Cell (kW)	EES (kWh)	Micro turbine (kW)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)	Operating Cost ($100k/year)	Initial Investment ($Mil)	Renewable Fraction	Utility Fraction (%)	Export Fraction (%)	CO_{2e} Emissions (Metric Tons/year)
0	44	0	0	0	0.131	8.01	6.81	0.1	1.1	98.7	0.0	1,451
10	400	0	0	0	0.135	8.24	6.15	1.0	10.0	87.9	0.0	1,318
20	44	200	0	0	0.142	8.66	6.51	2.0	29.3	64.7	0.0	1,034
30	88	200	0	0	0.142	8.67	6.41	0.9	30.4	63.3	0.0	1,017
40	485	200	0	0	0.146	8.99	5.73	1.7	40.1	52.2	0.9	870
50	44	400	0	0	0.150	9.33	6.22	2.8	56.5	32.6	2.0	616
60	221	400	0	0	0.150	9.42	5.87	1.6	60.5	28.2	2.9	551
70	750	400	0	0	0.151	9.98	5.07	2.8	70.2	17.8	8.5	355
80	353	600	0	0	0.140	10.23	5.39	2.7	80.1	7.3	20.0	85
90	528	1000	0	0	0.110	12.44	5.15	5.3	90.0	0.0	85.9	-812

Table 22: HOMER Results Optimized for Grid Connected Operation When Using 2021 Solar PV and EES Capital Costs

% Renewable Requirement	Solar PV (kW)	Fuel Cell (kW)	EES (kWh)	Micro turbine (kW)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)	Operating Cost ($100k/year)	Initial Investmen t ($Mil)	Renewable Fraction	Utility Fraction (%)	Export Fraction (%)	CO_{2e} Emissions (Metric Tons/year)
0	2,868	0	0	0	0.071	5.92	1.20	4.5	51.8	54.7	35.7	474
10	2,868	0	0	0	0.071	5.92	1.20	4.5	51.8	54.7	35.7	474
20	2,868	0	0	0	0.071	5.92	1.20	4.5	51.8	54.7	35.7	474
30	2,868	0	0	0	0.071	5.92	1.20	4.5	51.8	54.7	35.7	474
40	2,868	0	0	0	0.071	5.92	1.20	4.5	51.8	54.7	35.7	474
50	2,868	0	0	0	0.071	5.92	1.20	4.5	51.8	54.7	35.7	474
60	2,573	200	0	0	0.080	6.78	1.48	5.1	66.8	32.1	38.2	166
70	3,750	200	0	0	0.077	7.04	0.10	6.9	70.1	30.0	48.7	12
80	2,353	400	0	0	0.087	7.65	1.67	5.7	80.3	11.7	43.9	-154
90	2,353	800	0	0	0.085	9.76	1.76	7.7	90.0	0.1	87.6	-832

Table 23: HOMER Results Optimized for Grid Connected Operation When Only Solar PV and EES Technologies Are Considered

% Renewable Requirement	Solar PV (kW)	Fuel Cell (kW)	EES (kWh)	Micro turbine (kW)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)	Operating Cost ($100k/year)	Initial Investment ($Mil)	Renewable Fraction	Utility Fraction (%)	Export Fraction (%)	CO_{2e} Emissions (Metric Tons/year)
0	44	0	0	0	0.131	8.01	6.81	0.12	1.1	98.7	0.0	1,451
10	400	0	0	0	0.135	8.24	6.15	1.12	10.0	87.9	0.0	1,318
20	804	0	0	0	0.141	8.68	5.55	2.25	20.0	76.5	0.8	1,169
30	1,246	0	0	0	0.145	9.21	4.94	3.49	30.2	66.6	4.3	1,004
40	1,788	0	0	0	0.143	9.95	4.27	5.01	40.0	60.4	14.4	805
50	2,622	0	0	0	0.141	11.31	3.42	7.34	50.0	55.7	32.0	531
60	5,809	0	0	0	0.202	18.78	2.17	16.26	60.1	49.0	54.0	180

Table 24: HOMER Results for Scenario 3 Assuming the Recommended Scenario 1 DER System Was Adopted

% Renewable Requirement	Solar PV (kW)	Fuel Cell (kW)	EES (kWh)	Micro turbine (kW)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)	Operating Cost ($100k/year)	Initial Investment ($Mil)	Renewable Fraction	Utility Fraction (%)	Export Fraction (%)	Net CO_{2e} Emissions (Metric Tons/year)
0	1200	0	7200	0	0.164	18.21	10.15	6.46	17.7	80.4	0.1	2182
10	1200	0	7200	0	0.164	18.21	10.15	6.46	17.7	147.9	0.2	3716
20	1400	0	7200	0	0.166	18.45	9.88	7.02	20.6	142.3	0.6	3580
30	1200	200	7200	0	0.169	18.88	9.87	7.46	34.2	114.7	0.9	2945
40	1650	200	7200	0	0.172	19.45	9.27	8.72	40.2	104.2	4.1	2633
50	1200	400	7200	0	0.174	19.55	9.58	8.46	50.3	82.5	2.8	2168
60	1200	600	7200	0	0.176	20.24	9.31	9.46	65.3	52.8	7.1	1394
70	1200	800	7200	0	0.174	20.95	9.06	10.46	78.2	27.4	15.7	620
80	1700	800	7200	0	0.169	21.68	8.48	11.86	80.1	25.7	28.5	290

The results presented in Table 23 through Table 26 indicate that no microturbine is adopted under any DER technology or renewable fraction scenario. In all cases, neither the 200kW, nor the 65kW microturbines were adopted. In addition, all fuel cell systems are assumed to be operated exclusively using directed biogas to achieve the renewable fraction required. In these scenarios, and accounting for the low thermal load of the City Yards, the combined efficiency of the microturbine is found to be less economically attractive than the use of a high-temperature fuel cell. Note that these scenarios were rerun ignoring any SGIP incentives available for a biogas powered fuel cell, but the results remain unchanged.

Under all scenarios in which a fuel cell was adopted, the fuel cell system was adopted almost exclusively using biogas. Although HOMER provides options to cofire a generator using both conventional and renewable fuel, the HOMER model indicates that any fuel cell adoption is paired exclusively with the purchase of renewable fuel. This result indicates that the lowest cost solution for creating a microgrid for Scenario 2 includes securing an ongoing renewable gas provider.

If the DER system is designed for Scenario 2 islanding requirements, the adopted DERs include 387kW solar PV, three 200kW fuel cells (600kW total), and one 200kW microturbine. If the Scenario 1 system was already implemented on-site, then the fuel cell capacity decreases by one system (200kW). Note that the results presented in this section include the "Export Fraction," which is the amount of energy exported divided by the total City Yards load. In all high renewable fraction scenarios, a large portion of energy is exported back to the grid. Using additional EES systems to capture this energy would be a viable path towards ensuring continuous islanding operation.

Based on these considerations and to satisfy the electrical loads and resilience requirements of Scenario 2, it is recommended a DER system consisting of 1.2 MW solar PV, 7.2 MWh EES, and two 200kW fuel cells. The considered system is guaranteed to allow for continuous City Yards islanding operations, but can also meet over 80 percent of the Scenario 2 load.

Scenario 3 Optimization Results

In this case, the Scenario 2 Homer model was modified to add the electrical loads of the Metro facilities described in Task 3. This scenario includes the same electrical rates used in Scenario 1 and #2. Scenario 3 uses the same technologies considered in Scenario 2. In addition, a 1,200kW gas turbine was studied for this scenario given the increased electrical load. In general, the results for this scenario mirror results produced for Scenario 2. HOMER suggests that the optimal path towards achieving a high renewable fraction is through a combination of solar PV and fuel cells operated using renewable fuel. Under this load scenario, only an 80 percent renewable fraction is achieved with the considered technologies. The same four scenarios listed in the previous section have been used for this case that includes the Metro facilities load.

Table 25: HOMER Results for Scenario 3 Optimized for Grid Connected Operation

% Renewable Requirement	Solar PV (kW)	Fuel Cell (kW)	EES (kWh)	Micro turbine (kW)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)	Operating Cost ($100k/year)	Initial Investment ($Mil)	Renewable Fraction	Utility Fraction (%)	Export Fraction (%)	Net CO_{2e} Emissions (Metric Tons/year)
0	0	0	0	0	0.120	13.37	11.54	0.00	0.0	99.9	0.0	2628
10	678	0	0	0	0.125	13.95	10.41	1.90	10.0	163.5	0.0	4076
20	244	200	0	0	0.127	14.19	10.80	1.68	20.2	142.6	0.0	3600
30	122	400	0	0	0.133	14.81	10.77	2.34	35.0	112.3	0.0	2910
40	487	400	0	0	0.135	15.06	10.10	3.36	40.4	101.3	0.1	2658
50	122	600	0	0	0.139	15.47	10.47	3.34	51.6	78.4	0.1	2136
60	727	600	0	0	0.143	16.00	9.47	5.04	60.1	61.8	1.8	1720
70	325	800	0	0	0.144	16.25	9.79	4.91	70.4	40.5	2.3	1223
80	122	1000	0	0	0.144	16.82	9.91	5.34	81.1	19.8	9.5	588

Table 26: HOMER Results Optimized for Grid Connected Operation When Using 2021 Solar PV and EES Capital Costs

% Renewable Requirement	Solar PV (kW)	Fuel Cell (kW)	EES (kWh)	Micro turbine (kW)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)	Operating Cost ($100k/year)	Initial Investment ($Mil)	Renewable Fraction	Utility Fraction (%)	Export Fraction (%)	Net CO_{2e} Emissions (Metric Tons/year)
0	3687	0	0	0	0.082	10.82	4.31	5.8	43.8	61.6	18.3	1339
10	3687	0	0	0	0.082	10.82	4.31	5.8	43.8	61.6	18.3	1339
20	3687	0	0	0	0.082	10.82	4.31	5.8	43.8	61.6	18.3	1339
30	3687	0	0	0	0.082	10.82	4.31	5.8	43.8	61.6	18.3	1339
40	3687	0	0	0	0.082	10.82	4.31	5.8	43.8	61.6	18.3	1339
50	6088	0	0	0	0.081	11.48	1.60	9.6	50.0	57.8	26.9	1057
60	2977	400	0	0	0.094	12.55	5.05	6.7	63.3	36.7	19.6	743
70	2841	600	0	0	0.098	13.42	5.12	7.5	73.3	24.5	22.4	1223

Table 27: HOMER Results Optimized for Grid Connected Operation When Only Solar PV and EES Technologies Are Considered

% Renewable Requirement	Solar PV (kW)	Fuel Cell (kW)	EES (kWh)	Micro turbine (kW)	Cost of Electricity ($/kWh)	Net Present Cost ($Mil)	Operating Cost ($100k/year)	Initial Investment ($Mil)	Renewable Fraction	Utility Fraction (%)	Export Fraction (%)	Net CO_{2e} Emissions (Metric Tons/year)
0	0	0	0	0	0.120	13.37	11.54	0.00	0.0	100.0	0.0	2630
10	678	0	0	0	0.125	13.95	10.41	1.90	10.0	88.9	0.0	2378
20	1357	0	0	0	0.132	14.75	9.45	3.80	20.0	78.0	0.3	2123
30	2089	0	0	0	0.137	15.72	8.52	5.85	30.0	68.8	3.1	1849
40	3074	0	0	0	0.137	17.22	7.44	8.61	40.0	63.3	13.0	1499
50	6067	0	0	0	0.170	23.90	5.97	16.99	50.0	57.8	26.9	1057

When considering fuel cell and microturbine systems for this scenario, HOMER elects to adopt fuel cell systems powered through renewable fuel over the use of microturbines. This result was extended to the larger gas turbine, which was not adopted under any scenario. The selected systems were able of reducing utility imports by up to 90 percent. With the use of additional energy storage, the excess onsite energy generation can potentially be stored for later use, allowing for complete islanding operation.

Based on these results, it is recommended that the Scenario 1 system be paired with four 200kW fuel cell systems (800kW). This expansion would maintain the City Yards islanding capabilities while also adding additional generating resources necessary to continually support most of the Bergamot art center and Metro facility loads.

Results Discussion

The systems recommended in this section were strongly influenced by the Scenario 1 design. It is expected that Scenario 1 would be implemented prior to additional expansion into the adjacent areas. The addition of Bergamot Arts Center and Metro Facility loads allow for larger capacity DERs to be adopted. Due to the relatively small thermal loads, cogeneration technologies were adopted only in scenarios where full islanding operation was required. Since islanding operation for the additional areas out of the City Yards is not a requirement for the microgrid design, these results were discarded. In general, the results presented in this work show a clear technology adoption trajectory that is feasible with expansion of the microgrid. If possible, the lowest cost option would be to adopt additional fuel cells instead of solar PV to meet the growing microgrid load while also meeting a large portion of the load using renewable energy. Finally, note that all scenarios were run with both no electric vehicle operation, and when all vehicles are electric. The switch in operation did not affect technology selection.

Microgrid Optimization Conclusion

The case study presented in this report details the design of the City Yards Advanced Energy District while attempting to achieve the following goals:

- Approach zero net energy (ZNE) during normal operation
- Capable of operating in island mode during power outages
- Allows continuous City Yards yard operations for at least two days at full load
- Capable of integrating additional distributed energy resources (DER) in the future
- Achieves these goals at minimum cost

These goals were considered for three different load scenarios. The first considered only the current City Yards loads, the second considered both the City Yards and adjacent Bergamot Arts Center, and the third added a metro facility to the second scenario. The primary islanding requirements were only applied to the Santa Monica City Yards loads.

The process of designing the Advanced Energy District started with estimating the City Yards loads after the City Yards renovations have been carried out, evaluating potential DER for inclusion in the study, and the optimization of DER technologies for when the City Yards is operating in parallel with the grid and in island mode. The results of this work indicate that a

1.2 MW solar PV system and 7.2 MWh EES system will achieve the stated design goals. Additionally, the proposed Level 2 electric vehicle charging stations will be able to serve a large part of the fleet as the City Yards moves toward full electrification. The current potential for V2G is low given current rate structures and ancillary service prices. The solar PV and EES should be located next to the largest electrical loads, and the microgrid electrical infrastructure should be operated at a distribution level voltage (12 kV) to minimize resistive losses within the microgrid. Expanding the City Yards to include adjacent buildings and loads could be achieved through the use of high temperature fuel cell systems run using directed biogas. This would require the City to secure biogas for the site.

Chapter 5: Business, Regulatory, and Financial Models, and Implementation Plan

Overview

In task 3 and 4 of this study, HOMER software (Hybrid Optimization of Multiple Energy Resources) was used to optimally size the microgrid DERs. The microgrid must be optimized to operate in parallel to the grid, and independently from the main grid, referred to as "island mode".

This section explores the cost-effectiveness of the Santa Monica City Yards microgrid under multiple technology sizes, rates, and load scenarios with three potential financing options. The cost-effectiveness is analyzed for each scenario from two perspectives:

- Total resources: California as a whole.
- Participants: City of Santa Monica.

The methodology and assumptions followed for the development of this section can be found in Appendix B and C.

Results

This section illustrates the cost-effectiveness results for the City Yards microgrid under multiple load scenarios and sensitivities. Two cost tests are conducted for each case to examine the cost-effectiveness of the microgrid from different perspectives. Three potential financing options are also examined for Scenario 1 - the design-base scenario.

Scenario 1

Design Base Scenario

Participant Cost Test (PCT)

The PCT is designed to assess if a demand side program is cost-effective from the perspective of the end consumer who chooses to participate in a program or install a DER or energy efficiency measure. Figure 26 summarizes the net present value (NPV) of benefits and costs of the whole microgrid system over 25 years from the city's (the participant's) perspective. The microgrid system provides electricity bill savings, including energy and demand bill savings, Net Surplus Compensation (NSC) for surplus energy, as well as reliability revenues when there are system outages. The revenues from exporting energy to the grid is included in the energy bill savings and NSCR categories in the chart.

On the cost side, the whole microgrid system costs around $3.6 million in 2021 dollars with the Investment Tax Credit (ITC) but not SGIP incentives. As the microgrid system is sized to operate fully in Island mode, over a year the microgrid exports more energy than it imports from the grid. Under the tariffs explored in this study, all exports exceeding imports are compensated at the Net Surplus Compensation Rate. This rate is significantly lower than the compensation for exports to the grid that do not exceed imports. The CCA rate provides higher benefits because it has a much higher NSCR, of around $0.06/kWh, compared to $0.03/kWh provided by SCE. The CCA rate is therefore used in the following analysis for the design-base scenario.

Figure 26: PCT in Scenario 1, Design-Base Scenario

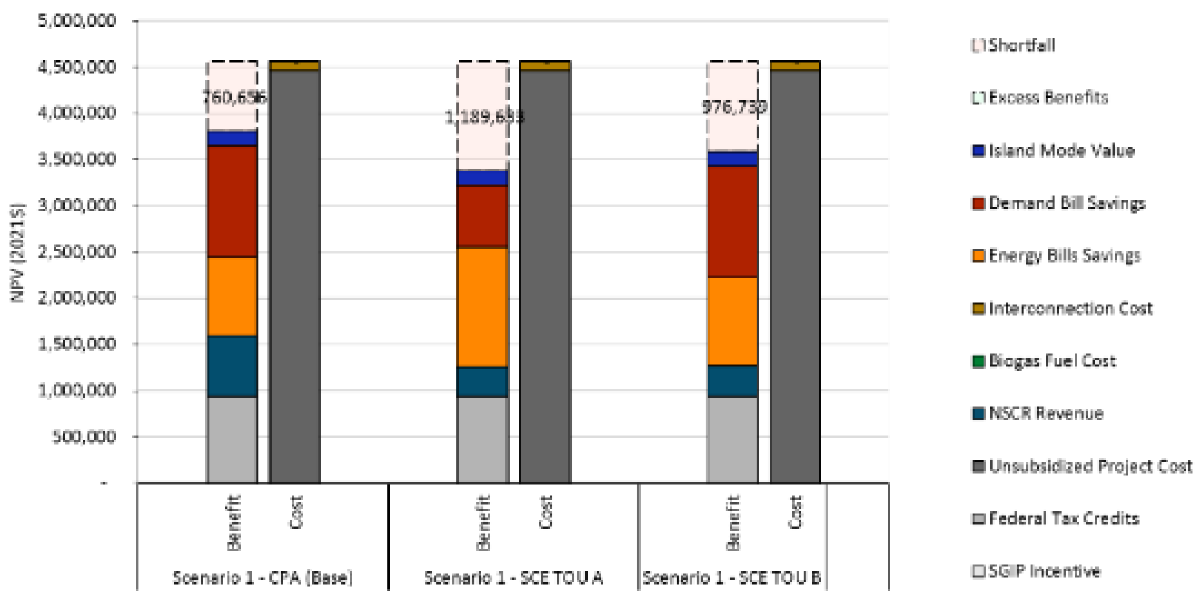
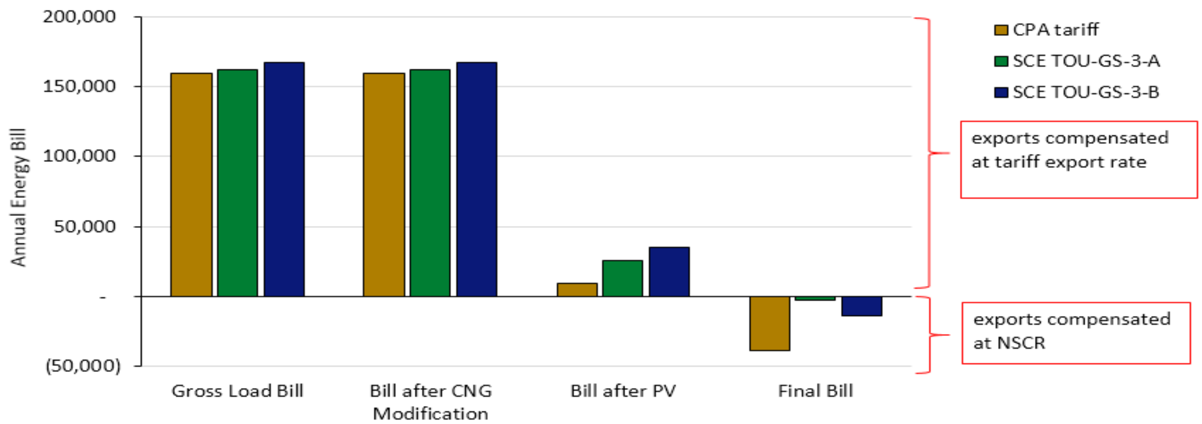


Figure 27 shows the bill before and after distributed energy resources (DER) installation for these three rates. From left to the right, bills are calculated every time a new DER is added to the system, starting with the CNG modification, PV is then added, and finally storage. The bill after storage category shows the final customer bills when the whole microgrid system is in place. A negative value means that even though City Yards purchases power from the grid, because it also exports a large amount of excess energy, at the end of the year, the city earns net revenue from exporting. Before installing the microgrid, the city pays a similar amount under all three rates. However, after installing the large solar system, the CCA rate provides better export compensation and therefore offers higher bill credits.

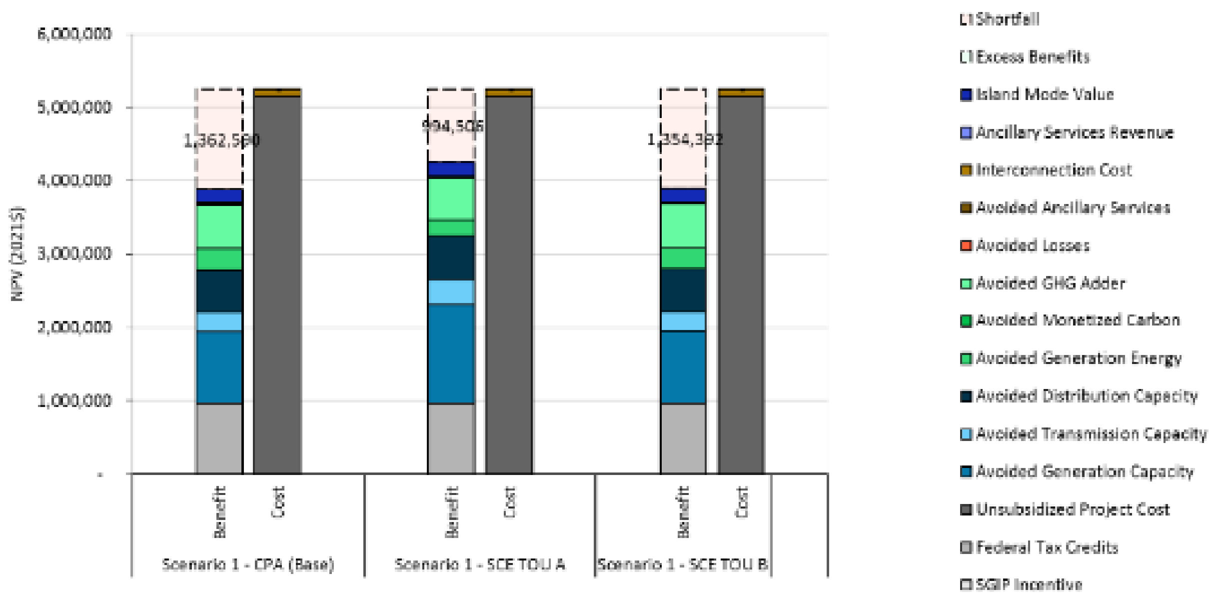
Figure 27: Bill Comparison Before and After Distributed Energy Resources



Total Resource Cost (TRC) Test

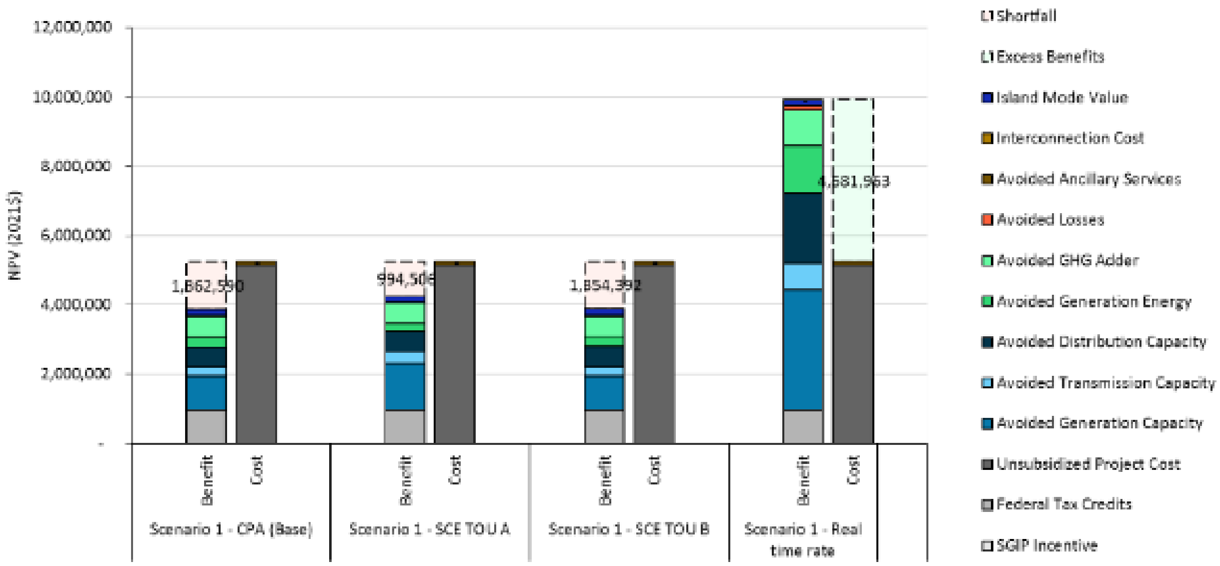
The TRC assesses the monetized costs and benefits to California. The costs are the purchase cost of the microgrid system. The benefits are the avoided costs of supplying energy and the ITC. As shown in Figure 28, more than half of the system benefits come from avoided capacity, including generation, transmission, and distribution. The remainder comes from avoided energy, avoided monetized carbon, and the reliability value provided by the microgrid during system outage events. The dispatch of energy storage and therefore the avoided cost benefit is similar under the three rate assumptions because the rates have the same TOU period and a very similar demand charge structure. Dispatching the storage system to minimize the bill under the SCE TOU A rate provides slightly more benefit than the other two rates because the SCE TOU A rate has higher energy charges and lower demand charges compared to the other two rates. Instead of dispatching to reduce the microgrid peak and therefore minimize demand charges, the storage has greater incentive to reduce energy charges by charging during off-peak hours and discharging during on-peak hours. Because the TOU peak hours align with the system peak, the microgrid provides higher avoided generation capacity to the system.

Figure 28: TRC for Scenario 1, Design-Base Scenario



To maximize the benefits that energy storage systems provide to the grid, the utility can design more dynamic rates that align the system needs with the rate signal. Critical peak pricing and other demand response programs are the powerful initial steps to direct storage to discharge during critical system peaks. Options like full value tariffs and real-time rates can unlock even more benefits from storage. To evaluate the maximum system benefits provided by storage, this study also simulates the storage dispatch under a real-time rate. Figure 29 compares the system benefits when the storage responds to three commercial rates and a real-time rate. The real-time rate provides much higher benefits to the system because it reflects the system marginal costs and enables the storage system to dispatch to maximize system benefits. Under a real time rate, the microgrid provides $4.6 million in net benefits to the system, more than double the benefit provided under the previous rates.

Figure 29: TRC with a Real Time Rate for Scenario 1, Design-Base Scenario

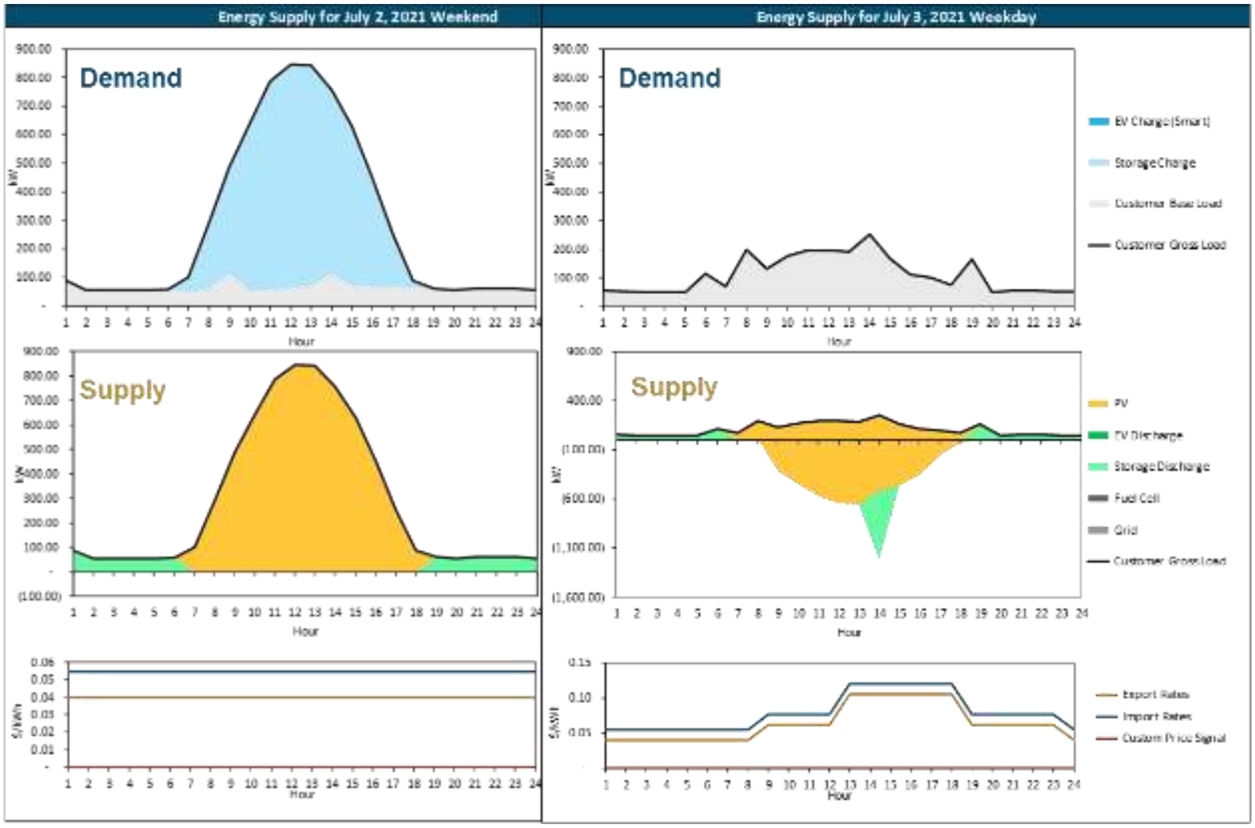


Example Dispatch

Figure 30 shows an example of how the microgrid operates during a typical summer weekend and weekday. The upper demand charts show the components that make up the microgrid load including the original base load and storage charging load. The energy supply charts show which technologies (PV or storage) the microgrid uses to meet the energy demand and when grid imports occur if no technologies are dispatching. Negative regions in the energy supply chart indicate when the microgrid is exporting energy to the grid. The bottom charts in the figure show the energy charges that apply to the microgrid for imports and exports.

Weekend operation is shown on the left side and weekday operation for the following day is shown on the right side. The figure shows typical operation during the summer when storage charges from PV in the middle of the day on the weekend when energy rates are lower and stores that energy to use on week days for demand charge management. This is not a very efficient way of using the battery since it only cycles about once per week.

Figure 30: Example Dispatch for a Summer Weekend and Weekday



Financing Options

As a public entity, the City of Santa Monica has access to tax and financing advantages not available to other microgrid owners – it does not pay tax and has access to low cost debt financing. However, because the city does not pay tax, it is also not able to receive the investment tax credit (ITC). To better understand the economics of different financing and ownership options, this analysis explored three common financing and ownership scenarios for the microgrid: a third-party lease, city purchase through low cost debt financing, and a hybrid option in which the PV system is procured through a Power Purchase Agreement (PPA) and the rest of the microgrid equipment is purchased through city debt financing. Appendix C describes the opportunities and financing parameters for these three options. The Third-party leasing option is used as the default financing method in the design-base scenario.

Figure 31 shows the net present value of the project costs by cost component under the three financing options. Even with the low-interest-rate debt that the city has access to, third-party leasing is the cheapest option because the ITC benefits outweigh the debt and tax savings that the city can obtain through self-financing. The third-party lender would be eligible for ITC benefits and could potentially pass that benefit to the city by charging a lower lease fee. By contracting with a third-party, the city can enjoy the ITC benefits that would not otherwise be available. The potential drawback is that the third-party might mark up its prices in the absence of competition from other lenders.

The cost of the hybrid financing option (solar PPA + city purchase) falls between the costs of third-party leasing and city self-financing. Since the solar PPA market is mature, it is more likely the third-party charges the company at a competitive rate. If the city does not receive a competitive quote for the microgrid combined, this option can also be a good choice.

Figure 31: Net Present Value of Project Costs under Three Financing Options

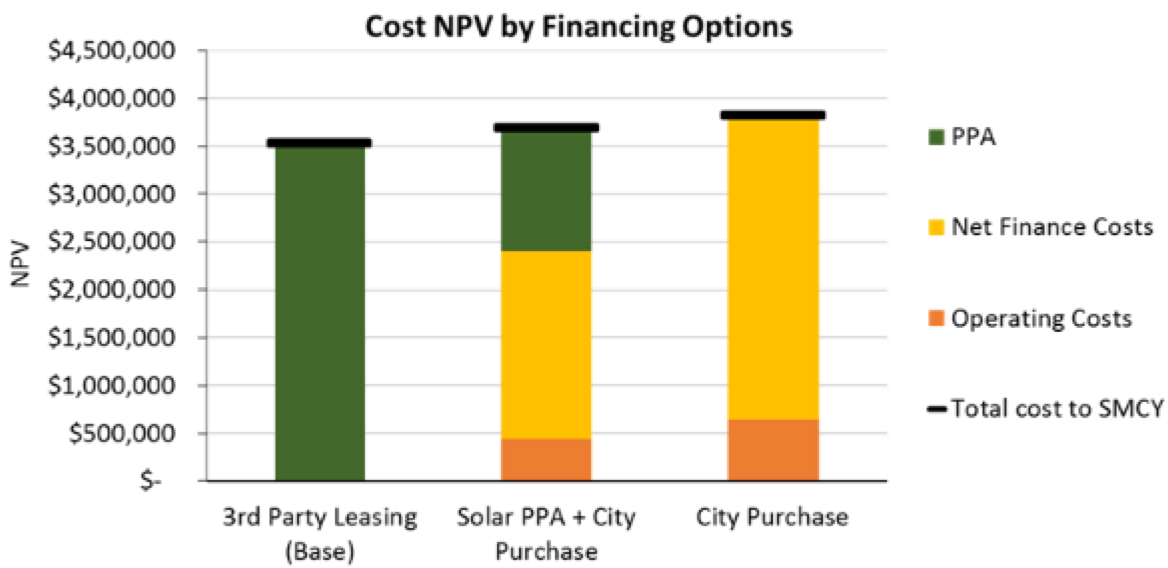
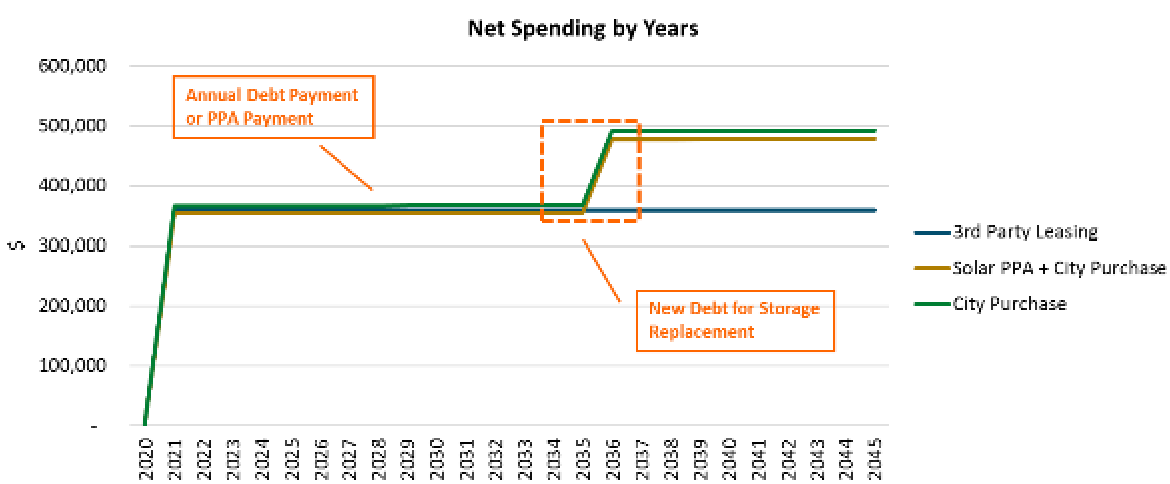


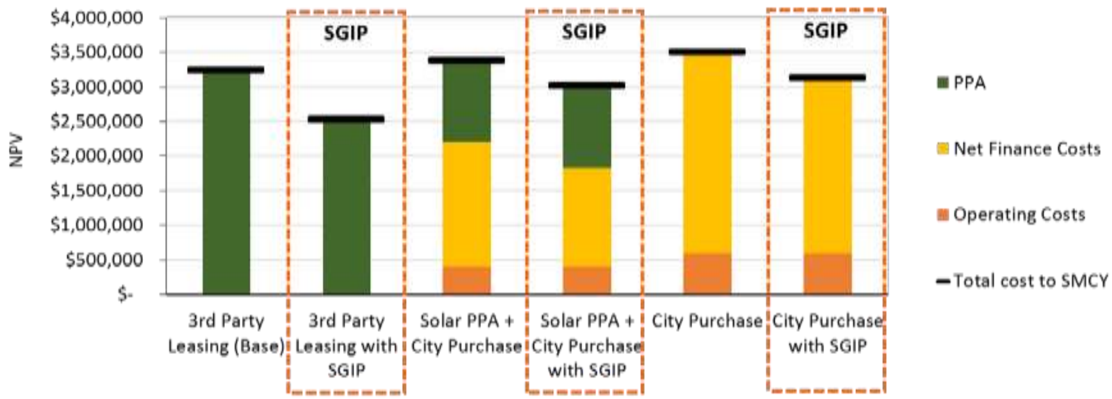
Figure 32 shows the annual net spending for the three financing options. City debt financing and PPA incur continuous monthly or annual payments throughout the project lifetime. The jump in value for the city purchase and solar PPA + city purchase options in year 2036 reflects the new debt financing required for the battery replacement after its 15-year lifetime.

Figure 32: Net Spending by Years for the Three Financing Options



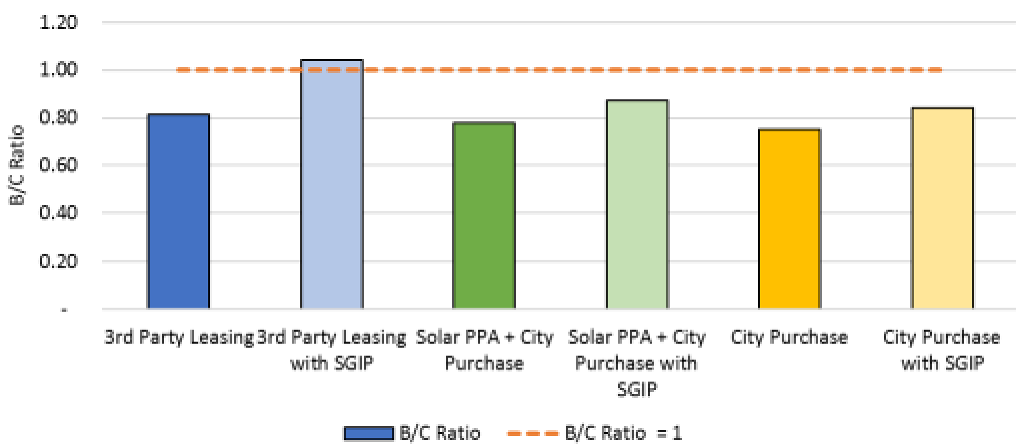
The study also tested the impact of SGIP incentives on project costs. Figure 33 shows the total costs for City Yards under six different financing scenarios. SGIP incentives reduce the total project costs by 11 to 22 percent depending on the financing option.

Figure 33: Financing Option Comparison With SGIP



The benefit to cost ratio (B/C ratio) for all financing options under the Scenario 1 base case is shown in Figure 34. Third-party financing provides the highest B/C ratio and actually becomes cost- effective if the SGIP incentive can be secured.

Figure 34: Benefit-Cost Ratios for Multiple Financing Options Under Scenario 1, Design-Base Scenario



Zero-Net-Energy Sensitivity

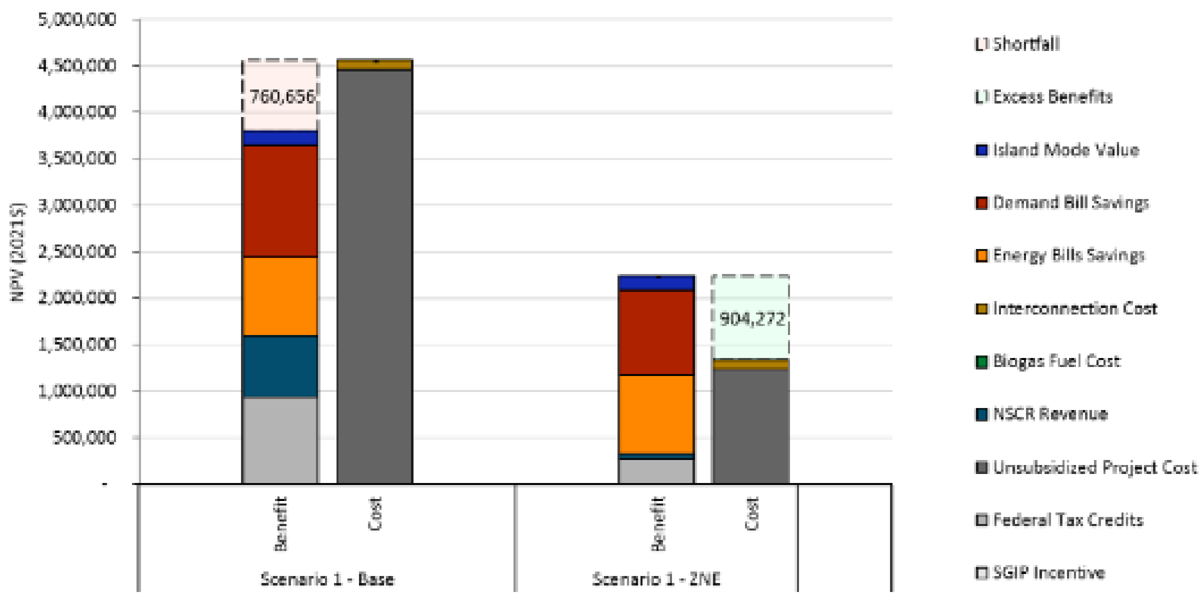
Initial analysis suggests that it might be too expensive to build a microgrid to cover the whole City Yards load during emergency events. To test a more economical option, this study also examines a smaller microgrid system sized by the HOMER model. This small system can support all loads in City Yards during emergency events, except the Natural Gas compressors and the car maintenance load. In addition, annual renewable generation from this system is 110 percent of the expected annual load, thus meeting the zero-net energy (ZNE) requirement. The technology and their sizes are summarized in Table 28.

Table 28: Technology Sizes for Scenario 1, ZNE Sensitivities

Scenario	Sensitivities	PV (kW)	Storage (kWh)	Fuel Cell (kW)
Scenario 1	ZNE	658	834	n/a

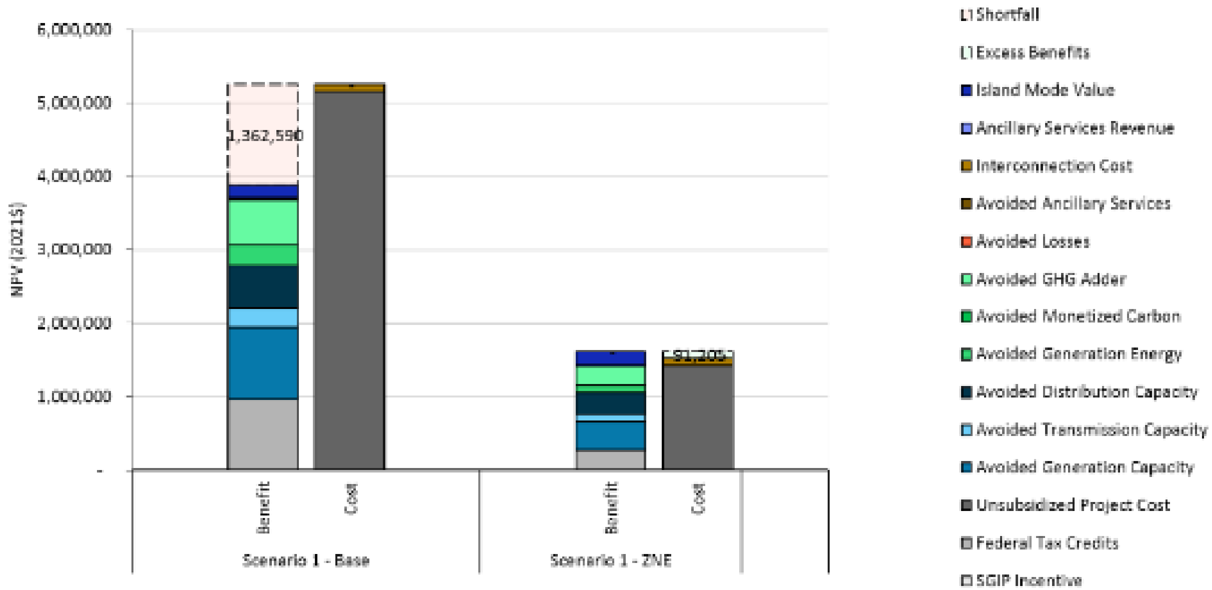
PCT results for the design-base scenario and the ZNE sensitivity are summarized in Figure 35. The ZNE microgrid design is cost-effective with a net benefit of $904,272. The ZNE case and the design-base scenario have very similar energy and demand bill reduction because the microgrid system in both cases is oversized and can reduce the city's electricity bill to almost zero. Any additional exported energy is compensated at a much lower rate (the NSCR). The ZNE case is more cost-effective because a larger proportion of the energy generated by the PV system is used to reduce onsite energy consumption, which is far more valuable than exporting energy to the grid and being compensated for it. In contrast, for the design-base scenario, half of the energy generated by PV is compensated at the much lower NSCR export rate, reducing its profitability.

Figure 35: PCT for Scenario 1, Base and ZNE Cases



Looking at the total resource cost test in Figure 36, the ZNE case provides a net benefit of $90,000 mostly because the microgrid system cost in the ZNE case is much cheaper.

Figure 36: Total Resource Cost Test for Scenario 1, Base and ZNE Cases



Fleet Electrification Sensitivity

Five Electric Vehicle (EV) charging scenarios were tested in the fleet electrification sensitivity, these are shown in Table 29.

Table 29: Charging Scenarios Tested for the Fleet Electrification Sensitivity

Charging Scenario	Description
Unmanaged Charging	On plugging the EV fleet in at 6pm on weekdays, EVs immediately charge at the maximum charging rate until their state of charge is 100 percent.
V1G (managed charging)	The EVs can time their charging needs to maximize bill savings for City Yards while ensuring they always have enough charge to perform their duties during the week.
V2G	With V2G capability, as well as being able to time their charging, the EVs can discharge to the grid to help further increase bill savings, for example by supporting rate arbitrage or customer peak shaving.
V2G + AS	EVs have the same charging and discharging capabilities as the V2G scenario but can also provide ancillary services to the utility, earning additional revenue from the ancillary service market.
Realtime V2G + AS	This scenario is the same as the V2G + AS case but City Yards is on a real-time electricity tariff that reflects system marginal costs.

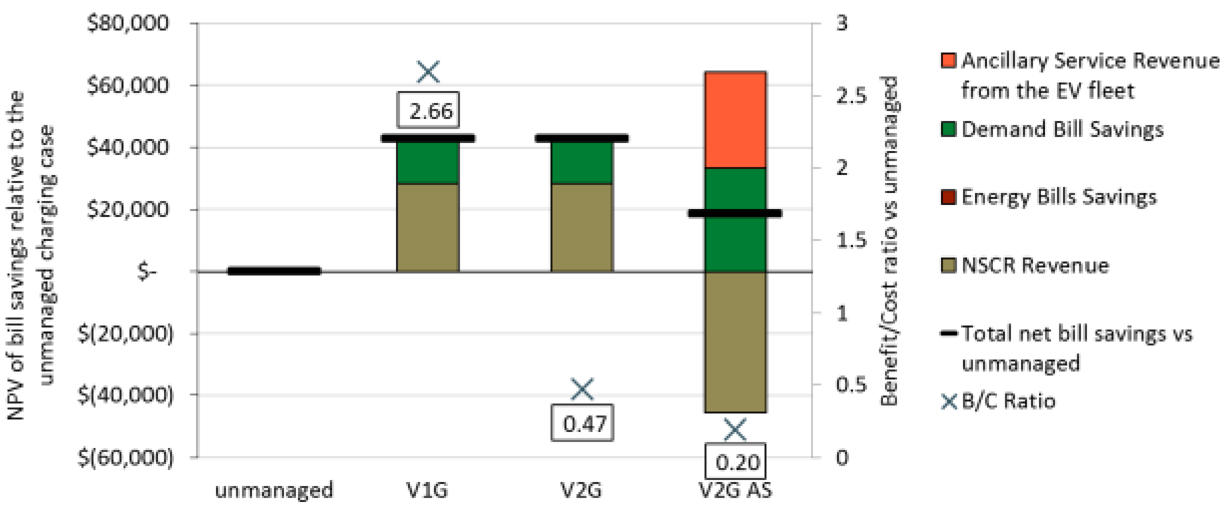
To analyze the results of the fleet electrification sensitivity, the impact of different charging scenarios is presented relative to the unmanaged charging case. The purpose of the Realtime V2G + AS case is to demonstrate the maximum potential system benefit achievable from employing vehicle to grid technology in City Yards where plugged in vehicles respond to a real-time rate that reflects the system marginal costs. Only the system cost impacts are shown for this case.

Customer Bill Savings

The overall bill savings impact of different EV fleet charging scenarios is small compared to the existing bill savings that the microgrid provides City Yards under the design-base scenario.

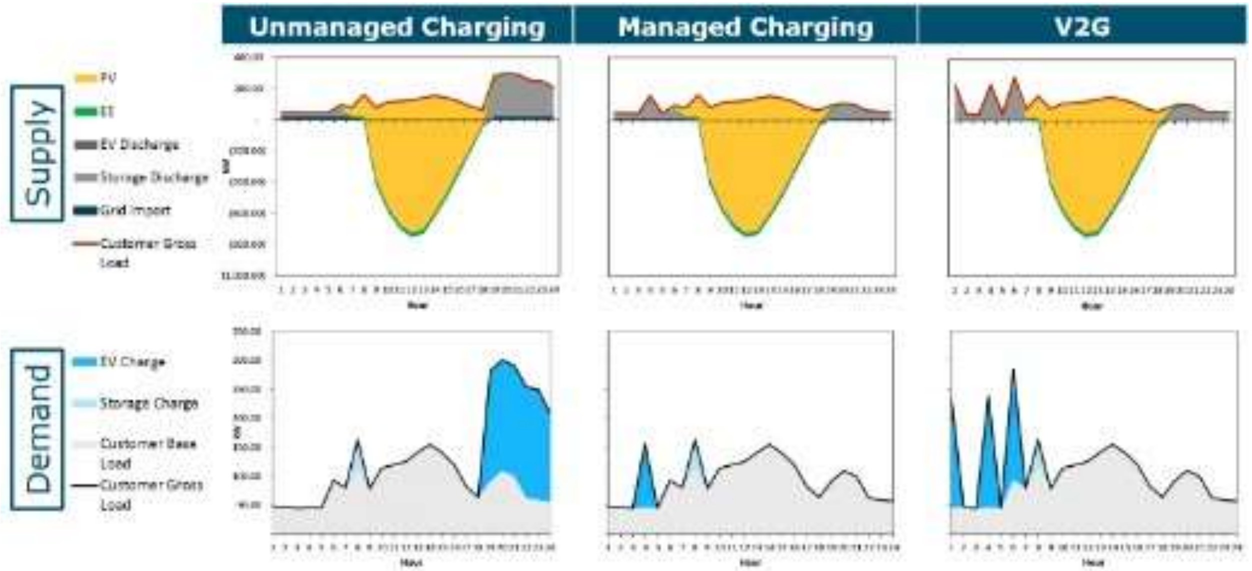
Both V1G and V2G charging scenarios increase bill savings by 1.8 percent, while the V2G AS case led to a 0.8 percent increase. Given the higher cost of employing V2G technology, only the V1G case is cost-effective with a benefit-cost ratio of 2.66. Figure 37 shows the size of bill savings relative to the unmanaged charging case.

Figure 37: NPV of Customer Bill Savings Achieved Between 2030 and 2045 Shown Relative to the Unmanaged Charging Case



From the V1G case we see that bill savings primarily arise from increased energy exports. (NSCR revenue). The technology dispatch behavior shown in Figure 38 demonstrates that in the unmanaged charging case, to ensure grid import does not spike when the EVs plug in at 6pm resulting in very high demand charges, the battery storage must supply the entire EV fleet charging load from 6pm onwards. Consequently, the storage is required to work much harder to meet the base load and the EV load to keep demand charges low. In the managed charging case the EVs can shift their own charge and support the flattening of grid import peaks and demand charge reduction.

Figure 38: Dispatch Behavior on Monday, April 17, under Different Fleet Charging Scenarios



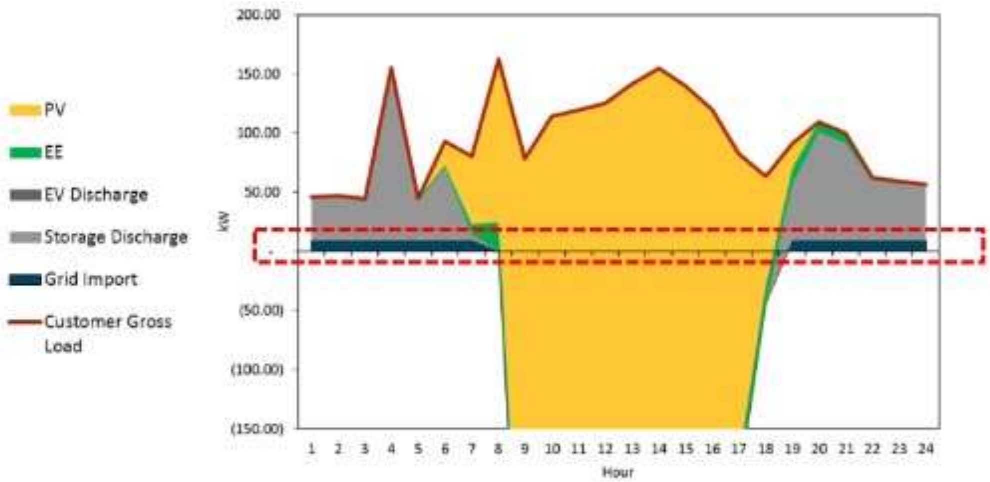
This translates to battery storage having to cycle much fewer times over the year in the V1G case compared to unmanaged charging as shown in Table 30, resulting in fewer energy losses and therefore higher net exports to the grid.

Table 30: Charge/Discharge Cycles per Year under Each Charging Scenario

	Unmanaged Charging	V1G	V2G
Storage cycles	94.5	54.9	54.9
EV cycles	19.8	19.8	19.8

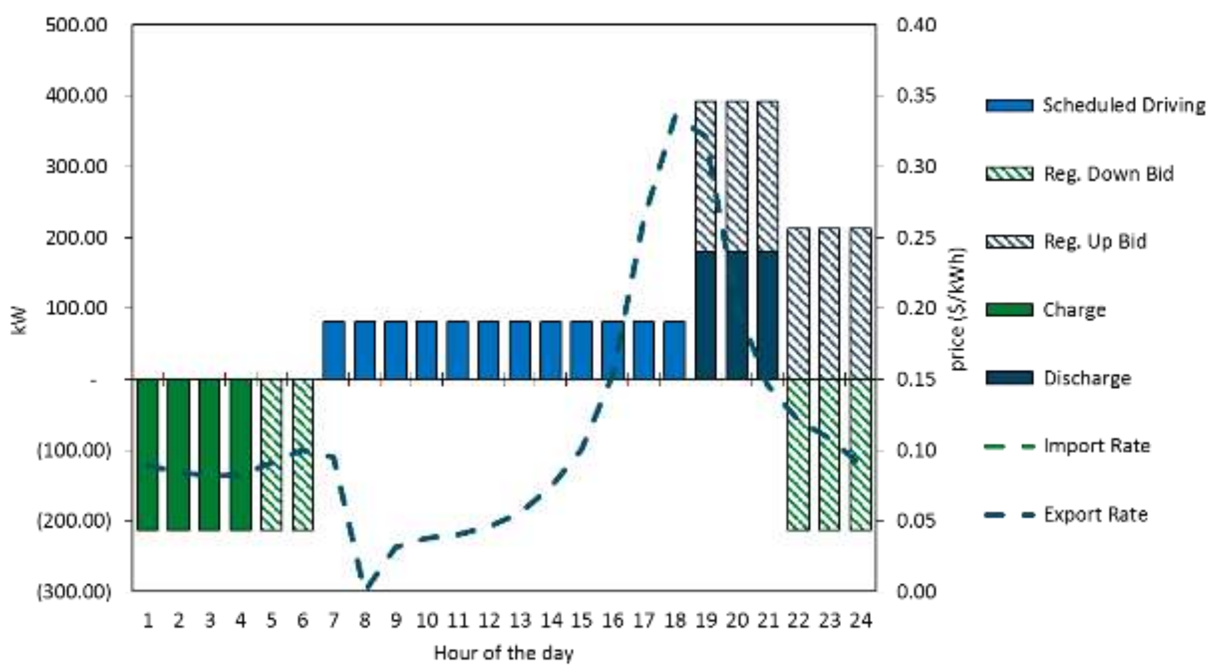
Adding V2G charging capability provides no additional bill savings benefit for City Yards and the EVs are not required to discharge at all throughout the modelling period. V2G capability effectively provides City Yards with a second battery storage facility with a lower round-trip efficiency and the constraint of only being able to dispatch in hours where City Yards' base load is generally low. The existing battery storage facility is already large compared to load and when combined with managed charging, City Yards' grid import throughout the year is completely flattened with very few additional peak reduction opportunities, as shown in Figure 39. Therefore, reducing demand charges further requires a large amount of energy for even a small reduction in peak demand. Finally, after accounting for round trip efficiency losses and lower export rates compared to import rates, the only opportunity for V2G to increase energy revenues is through arbitraging the summer off-peak and summer peak energy rates. However, the timing of these peak periods does not coincide with the assumed EV fleet driving hours (from 6am to 6pm), so this is not possible.

Figure 39: Enlargement of V1G Case



In the V2G AS case, it is assumed that only EVs participate in AS markets resulting in additional revenues with an NPV of $30,884. NSCR revenue declines relative to the unmanaged case because when AS market prices are high, EVs and battery storage alter their charging behavior to make AS market bids. This has the knock-on effect of freeing up EVs and storage to further reduce demand charges. A sample day demonstrating AS bidding behavior is shown in Figure 40.

Figure 40: Dispatch Behavior on August 3, 2031, Under a Real-Time Electricity Rate with AS Market Participation



It is important to note, the relative size of benefits for managed charging and V2G technology varies significantly by use case. A recent study conducted for the Energy Commission by E3 and the Electric Power Research Institute (2017) on workplace charging demonstrated that V2G can offer significantly more benefit versus managed charging for an office building with some employees who commute to work in electric vehicles.[2] Under this scenario, the office building in Southern California is a net importer of electricity with no generation or storage technologies on site and with vehicles that are plugged in from early morning to late evening. In this case, managed charging generates significant bill savings but is constrained by the EVs state of charge on arrival at the workplace. By allowing EVs to dispatch to support demand charge reduction, V2G achieves far greater bill savings than managed charging. City Yards is a very different case, the microgrid is sized to operate in island mode and meet its full design load, it is therefore hugely oversized for operation when connected to the grid. Furthermore, the electric vehicle fleet is for commercial purposes and is therefore not connected to the grid at times when additional storage would be most beneficial - through energy rate arbitrage or absorbing excess solar generation. Consequently, energy storage already provides all the load shifting benefit when the EV fleet is plugged in and while managed charging offers some additional value by reducing the amount of energy storage cycling required, V2G offers no additional benefit. However, this study only explores the benefit of adding V2G to the existing microgrid setup. Where V2G could potentially be more valuable is in reducing the size of the energy storage system. At 300 $/kW, the capital cost of energy storage is likely to outweigh the additional cost of V2G infrastructure. Accounting for the additional kW of energy storage that could be reduced by employing V2G functionality could significantly reduce the capital cost for storage and tilt the balance more in favor of V2G technology.

System Cost Savings

Under the CPA rate, managed charging and V2G technologies provide more benefit to the system than from increasing City Yards bill savings, as demonstrated in Figure 41. All technologies provide system benefits that exceed their costs, although V1G remains the most cost-effective technology. A large portion of the system benefit arises from increased distribution capacity savings, avoided generation energy and GHG emissions. However, the timing of charging incentivized by the CPA rate does not align well with Generation and Transmission capacity savings compared to the unmanaged case, consequently these savings decline.

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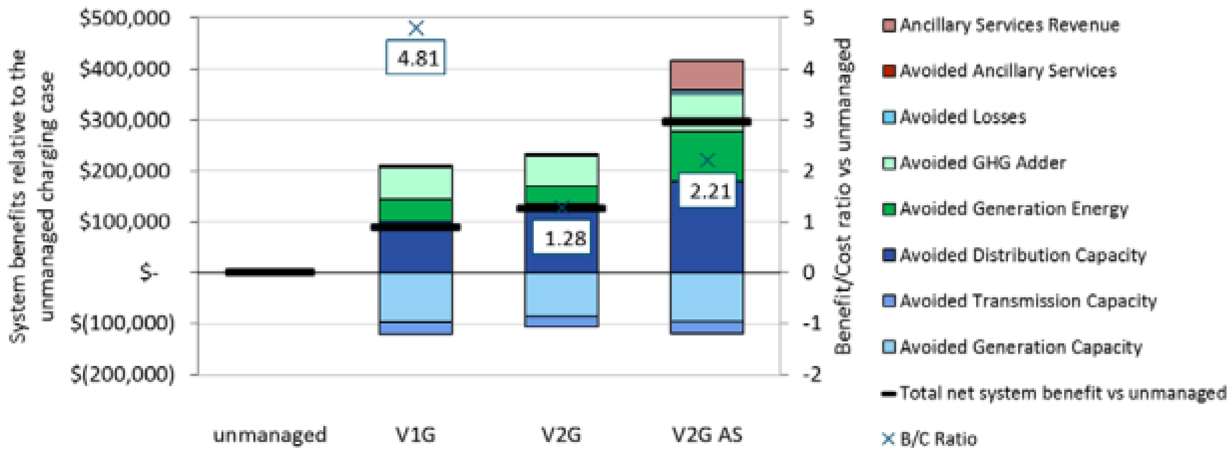
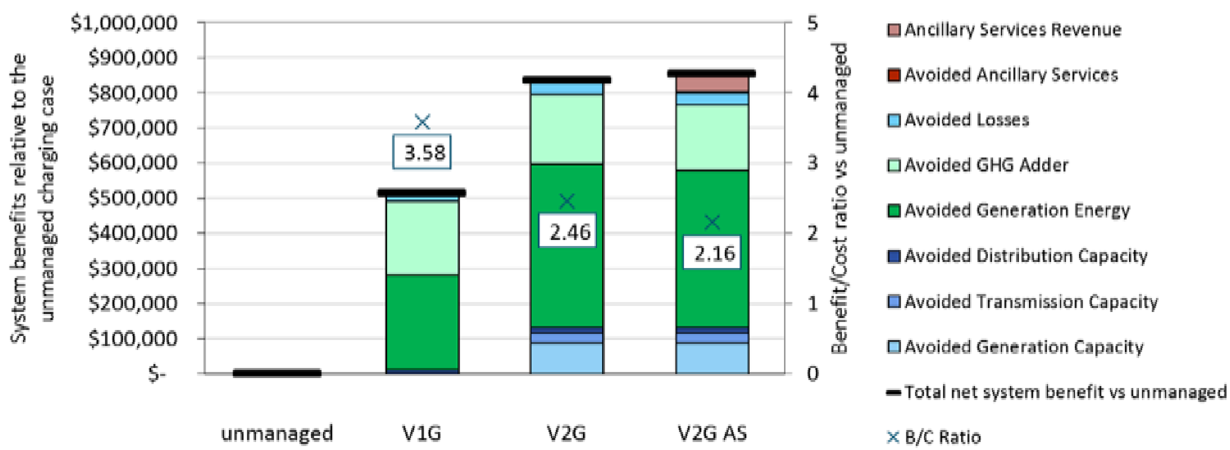
[2] Managed charging benefit valued at $154 per EV per year versus unmanaged charging under the design-base scenario, V2G benefit was $492 per EV per year versus unmanaged charging.

Figure 41: Total System Benefits for Different Charging Scenarios



The potential system cost savings under various electrification scenarios were also analyzed with a real-time electricity tariff based on the marginal cost of providing electricity. Under this real-time rate the potential system benefits more than double for most of the charging technology scenarios and there is no drop for any avoided cost category versus the unmanaged charging case due to the well-aligned price signal (Figure 42).

Figure 42: Total System Benefits for Different Charging Scenarios Under a Real-Time Electricity Tariff Aligned with System Marginal Costs



Avoided generation energy and emissions form the bulk of the system benefit in this scenario. However, V1G still remains the most cost-effective charging technology primarily due to the lower infrastructure and aggregator costs compared to the more advanced charging scenarios.

Scenarios 2 and 3

In Scenario 2 and 3, the microgrid is designed to accommodate more load from the nearby Bergamot Arts Center, and Metro facilities which may be added to the microgrid in the future. Adding the Bergamot Arts Center load requires at least 274kW of additional PV based on Santa Monica's Reach Code which requests 2W/sq.ft. while adding the Metro load requires at least 129kW of PV. Scenarios 2 and 3 build upon the microgrid system in Scenario 1, Design base. Based on the above requirements, one sizing was chosen for Scenario 2 and 3 from the optimal sizes provided by UCI under different renewable requirements.

Table 31: Technology Sizes for Scenarios 2 and 3

Scenario	Sensitivities	PV (kW)	Storage (kWh)	Fuel Cell (kW)
Scenario 2	Base	1700	7204	200
Scenario 3	Base	1700	7204	200

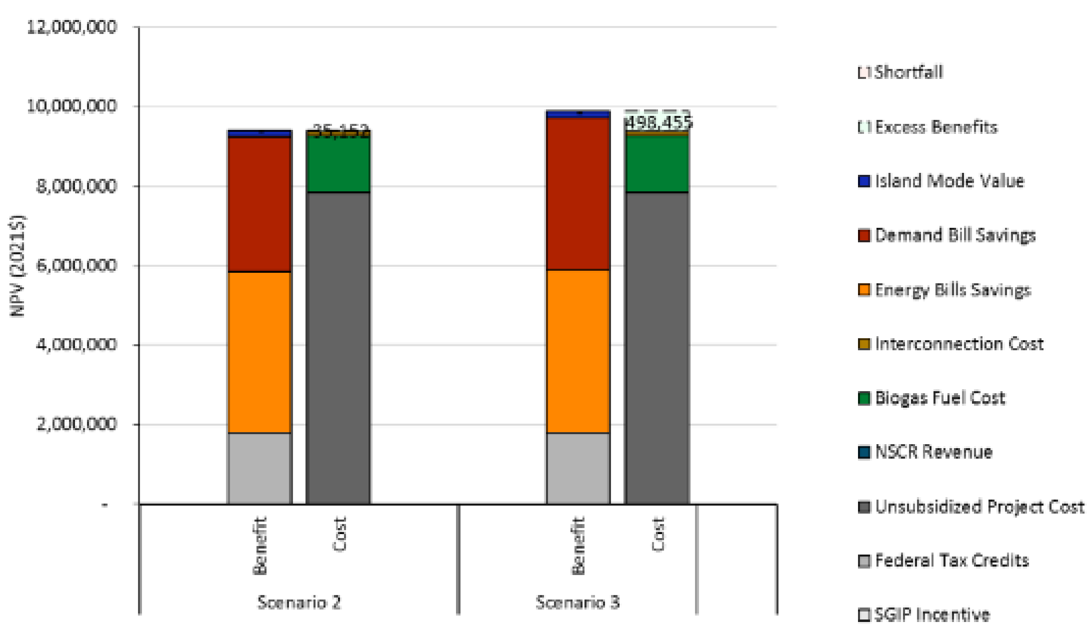
The technologies and their sizes are the same for Scenario 2 and 3 with a new fuel cell generator and more PV capacity compared to Scenario 1. The total load and renewable percentages for the different scenarios are summarized in Table 32. Onsite PV generation supplies 49 percent and 26 percent of the Scenario 2 and Scenario 3 loads, respectively.

Table 32: Load and Renewable Percentage Summary for Scenarios 1, 2, and 3

	Scenario 1 Base	Scenario 2	Scenario 3
Total Annual Load (kWh)	882,724	5,152,425	9,481,425
Annual Peak (kW)	335	1,128	1,817
RE % (PV gen/total load)	200	49	26
% of hours importing from the grid	45	81	97

From City Yards' perspective, the microgrid is cost-effective under Scenario 2 and 3. Scenario 3 shows slightly more bill savings than Scenario 2 because while the microgrid size is the same, the load is larger, which generally allows for more peak reduction opportunities. On the cost side, biogas fuel makes up a significant portion (~15 percent) of total cost.

Figure 43: PCT for Scenario 2 and 3



Total resource cost test results are also very similar for Scenario 2 and 3, and both are negative due to the expensive technology and biogas fuel costs. They provide similar benefits to the system because they receive the same rate signal and have similar load shapes.

Figure 44: TRC for Scenario 2 and 3

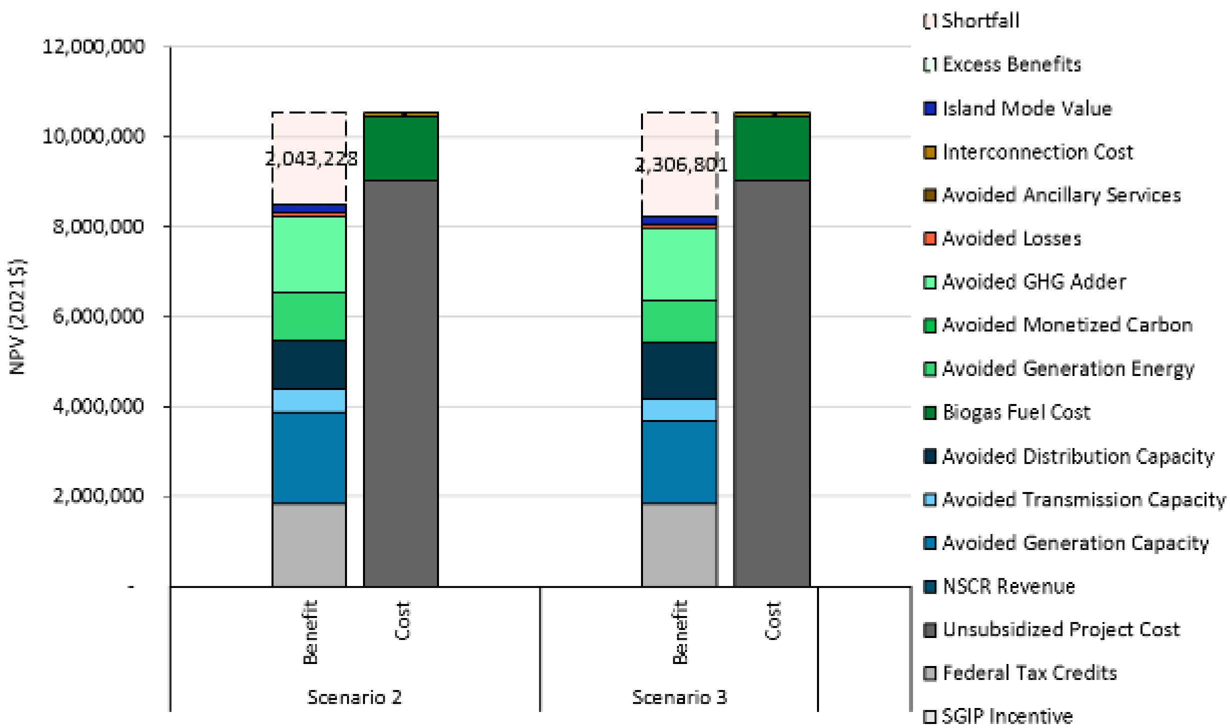
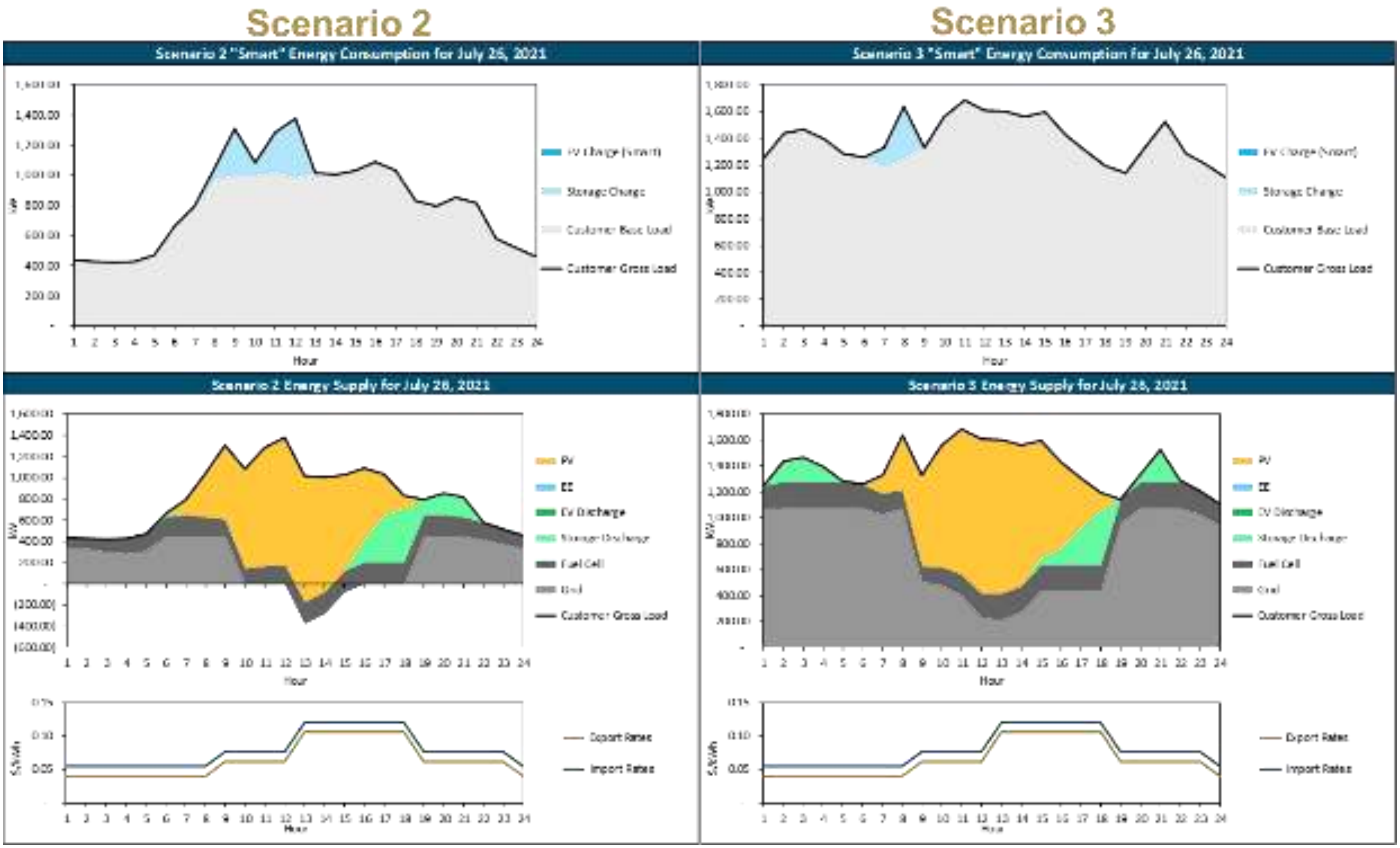


Figure 45 shows example dispatch behavior for a typical summer day for Scenario 2 and 3. In both scenarios storage charges in the middle of the day and discharges to either reduce the grid import during system peak time or reduce demand charges. Scenario 3 has a large load so it can use most of the energy generated by PV for electricity bill reduction.

Figure 45: Example Summer Day Dispatch Chart for Scenario 2 and 3



Summary

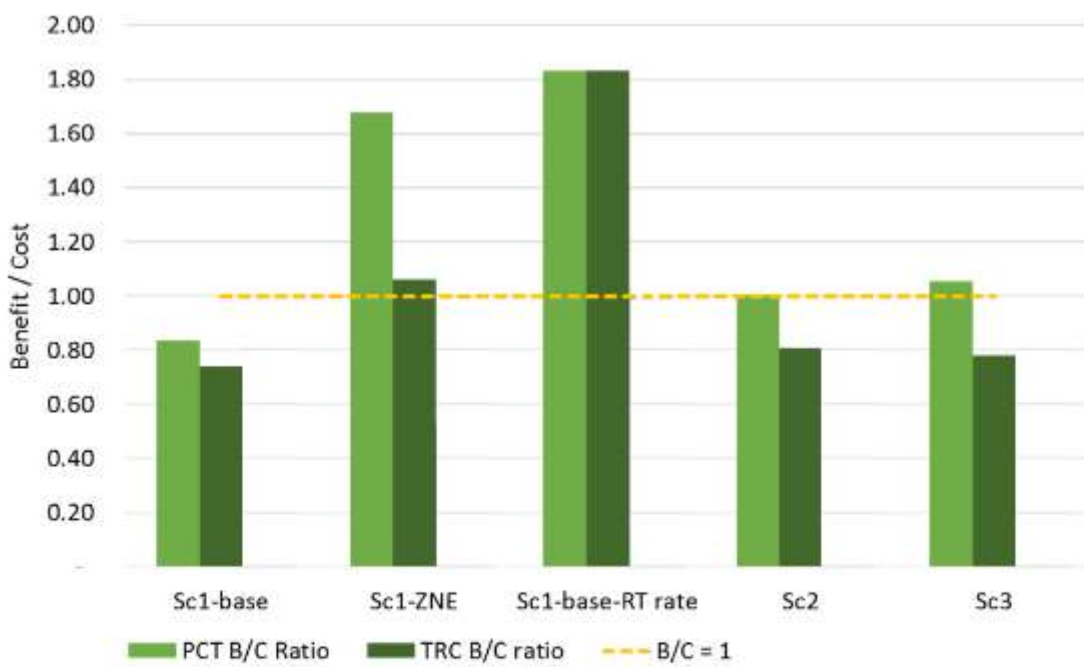
PCT and TRC results for four of the scenarios explored are summarized in the Figure 46. The Fleet Electrification sensitivities are not included here because electric vehicles provide additional benefits and incur additional costs that are not estimated in the standard microgrid cost tests. For example, gasoline fuel savings or the additional costs of purchasing EVs. The Fleet Electrification sensitivities were only shown on an incremental basis relative to the unmanaged charging case to avoid this issue.

The Benefit-Cost ratio (B/C Ratio) under the PCT and TRC perspectives for different scenarios are shown in light green and dark green, respectively. The Scenario 1 design-base scenario is not cost-effective from either the City Yards or the system perspective because it is sized for islanding operation during emergency events and therefore hugely oversized for regular operation. Most of the time the microgrid does not need such a large amount of self-generation which means almost 50 percent of generated PV is exported to the grid and compensated at a very low rate (NSCR).

The ZNE sensitivity for Scenario 1 shows that shrinking the PV and storage system enables much higher B/C ratios from PCT and TRC perspectives.

Scenario 2 and 3 are just cost-effective for City Yards as the PCT B/C ratios are slightly larger than 1. Both Scenarios are more cost-effective than Scenario 1 because with a larger load, the energy generated by PV can be used to reduce electricity bills instead of being exported to the grid and compensated for at the very low NSCR rates. However, due to the same misalignment issue of the CCA rates with system costs, these two scenarios do not pass TRC with a B/C ratio at 0.8.

Figure 46: PCT and TRC Results Summary for Five Scenarios



Economic Impact

Several reports have studied the economic and employment impacts of renewable and distributed energy investments in California using economic input-output analysis. To date, none have focused specifically on microgrids. Using results from prior studies on distributed solar and energy efficiency programs, a rough estimate is made of the potential economic and employment impact for microgrid investments.

Economic input-output analysis quantifies the economic, employment and tax impacts of specific changes in a regional or local economy. Direct impacts are the investments and payments made in the region, in this case, related to microgrids. Indirect impacts are the additional inflows and spending induced in the region from the direct impacts (known as the multiplier effect). Tax impacts are the increase on local and state taxes caused by the direct and indirect impacts. Finally, jobs created are also calculated based on the direct and indirect impacts. IMPLAN software is a commonly used input-output model used for such analysis.

The U.C. Berkeley Center for Labor Research and Education has produced recent reports on the economic impact of clean energy policies for several regions in California, including San Joaquin and the Inland Empire (Jones et al. 2017a, 2017b). These studies use IMPLAN to estimate Indirect and job impacts of several clean energy programs, investments, including energy efficiency and distributed energy programs. These programs and regions are not directly comparable to the microgrid investment in Santa Monica but nevertheless give some indication of the potential impacts for the local economy. The economic impacts from the U.C. Berkeley Center for Labor Research and Education reports are summarized in Table 33. Using these figures, investment in a microgrid in Santa Monica would have a multiplier effect of 1.4 and create 9 to 13 jobs per million dollars spent.

Table 33: Summary of Economic Impacts from UC Berkeley Center for Labor Research and Education

	Direct Investment ($Million)	Total Economic ($Million)	Tax Revenues ($Million)	Direct and Indirect Jobs	Jobs/$ Million in Direct Investment	Multiplier Effect	Tax Revenues/ Direct Investment
San Joaquin Commercial EE	$842	n/a	n/a	7,310	9	n/a	n/a
Inland Empire PV	$1,103	$1,506	$50	10,117	9	1.4	5%
Inland Empire EE	$612	$848	$30	7,935	13	1.4	5%

Table 34 summarizes the estimated tax revenues and job creation for each sensitivity based on project investments.

Table 34: Summary of Economic Impacts for City Yards Project

Case ID	Scenario	Sensitivities	Total Direct Investment ($2020 NPV)	Total Economic ($2020 NPV)	Tax Revenues ($2020 NPV)	Direct and Indirect Jobs
1	Scenario 1	Base	$4,463,467	$6,248,854	$223,173	40
1.2		ZNE	$1,346,871	$1,885,619	$67,344	12
2	Scenario 2	Base	$7,829,447	$10,961,225	$391,472	70
3	Scenario 3	Base	$7,829,447	$10,961,225	$391,472	70

Conclusions

The major conclusions from the study are summarized:

A microgrid with 1.2 MW of PV and 7.2 MWh of energy storage, sized to operate in island mode during emergency events, is not cost-effective given the current City Yards load (Scenario 1 – design-base scenario). Among the three existing rates the study examined, the most cost-effective for the City is the CPA TOU-GS-3-B which has a Net Surplus Compensation Rate (NSCR) double the size offered in corresponding SCE rates. The higher NSCR is the main reason for CPA being the winning rate because the microgrid is so oversized for daily operation that around 50 percent of the energy generated by PV is exported and compensated at NSCR.

When the technologies are down-sized to 0.7 MW of PV and 0.8 MWh of energy storage so only the 'No Vehicle Operation' loads can be supported (all loads except for CNG and vehicle maintenance loads) during emergency events, the microgrid is cost-effective with a net benefit of $0.9 Million. When PV is smaller, more energy can be used to reduce expensive electricity bills rather than being exported to the grid and compensated for at the low value NSCR.

The Total Resource Cost (TRC) test is slightly positive for the microgrid at smaller sizes. Energy storage systems are very flexible and capable of providing more benefit to the system. However, to unlock the full potential of energy storage requires a more dynamic rate/incentive design. When the energy storage system is dispatched against a real-time rate that reflects system marginal costs, the microgrid system provides $4.6 million in net benefits under Scenario 1.

If City Yards is to electrify its commercial vehicle fleet, the most cost-effective charging technology to deploy is managed charging (V1G). The additional benefit provided by V2G technology cannot be unlocked given the misalignment of the proposed tariff TOU peaks with fleet driving patterns and how flat City Yards' net load will be from storage dispatch and managed charging. If less energy storage was available and the vehicles' plug-in time was better aligned with City Yards' peak load, then V2G technology could potentially provide far more benefit, particularly in supporting demand charge reduction. Where V2G could potentially be of most value however is in reducing the need for such a large PV and storage system. If V2G storage could be relied upon, the additional cost of purchasing V2G rather than V1G technology is likely to be less than additional kW of storage and PV, therefore reducing project costs significantly. However, this analysis would need to be explored further in future studies.

The project is more cost-effective when additional load from Bergamot Art Center and Metro facilities is served by the microgrid. As with the Scenario 1 ZNE sensitivity case, if the microgrid system is smaller relative to load it can provide more benefits to participants because more of the energy generated is used to reduce electricity bills instead of being exported to the grid at lower compensation offered by NSCR. However, this also causes a bigger cost shift due to the misalignment between system costs and rates.

Third-party leasing is the cheapest financing option when compared to City debt financing or a hybrid financing option that combines a solar PPA with City debt financing for the rest of the microgrid. ITC benefits can only be obtained indirectly through third-party financing or a PPA option. Since the ITC benefits outweigh the other benefits offered through city self-financing (e.g. a lower debt interest rate, no required return on equity, etc.), third-party leasing is the most cost-effective. SGIP incentives can reduce the total project cost by 11 to 22 percent, which would lead to a slightly positive PCT for the City Yards under Scenario 1, design-base scenario.

Governance Structure

Governance is the way that programs are managed at the highest level and the systems that facilitate this management. In the context of this project, governance relates to the departments that will be involved in owning and operating the microgrid. The governance structure is highly influenced by the ownership and procurement models. As part of this analysis, the project team considered two main ownership options and a hybrid of the two.

City-Owned Microgrid

If the microgrid is to owned by the City of Santa Monica, its implementation would be paid for with the city's general funds, augmented by grant money. The city has already applied to the Energy Commission's Phase 2 grant funding opportunity 15-312, which could provide up to 5 million dollars to cover the implementation of the microgrid. There is also a self-generation incentive program, which is rewarded on a lottery basis. Considering that the city is not eligible to receive the federal investment tax credit, the maximum allowed total incentive for the project would be $1,225,000 (assuming 7.2 MWh of EES are installed).

It is expected that the microgrid will be operated and maintained by the city's Facilities Maintenance Division, which is part of the Public Works Department. The existing facilities operators will need to be trained in the new systems incorporated in the microgrid. Some of the more complex procedures for the operation may need to be outsourced.

Third-Party-Owned Microgrid

Third-party ownership of the microgrid would simplify the governance structure as the city is only required to pay for the monthly charges of the lease or PPA, with no down payment to start operating the microgrid. While there is no capital expenditure, the city will typically need to maintain the obligations with the lessee for 10 to 20 years.

The main difference between a lease and a PPA is that in a lease agreement, the city pays a fixed monthly payment for the lease of the PV panels ($/month), while in the PPA, the payments are associated with the amount of energy delivered with a set energy price ($/kWh).

In both cases, the operational cost of the microgrid would be covered by the city's Facilities Maintenance Division.

Figure 47: Leasing Agreement Diagram

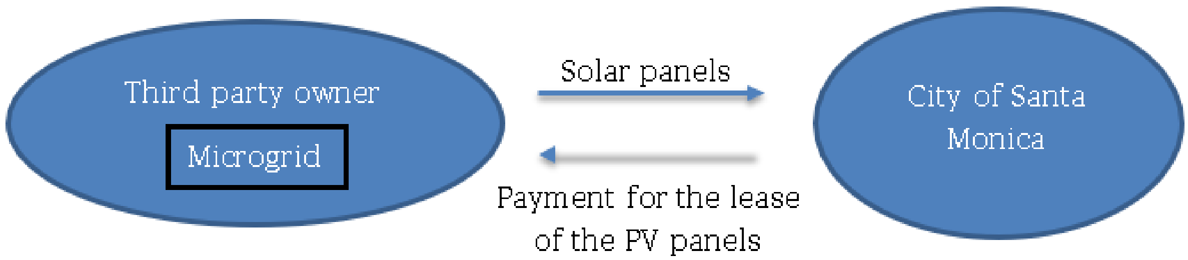
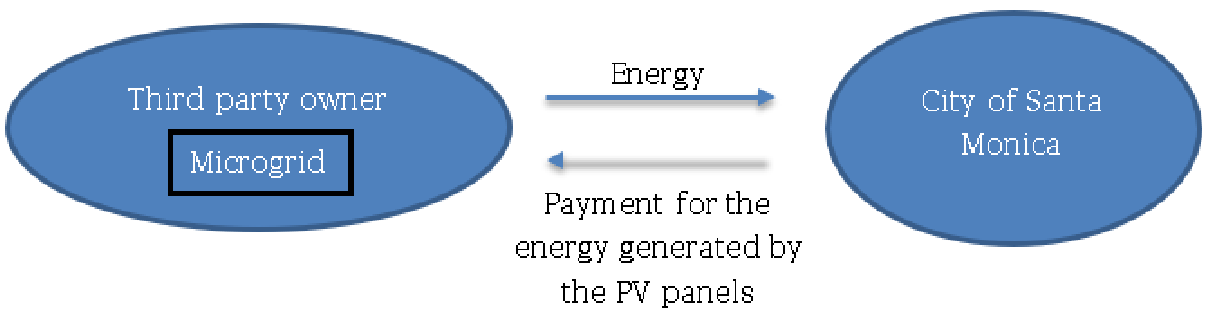


Figure 48: Power Purchase Agreement Diagram



Another option is a hybrid procurement method, in which the solar panels are acquired through a lease or PPA, displacing the capital cost of the solar panels and inverters to a third party, while the electric batteries, microgrid controller, and auxiliary microgrid systems are purchased by the city.

Next Steps: Microgrid Implementation Plan

The project team suggests the following implementation plan for the microgrid.

Complete Design and Construction Documents

The city currently has a design-build contract with Hathaway Dinwiddie (construction) and its subcontractors Miller Hull (architecture) and Buro Happold (engineering) for the renovation of the City Yards.

The design team developed the 30 percent schematic design package in parallel with this report and did not included the microgrid design. The components of the microgrid and support electrical infrastructure must be included in the 100 percent schematic design, design development, and construction documents. The EPIC project team has identified the following tasks, which should be completed for an integrated microgrid design:

- Design the microgrid configuration (demand mitigation, islanding requirements, and expandability).
- Specify electrical infrastructure (distribution, sensors, meters, building automation system, PV arrays, electrical energy storage).
- Design ground conduit from Package A to perimeter areas for future microgrid expansion.
- Determine location of microgrid controller, solar arrays, and electrical energy storage.
- Design PV racking and system components such as modules or multi-port inverters.
- Design conduit path from PV modules to combiner boxes to interconnection point. In June 2018, the project team submitted a Development Review Permit to the City Planning Division of the city. The project will be reviewed for approval by the Architectural Review Board and Planning Commission and then ultimately be submitted to city council for final approval.

Figure 49 identifies the submission requirements throughout the design process.

Figure 49: Submission Requirements Matrix

		Architecture Services	Other City Departments and Divisions	Arts Commission/ Public Arts Committee	Task Force on the Environment	Architectural Review Board	Community Outreach	Landmarks Commission	Planning Commission	City Council	Life Cycle Cost Analysis	Cost Update	Basis of Design Report	Code Review Report
Schematic Design	50% SD	X					X				X	X	X	X
	75% SD	X			X Courtesy Review	X			X					
	100% SD	**X**	**X**							**X**	**X**	**X**	**X**	**X**
Design Development	**50% DD**	**X**	**X**				X				**X**	**X**	**X**	**X**
	75% DD	X			X Courtesy Review	X			X					
	100% DD	**X**	**X**	X (Estimated)					X As Required	**X**	**X**	**X**	**X**	**X**
Construction Documents	**50% CD**	**X**	**X**					X (Demo permit)			**X**	**X**	**X**	**X**
	80% CD submitted to Plan Check	**X**	**X**								**X**	**GMP for Construction**	**X**	**X**
	100% CD	X								X				
	100% Plan Check/ Documents for Construction	**X**	**X**											

BOLD = Requires Notice to Proceed

Requires Council/ Commission/ Community presentation

In parallel, the project team is in the process of completing the Environmental Impact Report (EIR). The project team held a public scoping meeting on November 30, 2017. A public review period was held for 30 days and concluded on December 15, 2017. The team intends to release the Public Review Draft EIR in October 2018 for a 45-day public review period and then release a Final EIR on November 30, 2018. The project team will then submit the EIR for approval by the City's Planning Commission on December 12, 2018. Once completed, the team will apply for plan check and permits to initiate construction.

Table 35: City Yards EIR Schedule

Milestone	Estimated Date(s)	Actual Date
Notice of public review period (30 days)	October 2017	November 15, 2017
Hold public scoping meeting	November 14, 2017	November 30, 2017
Public review period ends	November 2017	December 15, 2017
Complete technical reports for City review	October 11, 2017	October 25, 2017
Complete Traffic Study	January 2018	January 31, 2018
Submit Administrative Draft EIR to City	May 4, 2018	May 7, 2018
Publish Draft EIR	October 2, 2018	
45-day public review period ends	November 16, 2018	
Publish Final EIR	November 30, 2018	
Planning Commission Hearing	December 12, 2018	

Procurement and Installation of Microgrid Assets

The purpose of this task is to document the sequence of actions from a construction and operational perspective. The renovation process for the City Yards will be separated into three phases that will take place over the course of five years. This process is complicated by the fact that all divisions within the City Yards must maintain operation during construction, and that a portion of the site is located over an abandoned landfill. This will require the temporary relocation of several operating divisions into existing or temporary facilities until the new ones have been constructed.

Parallel to the construction timeline, the project team will initiate a procurement process for the solar PV, inverters, EES, microgrid controller and EV charging stations. The project team will develop bid documents and specifications to solicit proposals to deliver and install the required solar PV, EES and microgrid equipment. The bid documents will be publicly released on the city's procurement website and the city will conduct an evaluation process to select the best value proposal based on the vendor's experience and approach, quality and performance of equipment, cost and financing options, and value-added services. The city will convene an expert panel of internal and external stakeholders to review the proposals.

The city would then enter into a contract with the selected provider and direct them to coordinate with HDCC the design, delivery, and installation of the microgrid assets. In coordination with the equipment provider(s), city staff will facilitate the process to apply for city plan check, permits, and SCE's interconnection application.

System Performance Measurement and Verification

The city will contract with an outside consultant to independently monitor and verify system performance on a regular basis. The team will develop bid documents to solicit proposals for the scope of work. Once selected, the city would then enter into a contract with the consultant and facilitate coordination with the design-build team.

For this project, verifying energy performance of the various DER components and energy efficiency measures following implementation is essential to optimize the microgrid. The consultant will assist the project team in developing the microgrid specifications and performance requirements. The microgrid should operate automatically with minimal input required, however there will be a requirement to inform site staff and system managers on system status and operational parameters. Therefore, a physical control center is proposed, for manual and automated report generation, status flags and alarms.

A rigorous measurement and verification process shall be pursued following the guidance of the International Performance Measurement and Verification Protocol (IPMVP).

When calibrated, the simulation model should reasonably predict the load shape and energy use of the City Yards and sub-systems and then be available for comparison against measured performance data (energy consumption), independent variables (weather or occupancy) and static factors (new building or equipment). Submeters and data loggers shall give an accurate representation of how energy is being distributed throughout the facility.

Coordinate Expansion into Bergamot Arts Center

In June 2017, Santa Monica City Council approved an interim, master ground lease for the Bergamot Arts Center with the Worthe Group, for three years. The site consists of approximately five acres with five buildings totaling approximately 62,000 square feet of total building space that is subleased to approximately 27 small, creative tenants, including art galleries, designers, a nonprofit theatre company, and a café.

Worthe has submitted a preliminary plan for six new buildings providing additional space for galleries and nonprofit cultural uses, a museum, a community center, restaurant/café space, and creative office space, as well as a hotel.

Figure 50: Bergamot Arts Center Preliminary Plan

Source: Worthe Development Group

The staff from Santa Monica's Office of Sustainability and the Environment and the Housing and Economic Development Department will engage Worthe Development Group to incorporate in its projects assets to be interconnected with the microgrid.

Before and throughout the development process, staff shall work with Worthe to develop requirements that must be met as a condition of the Development Agreement, such as the inclusion of solar PV, EES, net zero energy (ready) design, submetering, building management systems and microgrid interconnection.

Secure and Monetize Microgrid Value Streams

Depending on the final ownership model, only certain microgrid benefit streams may be monetized; similarly, the method of monetizing such benefits will differ based on the microgrids' operator. For example, if the City Yards' microgrid was owned by a third-party, this will recover the costs by billing for the provided services to the City Yards and other potential microgrid users. In the case the microgrid is owned by the city, the costs are recovered from energy cost savings, and selling services to the nearby potential users.

This project's business model is seeking to develop several revenue and savings streams. The microgrid serves primarily onsite usage within the City Yards and will likely be owned/operated by the city. This will allow for simplified decision-making and transparent costs and revenues. Sales to the macrogrid, CCA and to future non-city entities could provide additional revenue.

The overall economic success of a microgrid depends on realizing the revenue streams considered as part of the development and cost-benefit analyses. This should be done by securing major revenue streams through long-term contracts and active DER management.

The city will seek to prepare a DER Value Stream Plan. This plan should identify existing value streams that the city can take advantage of and describe the process by which the city can participate. Such value streams should include: demand response, critical peak pricing, load shifting, demand management, grid services, ancillary services, etc. The plan should also consider the interaction with the city's community choice aggregation provider, Clean Power Alliance, and the values and benefits that could be realized if implemented on a larger scale. The plan should develop valuation methods and activation methods for benefits that may not be directly monetized, such as deferred investment in macrogrid, emissions reductions, or emergency services.

Evaluation of Benefits

Santa Monica City Yards microgrid project can increase system resilience, provide cost reductions and add renewable generation into the local grid providing benefits to the city. The microgrid will provide a locally controlled DER system that can serve the existing, and future electrical loads, provide ancillary services, and serve the City Yards critical loads upon a grid outage.

Public Outreach

The City Yards is slated to become a state-of-the-art facility, transforming a long-held perception of dirty and polluted to that of a community-oriented, sustainable community asset. The benefits of the modernization project and that of the microgrid would be made highly visible to the public and key decision makers in various ways.

The City of Santa Monica has established an extensive set of sustainability plans and targets to achieve its environmental objectives. The city offers this information to the public through its Office of Sustainability and Environment website.[3] In this website, it is possible to find information related to the advancements of the city towards meeting its sustainable goals in aspects such as energy, waste, or water. As part of the products developed for this project, the city developed an Outreach Strategy and Outreach Materials to disseminate the case study and its findings to stakeholders and the public.

Since the commencement of the EPIC Phase I grant, city staff have already done public outreach about the project at conferences. These presentations have primarily been targeted towards other local government staff, utilities, regulatory agency representatives, and other practitioners. Possible venues or platforms for future presentations or workshops include:

- Clean Power Alliance of Southern California (CCA)
- ICLEI USA

[3] https://www.smgov.net/departments/ose/

- Southern California Regional Energy Network
- Utility meetings (Local government partnership program, All Partners meeting)
- Statewide Energy Efficiency Collaborative (SEEC)
- Business of Local Energy Symposium
- Local Government Sustainable Energy Coalition (LGSEC)
- Urban Sustainability Directors Network (USDN)
- Green Cities California

Public outreach to residents and businesses in the area has primarily occurred through city documentation of the planning and construction process to inform the public on why the project is happening. Staff shall create various media to showcase the facility at various stages of the project. Such media would include, but is not limited to staff reports, websites, videos, social media posts, interviews, press releases, community presentations. The city is planning to make a video documentary of the microgrid under construction that can be uploaded to the project website (City of Santa Monica 2018a).

Once the site is complete, City Yards will offer interpretive and interactive displays for the community to view, interact with and learn about the sustainability features of the facility. A public interactive display would take information from the microgrid control interface system and present in an educational format. Supplementary signage will be required to support educational programs and staff engagement.

Lessons Learned

Financial

- The initial use case survey and charrette with stakeholders provided guidelines regarding project needs, but much of the feedback was not grounded in representative costs for the project size. As a result, the project started with some mismatch between objectives, such as a high level of energy resilience and its associated cost. Providing information on economic trade-offs earlier in the process would have allowed stakeholders to make better-informed decisions.
- Early conversations with the city's Finance Department could have provided important input on the options to finance the project. For example, the City of Santa Monica has access to low-cost debt financing, but this is not available for innovative energy assets like solar and energy storage.
- The economic modeling found that the microgrid was significantly larger than needed to provide reliability to the whole site load. For future projects, additional work should be carried out to scrutinize the minimum load requiring backup.

- Current Southern California Edison (SCE) rates do not allow the city to take advantage of all the benefits a microgrid can provide. The current incentives for commercial customers are for reducing their demand charge. Because bill reduction gives more value to the customer than the utility, it does not become a sustainable source for the utility. To maximize the benefits that energy storage systems provide to the grid, SCE could design more dynamic rates to align the system needs with the rate signal. Critical peak pricing and other demand response programs are powerful initial steps to direct storage to discharge during critical system peaks. Options such as full-value tariffs and real-time rates can unlock even more benefits from storage.

Policy

- Reducing the crossing of rights-of-way will simplify application permitting.
- There are currently ways for microgrids to interact with the wholesale energy market, but the regulation is very complex. The team had some initial conversations with the Distributed Energy Resource Program at the California ISO; however, the California ISO stated they need to test the regulation and determine whether the use case can succeed. Having more flexible real-time rates would assist in the process.

Social and Political

- Comprehensive microgrid operator training, contingency planning, and user-friendly interfaces will be essential components to easily and consistently maintaining the microgrid's normal and emergency operations, such as during earthquakes and other natural disasters.
- Public agencies learn by doing and by observing others; however, public agencies consist of countless numbers of people who work in different functions of the agency. Often many of the staff do not concern themselves with energy or energy costs. Building an advanced energy community requires that the public agency understands its value. The entire state is witnessing a momentous shift in which local governments are more involved and active in energy, particularly in community choice aggregation. However, the technical capacity of electors and staff to understand, appreciate, and deliver advanced energy projects is limited. There is not enough time, people, or money within these organizations to achieve the capacity required to take advantage of and leverage the funding. The California Energy Commission could better serve these limited-capacity organizations by providing fully-funded technical support, with the intent to build internal capacity.
- For future projects, a more creative approach to project delivery could be considered. The city has not fully positioned itself to entertain new business models or partnerships. Private sector companies may be better prepared to design and operate the microgrid. More flexibility around partnerships, models, and changing conditions may allow for smoother operations and maintenance, particularly with stakeholders who are already knowledgeable about microgrids.

- The microgrid concept was added onto the renovation of the City Yards site, rather than incorporated in the beginning of the design process. As a result, the microgrid had to be designed around the City Yards renovation project, instead of being designed alongside the City Yards site, which constrained its optimization.
- A community-driven engagement process may be useful for building a stronger relationship with the residents and businesses in the surrounding area and discussing charged issues such as potential gentrification and displacement. Tools such as the Community-Driven Climate Resilience Planning framework[4] provide useful case studies for equitable and inclusive community planning.
- The project presented conflicting concerns over the City Yards construction project budget compared to the stakeholder microgrid use cases and Owner's Project Requirements. The value of a reliable and durable energy supply was not fully accounted for in the City Yards construction project budget.
- Applying for grant funding brings many interested stakeholders and potential vendors to the table, with little time and process for a competitive procurement process. Many public agencies do not have funds or resources to prepare and submit complex applications. Once funding has been secured, public agencies are then able to engage in a public procurement process for consultants and contractors. Public agencies should be supported with more capacity to apply for unique funding opportunities — this project relied on the serendipity of access to a consultant with flexible bandwidth and budget. Previously, SCE was developing a contractor stable for its Strategic Planning Grant. Public agencies would submit their interest to complete a Strategic Planning menu item and would then receive the consulting services of one of the SCE-vetted contractors. This concept would have been useful but was abandoned due to the recent adoption of Southern California Edison's rolling portfolio[5] and Annual Budget Advice Letters (ABALs).

Energy and Technical Methods

- The scenario modeling was based on the logic of least costly to most costly: working with energy efficiency measures, installing solar, joining the community choice aggregator, implementing a green tariff, and then adding storage. This type of scenario building may be useful for future projects.
- Load diversification will have technical and economic benefits. By gathering as many electrical loads as feasible, the microgrid may allow for additional renewable technologies and may reduce the electric energy storage size, thus reducing the cost.
- For other sites and cities where thermal energy is required, generation technologies should be considered where electricity and heat are produced and used — such as fuel

[4] https://movementstrategy.org/b/wp-content/uploads/2017/05/WEB-CD-CRP_Updated-5.11.17.pdf

[5] https://docs.wixstatic.com/ugd/0c9650_a0b40f88a30c4f0ab7b02d35f2360591.pdf

cells or microturbines. In this project, the City Yards' small thermal load did not present a strong rationale for implementation of fuel cells or combined heat and power.

- Most of the technical barriers can be overcome by making the grid smarter and speeding up the proceedings.
- Juggling the needs of a new project design and a microgrid feasibility study created a lot of moving parts. For example, the energy loads and hourly profiles of the new buildings were fixed only at the end of the project. This made the modeling and sizing of the microgrid's components and economics difficult, until those decisions and designs were finalized.
- When grant funding can be anticipated, it is best to conduct preliminary assessments of potential project sites and available capital funds that can be used to supplement the grant funds. It is challenging to develop a project and apply for a grant if the organization has not been thoroughly prepared. Projects that are already in planning phases should be considered so it is possible to insert a performance or design criteria for ideas the team would not otherwise consider (microgrids, distributed energy resources, etc.).
- Some analyses consider the cost of lost business operations or productivity, but these do not reflect the larger communal value that critical community services provide, particularly during disasters and emergencies.

GLOSSARY

Advanced Energy District	An innovative power system implemented on a district-wide scale.
Bergamot Arts Center	An internationally renowned creative arts complex with some 30 venerable galleries and creative businesses. Originally, the arts center was established in 1994 as Bergamot Station. In 2018, the City of Santa Monica–owned property went under new management and was renamed Bergamot.
black start	The process of restoring an electric power source or a part of an electric grid to operation without relying on the external electric power network. This capability can be used to start emergency generators or a cogeneration engine if the external network fails.
California ISO	The Independent System Operator that serves California. It manages the operations of a large portion of the state's wholesale transmission grid. It supports its member utilities by overseeing the electricity market they generate and by providing infrastructure planning efforts.
CCA (community choice aggregators/aggregation)	Is program that allows cities and counties to buy and/or generate electricity for residents and businesses within their areas.
City Yards design team	The businesses involved in the design of the redeveloped City Yards: Hathaway Dinwiddie, Miller Hull, and Buro Happold.
CNG (compressed natural gas)	Methane stored at high pressure that is often used as an alternative to gasoline, diesel and propane in automotive vehicles.
CPUC (California Public Utilities Commission)	An agency that regulates privately owned public utilities and transportation companies in California. It investigates unjust practices, governs utility rate changes, and sets safety and service standards.
demand response	A utility customer's change in electricity consumption in response to a utility's request. Demand Response helps shifts electricity usage from peak periods in order to better match the power demand with power supply. To incentivize customer participation, utilities typically offer financial incentives in return.
DER (distributed energy resources)	DERs are the individual components of decentralized energy generation systems that form distributed generation (DG). Examples of DERs include energy storage, demand response applications and generation technologies like solar PV.
DG (distributed generation)	Decentralized power generation located closer to the load than conventional power plants.

EES (electrical energy storage)	A device used to capture electrical energy for use at a later time.
EIR (Environmental Impact Report)	A document used to inform the public and relevant decision makers on the environmental effects of a proposed project. It includes ways to eliminate, mitigate or offset those impacts.
Envision	A green rating system for infrastructure projects created and administered by the Institute for Sustainable Infrastructure. It assesses the sustainability and resilience of infrastructure projects across 5 categories: Quality of Life, Leadership, Natural World, Resource Allocation and Climate and Resilience.
EPIC (Electric Program Investment Charge)	The Electric Program Investment Charge, created by the California Public Utilities Commission in December 2011, supports investments in clean energy technologies that benefit electricity ratepayers of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company.
GHG (greenhouse gas)	A gas that contributes to the greenhouse effect by absorbing and reradiating infrared radiation. A common example is carbon dioxide.
IOU (investor-owned utility)	A provider of natural gas or electricity that is privately owned by shareholders or investors. IOUs in California are regulated by the California Public Utilities Commission (CPUC). Examples of IOUs in California include Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company.
island mode	The ability to operate autonomously from grid.
ITC (investment tax credit)	A federal tax incentive that allows individuals or businesses to deduct a specified percentage of investment costs from their taxes. An example of an ITC is the Solar Energy ITC, which allows businesses to claim a portion of the cost of installing solar generation equipment as a deductible.
LEED (Leadership in Energy and Environmental Design)	A green building rating system for buildings, homes and neighborhoods that was established by the U.S. Green Building Council (USGBC). It assesses the sustainability of building projects in 9 categories: Integrative Process, Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources, Indoor Environmental Quality, Innovation and Regional Priority.
MAIFI (Momentary Average Interruption Frequency Index)	A metric used to measure the average number of times a utility customer experiences a momentary interruption during a given period. It is used as a reliability indicator of a utility's power system.

MCC (microgrid master controller)	A system that automatically monitors and detects faults so that microgrids can disconnect from the grid before anti-islanding mechanisms are activated.
NPV (net present value)	A metric used to gauge profit. It equals the present values of cash inflows (i.e. benefit cashflows) minus the present values of cash outflows (i.e. cost cashflows) over a duration of time.
operational point	A set of values for parameters to achieve a certain operating condition. In the context of this report, it is the capacity a system is operating at, thus consuming a certain amount of energy.
OPR (Owner's Project Requirements)	A document prepared by the owner or authorized representative of the owner that details the functional requirements of a project and the owner's expectations of the project's use and operation.
PCC (point of common coupling)	The point where the microgrid connects to the distribution grid.
PEER (Performance Excellence in Electricity Renewal)	A rating system for power systems administered by Green Business Certification Inc. (GBCI). It assesses a system's performance, resilience, and sustainability. It evaluates the power system across 6 categories: Reliability and Resiliency; Operations, Management and Safety; Energy Efficiency and Environment; Grid Services; Innovation and Exemplary Performance; and Regional Priority.
PPA (Power Purchase Agreement)	A common financing method for PV and energy storage purchases. Instead of financing the project using owner's own cash and debt, third-party leasing allows a project owner to pay a fixed monthly payment. The third-party is responsible for maintaining the technology and guaranteeing performance instead of the project owner.
PV (photovoltaic)	A type of solar technology that absorbs light energy and converts it to electricity.
R&D (research and development)	Work directed towards improving existing products or processes, or towards innovating new products or process.
Resilience (of an energy system)	The ability of an electric power system to withstand and recover from extreme, damaging conditions, including weather and other natural disasters, as well as cyber and physical attacks.
SAIDI (System Average Interruption Duration Index)	A metric used to measure the average outage duration a utility customer experiences. It is used as a reliability indicator of a utility's power system.
SAIFI (System Average Interruption Frequency Index)	A metric used to measure the average number of interruptions a utility customer experiences. It is used as a reliability indicator of a utility's power system.

SCE (Southern California Edison)	One of the largest electric IOUs in Southern California. It is a subsidiary of Edison International, and the incumbent utility in this project.
UCI (University of California, Irvine)	A public university that is part of the University of California system. It is a research university known for its research and development endeavors.
use case study	A process used to solicit and receive tangible owner and stakeholder input — via preferences, attitudes, and perspectives — regarding the specific desired functional uses of the microgrid.
ZNE (zero net energy)	A characteristic that indicates a system (usually a building, campus, portfolio or community) produces more or the same amount of renewable energy as the amount of energy the system consumes over a year.

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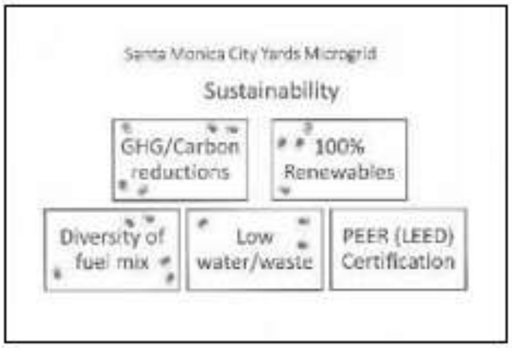
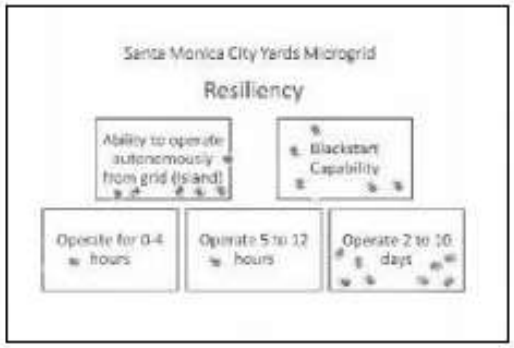
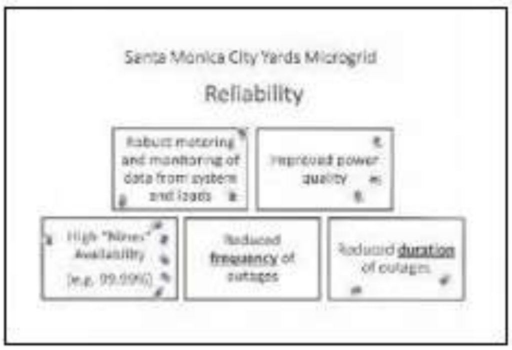
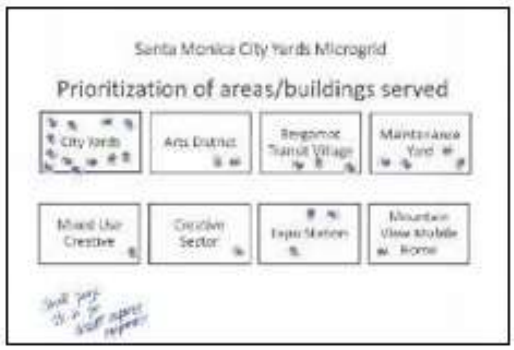
APPENDIX A:
Owner's Project Requirements

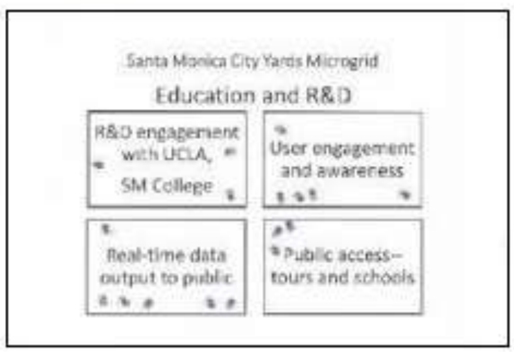
Voting Panels

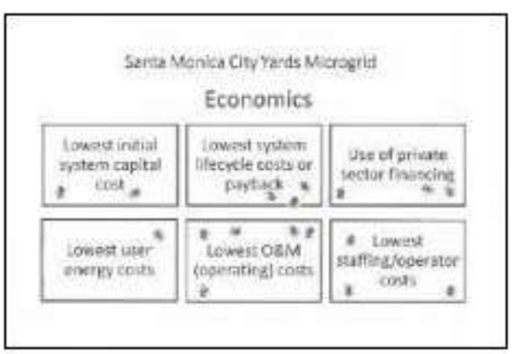










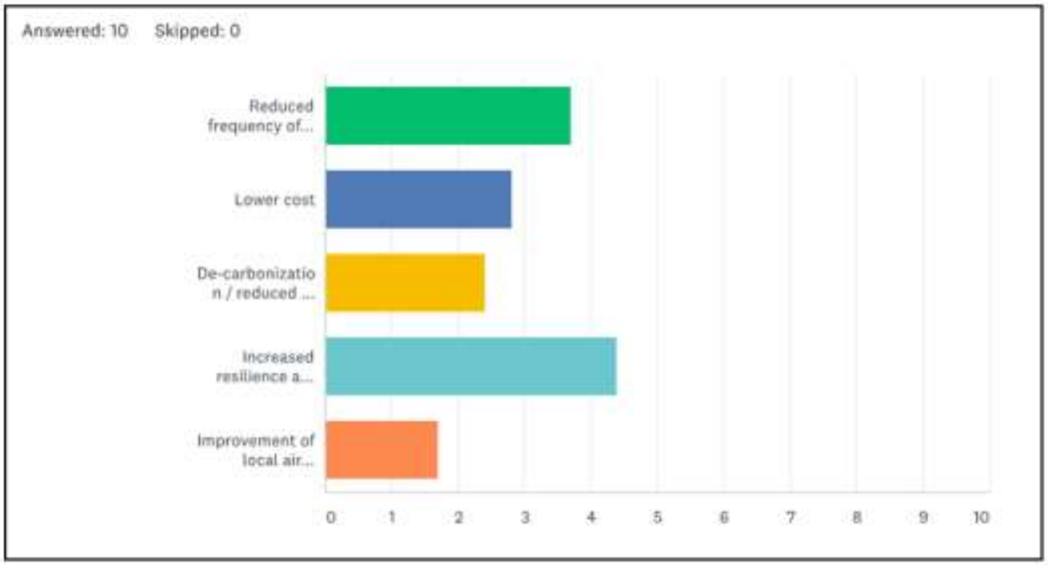


Online Survey

The following survey was distributed to the City Yards staff on the 5th of October 2017.

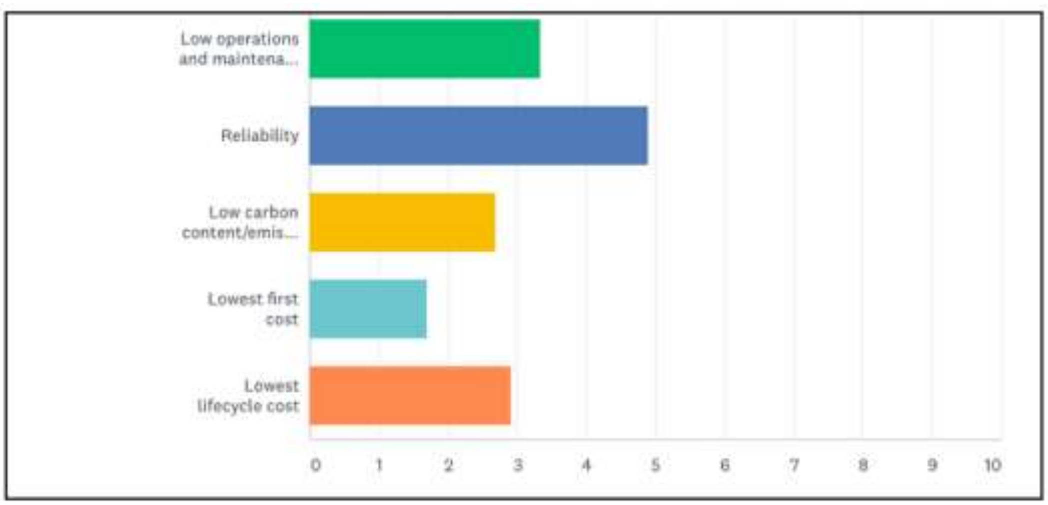
Question 1

When considering energy delivered to your facilities, please rank the following in order of importance (1 = most important, 5 = least important)



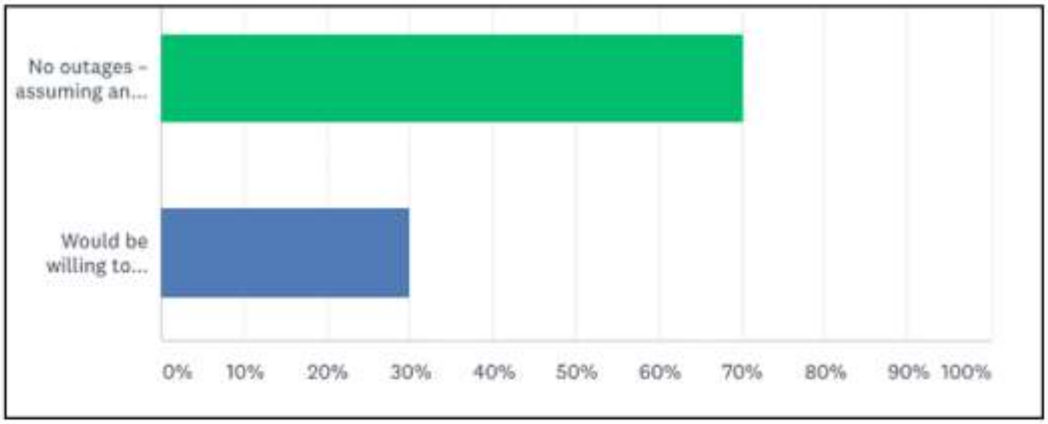
Question 2

When considering possible energy production technologies located at the City of Santa Monica's facilities, please rank the following in order of importance (1 = most important, 5 = least important)



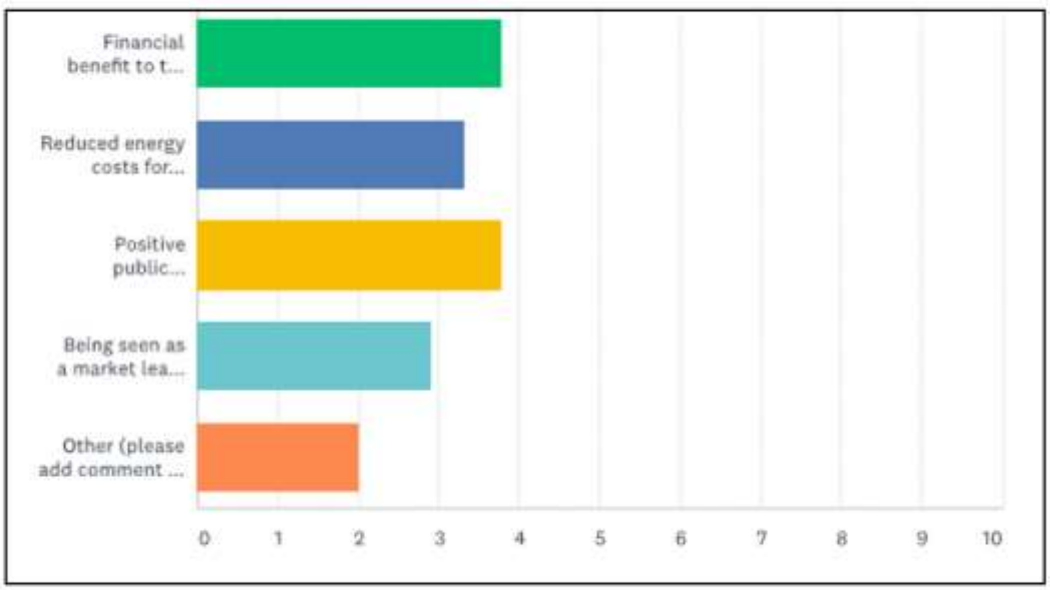
Question 3

When considering outages to the energy systems serving your facilities, which of the following would be acceptable?



Question 4

If the City were to own and operate its own energy network at the City Yards project, what key benefits would also be necessary for the City to consider serving non-city facilities in adjoining areas? Please rank the following in order of importance (1= most important, 5= least important)



Emergency Power Survey

In a disaster or emergency response situation, what buildings & operations would be the most important to ensure power is sustained on stand-by power?

	Response #1	Response #2	Response #3	Response #4	Response #5	Response #6	Response #7	Response #8	Response #9
Water Resources Division	2	5	8		8		5	17	4
Traffic Controls		6	5		9		4	1	14
Radio Shop			18		5		12	9	13
Public Works/CY Administration		8	3		6		7	5	15
Fire Department	1	10			1		1	18	1
Fueling Stations	3	2	4		3		6	10	3
Resource Recovery & Recycling			12		13		14	12	7
Hazardous Waste Center/Storage		8	14		14		11	7	12
Streets Division		3	7		7		13	15	9
Data (servers, internet	4	4	1	11	4		2	8	
Fleet Division	`	1	9		2		9	14	
Facilities Maintenance		9	11		12		8	4	
HVAC Shop			15		15		16	6	
Paint Shop			17		17		18	2	
Electrical Shop			10		11		10	11	
Information Systems Department			6		10		3	16	
Carpentry Shop			13		16		17	3	
Plumbing Shop			16		18		18	13	

To the best of your ability, please describe the types of 'powered' functions that would be essential during a disaster or emergency situation within each building or operation.

	Response #1	Response #2	Response #3	Response #4	Response #5	Response #6	Response #7
Facilities Maintenance	would be needed	computers					
Fleet Division	break downs of emergency vehicles	equipment trucks ,light and heavy duty would be needed	Lights, air compressors and lifts operating.	computers			
Water Resources Division	make sure the fire dept has water for the fire and citizens to drink	would be needed	cpmputers, conference rm	all systems			
Traffic Controls	power for traffic light to remain on	no one would care	controls, computers				
Radio Shop	comunication between devisions	for comunication	no longer needed per ISD				
Public Works/CY Administration	if 911 calls are routed there	n/a	computers, conference rms				
HVAC Shop	fresh air for citizens and employees	n/a					
Electrical Shop	keeping the power on for the depts to sustain the to function	power probably would need to be restored					
Paint Shop	n/a						
Fire Department	for comunity support and fire support	fire support would be needed	Able to fully operate.	all functions	all systems		
Fueling Stations	for emergancy vehicles	would be needed	X	Have the ability to fuel.	all fiunctions	Dispensing functions	all systems
Data (servers, internet)	communication to other cities and depts	communication is essential in these situations	X	all functions	all systems		
Information Systems Department	the main hub to keep the city aprized of everything	information would be needed	X	Servers for maintenance mngt, billing, and SCADA	computers		
Resource Recovery & Recycling	keep the alley ways and streets clear	for waste pick up and cleaning would be needed	dispatch				
Hazardous Waste Center/Storage	flamable and crosive materials	would be needed					
Streets Division	lighting at night	would be needed for clean up					
Carpentry Shop	n/a						
Plumbing Shop	fresh water for the people	water leaks would be a problem					

Of the powered functions described above, what bare minimum of operating capacity would be acceptable during a disaster or emergency situation?

	0%	25%	50%	75%	100%	Total
Facilities Maintenance	0	2	0	2	0	4
Custodial Services	3	1	0	0	0	4
Water Resources	0	0	3	0	2	5
Traffic Controls	0	1	2	1	0	4
Radio Shop	1	0	2	1	0	4
Public Works/CY Administration	0	3	1	1	0	5
HVAC Shop	2	1	1	0	0	4
Electrical Shop	0	2	0	2	0	4
Paint Shop	3	1	0	0	0	4
Fire Department	0	0	0	0	5	5
Fueling Stations	0	0	2	2	2	6
Data (servers, internet)	0	0	2	2	2	6
Information Systems Department	0	0	2	2	1	5
Resource Recovery & Recycling	0	2	2	0	0	4
Hazardous Waste Center/Storage	1	2	1	0	0	4
Streets Division	0	4	1	0	0	5
Carpentry Shop	2	2	0	0	0	4
Plumbing Shop	1	2	1	0	0	4

APPENDIX B: Project Technology Assumptions

This section summarizes assumptions for technology costs and operating parameters, rates, and financial assumptions that are used in this study.

Solar Photovoltaic Panels

A “Generic flat plate” system was selected in Homer software. It was assumed that a derating factor of 80 percent exists due to soiling of panels, wiring losses, and other real-world impacts.

PV cost forecast comes from the National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB) data (NREL 2018). Based on the ATB data, the overnight capital cost for a 300kW PV in Los Angeles is $1,520/kW in 2021. This assumption reflects about 6 percent/year price drop compared to today’s PV costs. The PV in the microgrid system is sized at 1,200 and 1,700kW and both are much larger than the 300kW, so that the cost might be cheaper than $1,520/kW. In this study, PV overnight upfront cost is assumed as $1,520/kW to be a conservative estimate.

Table B-1: Capital Cost Solar PV

Technology Costs	Capital Costs	Replacement Costs	O&M	Lifetime
PV	$1,520/kW	n/a	$15/y-kW	25 years

Electrical Energy Storage

The primary electrical energy storage (EES) technology considered in this work are lithium-ion based batteries.

Storage cost forecast are based on the Levelized Cost of Storage report by Lazard (2017). This study assumes 8.5 percent/year price decline between now and 2021. A battery can be more expensive on a $/kWh basis if it has a larger charge and discharge capacity due to increased Balance of System (BOS). HOMER model assumes the battery costs are linear as $/kWh when it conducts sizing optimization, so a 4-hour 5 MW battery costs the same as a 0.5-hour 40 MW battery to HOMER. However, in real life, the 0.5-hour 40 MW battery costs more due to the expensive inverter and other BOS costs. Based on the Lazard estimation, a 0.33-hour duration battery costs ~$2000/kWh and a 4-hour battery with the same energy capacity battery costs only $366/kWh in 2021. Given that the City Yards give more importance to duration and cost savings (e.g demand charge reduction, energy arbitrage within the TOU period) than capacity focused (e.g. energy arbitrage for real time market, providing ancillary services), this study assumed the battery is sized as a common 4-hour duration.

For the future prices, people hold different opinions about whether and to what degree battery prices will drop in the future. Some studies predict that battery prices will drop down to 30 percent of current prices by 2036 (Gupta 2018, Berckmans et al. 2017). To be conservative, this study assumes the replacement cost is 50 percent of the current price in nominal term ($300/kWh).

Table B-2: Capital Cost EES

Technology Costs	Capital Costs	Replacement Costs	Lifetime
Li-ion Storage	$366/kWh	50% of the first-year upfront cost	15 years

Incentives, such as the Self-Generation Incentive Program (SGIP) have the potential to significantly reduce capital costs. Currently, SGIP incentives have the potential to reduce capital cost by up to $350 per kWh or $250 per kWh when the income tax credit (ITC) is claimed (State of California and SGIP 2015). Incentive rates depend on EES size and storage duration. Table B-3 shows SGIP incentive rates as a percent of the base incentive rate versus capacity, while Table B- 4 shows incentive rates versus storage duration. The ITC value in this work is assumed to reduce initial capital cost of the EES system by 30 percent.

Table B-3: SGIP EES Incentive Rates by EES Capacity

Energy Capacity (MWh)	Incentive rate (% of Base)
0–2	100
2–4	50
4–6	25
>6	0

Table B-4: SGIP EES Incentive Rates by EES Storage Duration (Center for Sustainable Energy 2017)

Storage Duration (hours)	Incentive rate (% of Base)
0–2	100
2–4	50
4–6	25
> 6	0

AC-DC Inverter

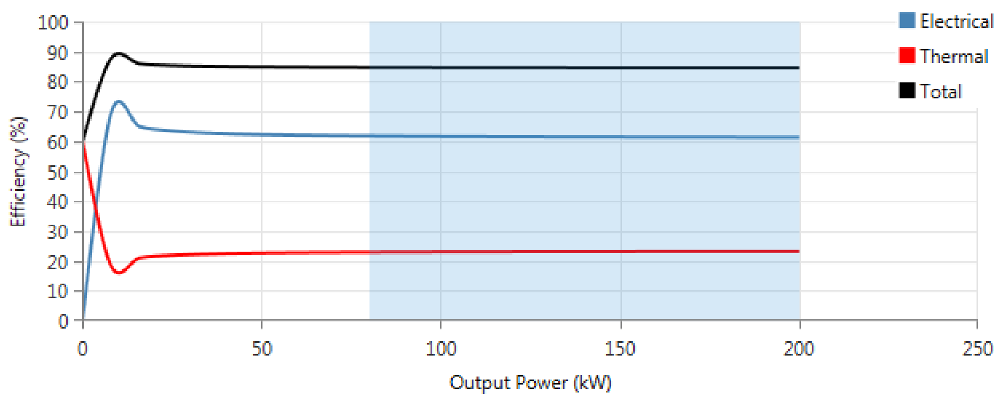
It was assumed that the selected inverter has a capital cost of $300 per kW with a $1 per year per kW O&M cost. Overall efficiency of the inverter was assumed to be 90 percent.

Fuel Cell

Multiple fuel cell models were considered for this work, including products by FuelCell Energy, Plug Power, Doosan Fuel Cell, and Bloom Energy. The only product considered for inclusion in the HOMER model is a commercial 200kW fuel cell system. All other products were excluded due to lower electrical efficiency, or the requirement for either pure hydrogen or methanol to achieve high-electrical efficiency.

Fuel cells are usually used as a baseline generator since it is costly to turn them on and off. This study assumes the fuel cell generator in Scenario 2 and 3 is a must run unit. Minimum load ratio was assumed to be 90 percent. The part load efficiency used for this work is shown in Figure B-1.

Figure B-1: Efficiency Curve Assumed for the EES



Source: Bloom energy

Cost assumptions are summarized in Table B-5.

Table B-5: Capital Cost Fuel Cells

Technology Costs	Capital Costs	Replacement Costs	Variable O&M	Biogas	Lifetime
Fuel Cell Generator	$5000/kW	$3500/kW nominal	$0.01/hour	$1/therm	5.7 years

Microturbines

Multiple microturbine models were considered in this work, however latest market trends are increasing the available size of the microturbines, requiring higher electrical and thermal demands than the City Yards existing loads. Two engines were examined in detail, with 65kW and 200kW. It was assumed that the 65kW microturbine has a capital cost of $3,000 per kW, and the 200kW microturbine has a capital cost of $2,800. Replacement cost was assumed to be $500 lower than initial capital cost, and O&M cost is $0.01 per operating hour per kW. Microturbine operation is traditionally very flexible, allowing for on-off operation if needed.

However, this work assumes a minimum run time of one hour. These engines are not eligible for SGIP funding.

Given the low and sparse thermal load of the City Yards, this technology was not selected by the optimization software.

Electric Vehicle

This project included in the analysis the electrification of the City Yards commercial vehicle fleet consisting of vans, pickups, sedans, trucks, SUVs, and waste disposal trucks. Table B-6 provides a breakdown of the fleet characteristics used for modelling.

Table B-6: Electric Vehicle Fleet Assumptions by Vehicle Type

Vehicle Type	Total EVs	Fleet electric (miles/day)	Vehicle efficiency (miles/kWh)	Fleet energy demand (kWh/day)	EV energy storage (kWh/EV)	Max charging capacity (kW/EV)
Van/Pickup	48	604	2	302	80	6
Sedan/SUV	21	185	3.5	53	80	6
Truck	12	113	1.3	89	300	7.2
Truck/Garbage	26	317	0.6	530	200	7.2

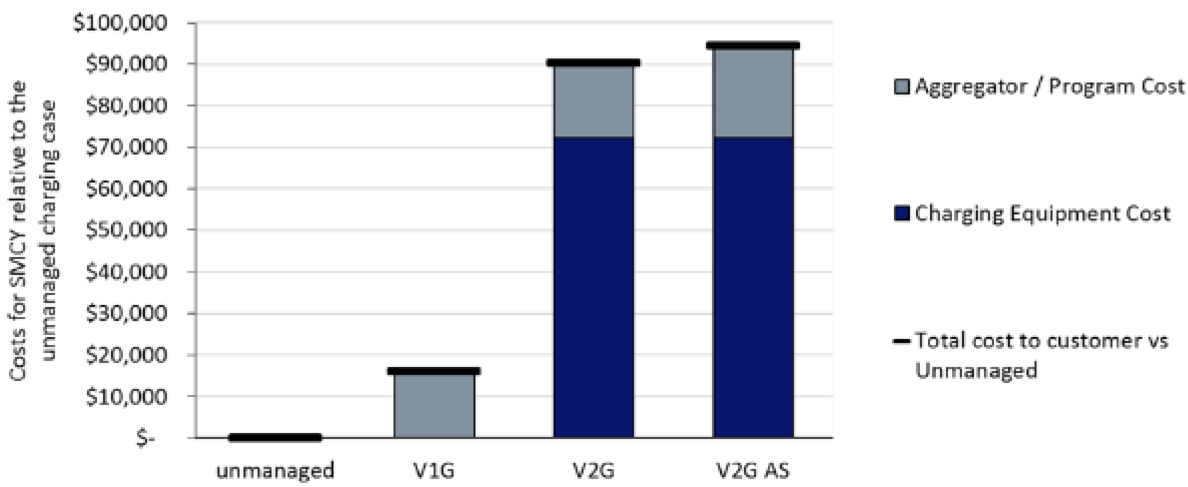
This fleet was modeled from 2030 onwards once equipment costs, technology types, and fleet composition have leveled out, so the above parameters could be held constant over the modelling horizon.

To service the electric fleet, the city plans to construct 24 new L2 chargers, adding to the 9 existing L2 chargers on site, all of which have a charging capacity of 7.2kW. Based on an extensive recent study on power loss during EV charging and discharging (Apostolaki-Iosifidou, Codani, and Kempton 2017a), charging efficiency was set at 90 percent, while discharging efficiency was assumed to be 75 percent (transformer losses of 1.5 to 2 percent were included [2018]).

During the hours of 6am – 6pm Monday - Friday (excluding holidays), the vehicle fleet was on duty and not connected, in all other hours throughout the year the vehicle fleet was plugged in to the charging system. By 2030 it is assumed all vehicles can be simultaneously connected, and power flow from the 33 L2 chargers is automated to vehicles with the lowest state of charge.

Cost assumptions vary depending on whether the fleet is only able to shift the timing of charging in response to price signals, known as managed charging (V1G), or whether it can both shift charging timing and discharge to the grid, requiring bidirectional power flow, known as Vehicle to grid (V2G). By 2030 it is assumed V1G capability is standard with public L2 chargers in Southern California with a cost of $2,188 per unit.[6] V2G chargers are assumed to cost $4,500 per unit, based on an LBNL study,[7] and EVs are assumed to be V2G compatible by 2030 so no hardware upgrades are required. To monitor V1G and V2G charging, it is assumed the City Yards employs an aggregator that takes a percentage cut of all bill savings arising from smart charging. The percentage cut of revenues increases with increasing complexity of the service provided by the aggregator, for a V1G service the aggregator takes 40 percent of bill savings, for V2G this increases to 45 percent and for V2G with ancillary service revenue the aggregator takes 50 percent of revenues and bill savings. The total costs for each fleet electrification scenario are summarized in Figure B-2: NPV of total costs from 2030 to 2045.

Figure B-2: NPV of Total Costs from 2030 to 2045



Utility Grid

Even though the microgrid can operate in island mode, it is usually cheaper and more reliable to connect to the grid when no grid outage event has occurred. This study considers three different time-of-use (TOU) electricity rates for the City Yards that are suitable for commercial customers with maximum monthly demand between 200 and 500kW connected at voltages between 2 and 50kV. Two of the rates, SCE TOU-GS-3-A and SCE TOU-GS-3-B, are offered by SCE,[8] the current service provider, while the third rate, CPA TOU-GS-3-B, is an equivalent rate offered by Clean Power Alliance (CPA).[9] CPA is a recently established local CCA offering tariff options with various levels of renewable production (36 percent, 50 percent, and 100 percent renewable production). The CPA rate selected for this analysis was the 100 percent renewable option.

Table B-7 summarizes the final import charges for the three rates modelled. The SCE TOU-GS-3-B and the CPA rate are similar with both offering low energy charges and TOU demand charges.

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[6] Level 2A charging (integrated network capability) From SCE's "Charge Ready and Market Education Programs - Pilot Report", April 2018. Based on info from 2016-2018. Link

[7] https://www.nrel.gov/docs/fy17osti/69017.pdf

[8] https://www.sce.com/NR/sc3/tm2/pdf/ce54-12.pdf

[9] https://www.cleanpoweralliance.org/rates/

The CPA rate is slightly cheaper than SCE TOU-GS-3-B since CPA has a lower generation component. SCE TOU-GS-3-A has higher energy charges and but only a non-TOU demand charge. In addition to the rates in Table B-8, a fixed customer charge of 314.3 $/meter/month was applied to all three rates.

Table B-7: Electricity Rates Used in the Study Taken From SCE and CPA Tariff Books

Charge Type	SCE TOU GS 3 A	SCE TOU GS 3 B	CPA TOU GS 3 B	Notes
Summer On-Peak ($/kWh)	0.35178	0.12173	0.11022	Summer weekdays from 12pm–6pm
Summer Mid-Peak ($/kWh)	0.11475	0.07895	0.07001	Summer weekdays from 8am–12pm or 6pm– 11pm
Summer Off-Peak ($/kWh)	0.05669	0.05749	0.04984	All other summer time
Winter Mid-Peak ($/kWh)	0.07318	0.07398	0.06534	Winter weekdays 8am - 9pm
Winter Off-Peak ($/kWh)	0.06227	0.06307	0.05508	All other winter time
Non-TOU Demand Charge($/kW)	18.0700	18.0700	18.2900	Applied to monthly maximum demand
Summer On-Peak Demand Charge	0	19.6200	18.8100	Applies to monthly maximum summer on peak demand
Summer Mid-Peak Demand Charge ($/kW)	0	3.55000	3.71000	Applies to monthly maximum summer mid-peak demand
Export related charges & compensation				
Non-bypassable charges ($/kWh)	0.01409	0.01489	0.01348	These charges are subtracted from export rates under NEM 2.0
Net Surplus Compensation Rate ($/kWh)	0.0300	0.0300	0.0600	Applies to all exports that exceed a customer's imports – not time dependent

Under the new Net Energy Metering (NEM) program offered by SCE and CPA, customers are compensated for exports to the grid at their import rate less non-bypassable charges (NBCs).[10]

This export rate reduces a customer's energy charges but does not impact demand charges and applies to all exports that do not exceed a customer's total imports from the grid over the course of a year. Under Net Surplus Compensation, customers that are net exporters of electricity over the course of a year will have all electricity they export to the grid exceeding their total imports from the grid, compensated at a flat rate known as the Net Surplus Compensation Rate (NSCR). NSCR is calculated using the Default Load Aggregation Point (DLAP) price and accounting for imports and exports occurs during the annual billing cycle.[11] NSCR is a flat rate so there is no cost or benefit for shifting net exports to different times of day. All rates shown in Table 45 are assumed to increase annually at a 3 percent escalation rate.

[10] https://www.sce.com/NR/sc3/tm2/pdf/CE382.pdf

[11] https://www.sce.com/wps/portal/home/regulatory/tariff-books/rates-pricing-choices/net-surplus-compensation

This work assumes an emission factor based on the average SCE emissions rate from 2016 of 0.24 metric tons of CO_2 equivalent (CO_{2e}) per MWh. Using this factor, the annual CO_{2e} emissions were calculated and are shown in Table B-8.

Table B-8: Annual CO2e Emissions When Only Using SCE Imports to Meet Electrical Needs

Building	Annual CO_{2e} Emissions (CO_{2e} metric ton/year)
City Yards Today	243
City Yards projected	212
Bergamot Sta. Arts Center	785
Hotel	233
Metro facility	1,051

Island Mode Infrastructure and Interconnection Costs

Additional interconnection costs, wiring, and a control center might be required for the microgrid to operate in island mode. A $100,000 upfront cost is assumed for islanding operation infrastructure and additional interconnection costs.

APPENDIX C: Method for Cost Tests, Financing, and Cost-Benefit Analysis

This appendix describes the method and assumptions used to develop the cost tests, financing options and cost-benefit analysis. This study assumes the microgrid is connected to the main grid allowing power to be purchased from and exported to the grid during normal operation.

During grid outage events, the microgrid can disconnect itself from the main grid and operate in island mode to provide services.

Method

Optimal Dispatch

To evaluate the benefits provided by the microgrid system, this study used the E3 in-house RESTORE[12] tool to simulate optimal operation of the dispatchable technologies in the microgrid system. The applicable dispatchable technologies in the City Yards microgrid are solar PV (PV), electrical energy storage (EES), electric vehicles (EV), and fuel cells. Their sizes and availability vary by scenarios. The core "engine" of the tool is a price-taker optimal dispatch algorithm, which identifies the profit maximizing operation pattern for the microgrid given its size, performance characteristics, market prices, utility rates or utility avoided costs. In this study, dispatchable technologies are dispatched to minimize the electricity bill for SMCY.

In sensitivity cases, technologies are also dispatched to maximize utility avoided costs to show the benefits the microgrid can provide to the electric system. Some dispatchable technologies are also able to provide ancillary services (AS) when an agreement is reached among the City, the incumbent electric utility, and California Independent System Operator (CAISO). The revenues from electric vehicle providing ancillary services are also investigated in the Vehicle to grid (V2G) sensitives. This analysis assumes EES in the microgrid system can only charge from solar to be eligible for the Federal Investment Tax Credit (ITC).

Benefits Quantified in the Model

System Avoided Costs

The benefits provided by the microgrid system are quantified using the 2018 Avoided Cost Calculator[13] published by California Public Utilities Commission (CPUC) and the California ISO report, 2017 Annual report on market issues & performance.

[12] See www.ethree.com/restore for more information.

[13] http://www.cpuc.ca.gov/General.aspx?id=5267

This sub-section provides a brief overview of the electricity avoided cost components and their contribution to the total electricity avoided costs. The avoided cost is calculated as the sum of six components shown in Table C-1.

Table C-1: Components of Electricity Avoided Cost

Component	Description
Generation Energy	Estimate of the hourly wholesale value of energy
Generation Capacity	The costs of building new generation capacity to meet system peak loads
Ancillary Services	The marginal costs of providing system operations and reserves for electricity grid reliability
Transmission and distribution (T&D) Capacity	The costs associated with expanding transmission and distribution capacity to meet peak loads
Monetized Carbon (cap and trade)	The cost of Cap and Trade allowance permits for carbon dioxide emissions associated with the marginal generating resource
GHG adder	The difference between the CPUC-adopted total value of CO_2 and the Cap and Trade value of CO_2.
Avoided RPS	This component has been set to zero.

Each of these avoided costs is determined for every hour of the year. The hourly granularity is obtained by shaping forecasts of the average value of each component with historical day-ahead and real-time energy prices and actual system loads; Note that the T&D capacity avoided costs are estimated separately for three IOU levels and represents the average avoided costs across each utility's territory. Avoided T&D costs are specific to feeders and can vary dramatically across the territory. Distribution network and potential distribution upgrade information is required at the feeder for a more detailed estimate of T&D avoided costs. This study uses the SCE system average as an estimate because distribution system data is difficult to obtain from the utility. Table C-2. Summary of methodology for electricity avoided cost component forecasts summarizes the methodology applied to each component to develop this level of granularity.

Table C-2: Summary of Method for Electricity Avoided Cost Component Forecasts

Component	Basis of Annual Forecast	Basis of Hourly Shape
Generation Energy	Forward market prices and the $/kWh fixed and variable operating costs of a CCGT	Historical hourly day-ahead market price shapes from MRTU OASIS
Generation Capacity	Residual capacity value a new simple- cycle combustion turbine	RECAP model that generates outage probabilities by month/ hour and allocates the probabilities within each month/hour based on 2017 weather
Ancillary Services	A percentage of Generation Energy value	Directly linked with energy shape
T&D Capacity	Marginal transmission and	Hourly 2017 temperature data by

Component	Basis of Annual Forecast	Basis of Hourly Shape
	distribution costs from utility ratemaking filings	climate zone
Monetized Carbon (cap and trade)	CO_2 cost forecast from revised 2017 IEPR mid-demand forecast, escalated at inflation beyond 2030	Directly linked with energy shape with bounds on the maximum and minimum hourly value
GHG Adder	Difference between total value of CO_2 and monetized carbon cost in the energy market prices	Same as monetized carbon
Avoided RPS	Set to zero to be consistent with GHG adder	NA

Customer Bill Savings

The City Yards microgrid is assumed to be connected to the main grid but can be operated in island mode during outage events. Current electricity service provider is Southern California Edison (SCE) but the emergence of Community Power Alliance (CPA), a local community choice aggregator (CCA), offers the City Yards greater retail choice. CPA provides tariffs with different levels of renewable production, including a 100 percent renewable option. This study examined the bill savings from installing the microgrid under the SCE TOU-GS-3 option A and B rates, and the 100 percent renewable CPA rate. The energy and demand charges associated with these rates are summarized in section Project Technology Assumptions.

Reliability

The microgrid is designed to be able to operate in island mode to cover some or all the load during system outage events. During system outage events, the City Yards can continue supporting traffic signals and fire station operation. And during a natural disaster, can also serve as an emergency center to provide food and shelter for Santa Monica citizens. The reliability value of the microgrid is based on the probability of an outage and the value of lost load to the city.

Outage Probability is estimated based on the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) for the City of Santa Monica published by SCE[14] and included in Table C-3.

Table C-3: SAIDI and SAIFI Figures Published by SCE

	Santa Monica	
Year	SAIDI (mins)	SAIFI
2016	75.9	1.1
2017	48.9	0.6

[14] https://www.sce.com/nrc/reliability/reports/SantaMonica.pdf

$$\text{Average outage probability} = \frac{SAIDI \times SAIFI}{8760\ hours \times 60\ minutes/hour}$$

This study used the average SAIDI and SAIFI from 2016 and 2017 to calculate the average outage probability.

The estimates of customer reliability vary widely. Residential customers typically indicate a low willingness to pay to improve reliability and value of service estimates are correspondingly low. On the other hand, commercial value of service is much higher, nevertheless, the demonstrated willingness to pay for reliability is typically much lower than values suggested by surveys. This study uses interruption cost data from Interruption Cost Estimate (ICE) Calculator[15] developed by Lawrence Berkeley National Laboratory and Nexant, Inc. This data is shown in Table C-4.

Table C-4: $/kW VOLL Numbers Taken From Interruption Cost Estimate (ICE) Calculator

Customer Class	Cost per Unserved kWh
Residential	$5.82
Small Commercial & Industrial	$288.71
Medium and Large Commercial & Industrial	$147.27

When getting value of loss load (VoLL), this study assumes the City Yards as a commercial customer. The VoLL is assumed to be $147.27/kW for one-hour duration.

The reliability value is calculated using the following formula:

$$\text{Reliability Value}\ (\$) = VoLL \left(\frac{\$}{kWh}\right) \times \text{Outage Probability} \times \text{Critical Load}\ (kWh)$$

Ancillary Services Revenue

The ancillary service revenue has been developed using the system planning cases from the CPUC Integrated Resources Planning (IRP) proceeding.[16] With resource portfolios from the IRP cases, the AuroraXMP production simulation model is used to produce ancillary service prices that are used in the fleet electrification cases employing V2G technology and participating in ancillary services markets. The reference plan, designed to limit statewide GHG emissions to 42 million metric tons (42 MMT), is used to generate ancillary service prices.[17]

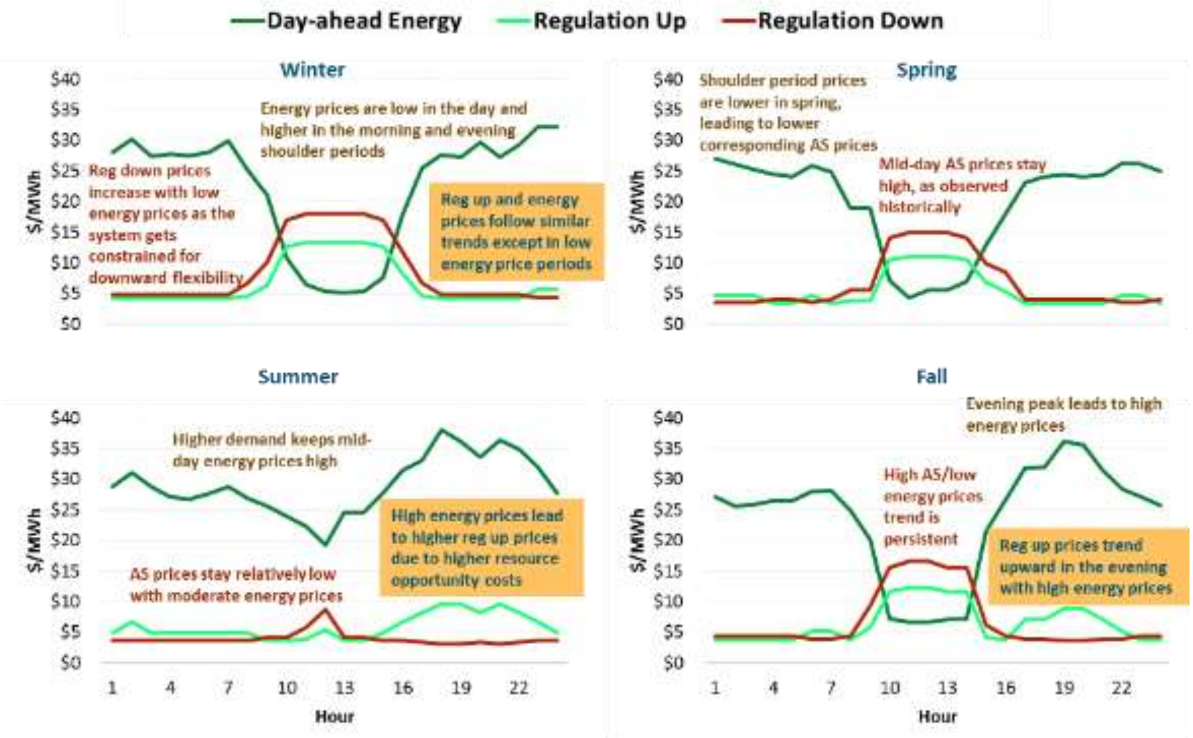
The relationship of frequency regulation prices to energy prices are illustrated in Figure C-1 by season. For the V2G AS case, these relationships are based on current market conditions when fossil fuel plants are often on the margin.

[15] https://icecalculator.com/interruption-cost

[16] CPUC IRP Proceeding information available at: http://www.cpuc.ca.gov/irp/

[17] Details on the 42 MMT reference plan and additional sensitivities, including the 80% RPS case are available at: http://cpuc.ca.gov/irp/proposedrsp/

Figure C-1: Historic Relationship of Energy and Frequency Regulation Prices



CPUC Standard Practice Manual Cost Tests

This subsection presents a brief overview of the CPUC cost-effectiveness tests for demand side programs and how they were applied in this study. The two cost tests implemented for this study are the Participant Cost Test (PCT) and Total Resource Cost Test (TRC). Table C-5 shows how the various economic impacts are viewed as costs or benefits from both cost test perspectives. A green cell with a plus sign indicates that the component is considered as a benefit, while a red cell with a minus sign indicates that the component is a cost.

Table C-5: Costs and Benefits from Each Cost Test Perspective.

Benefit and Cost Component	TRC	PCT
Federal Tax Credits	+	+
SGIP Incentive		+
Utility Bill Savings		+
Island Mode Reliability Value	+	+
Unsubsidized Total System Cost	−	−
Avoided Generation Energy	+	
Avoided Generation Capacity	+	
Avoided Ancillary Services	+	
Avoided T&D Capacity	+	
Avoided Monetized Carbon (cap and trade)	+	
Avoided GHG Adder	+	

Participant Cost Test (PCT)

The PCT is designed to assess if a demand side program is cost-effective from the perspective of the end consumer who chooses to participate in a program or install a DER or energy efficiency measure. The costs to the city are the purchase cost of the microgrid system, which is composed of PV system, an electric battery and controls. The consultant assumes that energy storage and PV system are leased through a third party. The benefits to the Santa Monic City are the Federal Investment Tax Credit (ITC) for solar and energy storage systems, the California Self-Generation Incentive Program (SGIP), retail electricity bill savings, and reliability value from the microgrid providing an uninterruptible power supply.

Total Resource Cost Test (TRC)

The TRC assesses the monetized costs and benefits to California. For this project, the costs are the installed cost of the Microgrid system. The benefits to California are the avoided costs of supplying energy and the ITC. Costs of supplying energy are avoided when load is reduced or shifted from times when resources are expensive or limited to times when they are less expensive. The avoided costs of supplying energy include avoided ancillary services purchases, avoided resistive transmission and distribution losses, avoided emissions compliance costs, avoided generation capacity costs, avoided energy purchase or generation costs.

Financing

Financing and Ownership Options

The City of Santa Monica enjoys tax and financing advantages compared to the other microgrid owners. The city doesn't need to pay tax and has access to low cost debt financing. However, also because of the city doesn't pay tax, it is not able to receive the investment tax credits (ITC). To better understand the economics of different financing and ownership options, this analysis explored three common financing and ownership options for the microgrid: a third-party lease, city purchase through low cost debt financing, and a hybrid option in which the PV system is procured through a Power Purchase Agreement (PPA) and the rest of the microgrid equipment is purchased through city debt financing. The following sections describe the opportunities and financing parameters for these three options.

Note that some costs are relatively small, for example, the costs for improving CNG compressor operating, the upgrade costs for enabling V2G etc. They are about 1 percent of the total system costs thus this study assumes city makes an upfront cash payment for those items.

Third-Party Leasing (Microgrid-as-a-Service)

Third-party leasing/PPA is a common financing method for PV and energy storage purchases. Instead of financing the project using owner's own cash and debt, third-party leasing option allows to pay a fixed amount of lease fee or PPA payment each month. This financing method might be more expensive but since the third-party is responsible for maintaining the technology and guaranteeing performance, the City does not need to pay if the third-party fails to perform and, as a result, carries much less risks. In addition to that, there won't be a big cash expenditure in the balance sheet. This option allows city to indirectly enjoy the ITC benefits through the third-party. This more expensive but less risky option could be a good fit for City especially for new technologies.

The City of Santa Monica has access to low cost debt financing, but according to the City, this option is currently not available for new technology assets like solar and EES. If the city is not able to find a low-cost debt financing for new technology assets, third-party leasing might be their only option. As a result, this study assumes the project is financed through the third-party leasing option in the base scenario.

To estimate how much a third-party will charge City for the leasing agreement, this study set up a pro forma model to calculate the breakeven revenue for the third-party given its debt interest rates and return on equity. The breakeven revenue is then used as an estimate for the lease fee. In reality, the third-party lender might mark up its lease fee to earn additional revenue if there is no competition, or, mark down prices to gain market share in the short term. In the long run, however, when the market has matured and become competitive, the lease fees will converge to the breakeven revenues Table C-6 summarizes the financing assumptions for a third-party lender.

Table C-6: Financing Assumptions for a Third-Party Company Provide Leasing Options

Financial Assumptions for Third Party	
% Financed w/ equity	55%
% Financed w/ debt	45%
Debt Interest rate (%)	5.3%
WACC	7.0%
Federal Tax Rate	21%
State Tax Rate	8.84%

To establish a viable debt interest rate, long-term debt and interest expense data was extracted from the balance sheets and income statements of publicly traded solar leasing companies (SunPower, SunRun and First Solar) and averaged. This was benchmarked against returns on investment grade corporate bonds from FINRA TRACE. The return on equity values for these companies are erratic due to wildly different net incomes across the sector, as expected in a nascent industry. Therefore, we used a typical utility WACC value for a larger infrastructure project of 8.8 percent as starting point and then discounted this value to account for the lower risk of having the city as an off taker, and to reflect the competition among third-party providers to do business with a low risk customer like the city. This gave a value of 7 percent for WACC which translates to an equity return of 9.6 percent. This value is in line with ROEs for more mature segments of the renewable sector and is likely to reflect those of solar leasing companies in a few years once they are more established and the market has stabilized.

City Purchase

Instead of leasing from a third party, the city could choose to finance the project using low-cost debt, a common option for city councils. This option is usually cheaper, but the City would need to take on additional risk associated with technology maintenance and performance. This study explored this financing option using the parameters listed in Table C-7 debt interest rate is assumed to be 4.5 percent based on the city's inputs, which are usually lower than commercial financing products.

Table C-7: Financing Assumptions for the 100 Percent City Debt Financing Option

% Financed w/ equity	0%
% Financed w/ debt	100%
Debt Interest rate (%)	4.5%
WACC	4.5%
Federal Tax Rate	0%
State Tax Rate	0%

Solar PPA + City Purchase

The final option explored involves the city signing a third-party leasing agreement (or PPA) for a subset of the microgrid technologies and self-financing the remaining technologies. This study assumes the city purchases the PV system through a PPA and finances the remainder of the system through debt. This hybrid option is a combination of the previous two financing methods and therefore uses the same parameters.

Self-Generation Incentive Program (SGIP)

Self-Generation Incentive Program (SGIP) is provided by California Public Utilities Commission (CPUC) to support existing and new distributed energy resources. SGIP provides rebate for qualifying distributed energy resources installed behind the customer's meters. Among the technologies selected for the microgrid system, battery storage and the fuel cell generator qualify for this program. However, because the program budget is limited and there are many qualified projects, the incentives are currently rewarded on a lottery basis. Given the uncertainty of the rebates, this study assumes no SGIP incentives for the base scenario.

Sensitivities are conducted to estimate the impact of SGIP incentives on project cost-effectiveness. The incentive structure is based on data from the 2018 SGIP handbook[18]. It is assumed that financing can be secured while the SGIP incentive fund is in step 3 which translates to an incentive rate of 0.25 $/Wh for the "Large Storage Claiming ITC" category and 0.35 $/Wh for large storage not claiming ITC. Given the optimal size of EES established by the HOMER model is 7.2 MW, the storage facility is above the 6 MW maximum incentive threshold and therefore will obtain the maximum allowed total incentive which for step 3 in the Large Storage Claiming ITC category is $882,000 while for the Large Storage not Claiming ITC

[18] https://www.selfgenca.com/documents/handbook/2017

category it is $1,225,000. Table C-8 provides a summary of the incentives for the design case and compares it to the incentives for a smaller battery size of 834kWh which is tested in the ZNE sensitivity. Since the incentive declines with increasing storage size, an 834kWh battery receives a much higher incentive on a $/kW basis than the larger battery required for the design sizing.

Table C-8: ITC for Different Storage Sizes, Assuming 4-hour Storage Duration

Storage Size (kW)	SGIP Step 3, Claiming ITC (0.35 $/Wh)		SGIP Step 3, Not Claiming ITC (0.25 $/Wh)	
	$ / kW	Total Value	$ / kW	Total Value
7,204	$680	$1,225,000	$489	$882,000
834	$1,400	$291,900	$1,008	$210,168

Half the incentive is paid upfront, and we assume the ESS will meet the criteria to obtain the remainder of the incentive which is paid out over the following five years. It is assumed that after the first ESS has reached the end of its life in 2035, the second ESS installation will not receive any SGIP incentive payment.

As a generator, fuel cells also qualify for SGIP, the incentive assumptions for the fuel cell modeled in Scenario 2 and 3 are summarized in the Table C-9.

Table C-9: SGIP Assumptions for Fuel Cell Generators

Fuel Cell Size (kW)	SGIP Incentives ($/kW)	Notes
200	1200	$600/kW Initial incentive rate for fuel cell generators and $600/kW adder for biogas usage

Federal Investment Tax Credit (ITC)

The other incentive opportunity is the Federal Investment Tax Credit (ITC). This incentive is included in the design scenario. According to the current Investment Tax Credit (ITC) program information[19] summarized in Table C-10, PV and storage installed in 2021 qualify for a 22 percent ITC. To comply with ITC rules, the ESS is assumed to only charge from the solar. The lifetime of the whole microgrid project is 25 years, and the Li-ion battery will be replaced at the end of its lifetime (15 years) in 2036. And for the second replacement, ESS will be qualified for 10 percent ITC.

[19] https://www.energy.gov/savings/business-energy-investment-tax-credit-itc

Table C-10: Annual ITC Assumptions

Year	2016	2017	2018	2019	2020	2021	2022	Future Years
ITC %	30%	30%	30%	30%	26%	22%	10%	10%

Scenarios and Sensitivities

This section summarizes the scenarios and sensitivities for this study, described in Table C-11. Scenario 1 represents the near term microgrid operation situation where only the city yard load is included to size the microgrid system. Multiple sensitivities are conducted in this scenario to explore potential rate options, vehicle-to-grid (V2G) integration, and other sizing options.

Scenario 2 and 3 represent future microgrid planning in which loads from the Bergamot Arts Center and Metro facilities are included. All loads are assumed to be billed conjunctively.

Table C-11: Scenarios and Sensitivities Summary

Case ID	Scenario	Sensitivities	Rate	Notes
1.0.1	Scenario 1	Base	CPA	Able to cover SMCY load during grid outage
1.0.2			SCE-TOUA	
1.0.3			SCE-TOUB	
1.1		V2G	CPA	Multiple vehicle to grid intergradation levels are investigated
1.2		ZNE	CPA	Net import close to 0; Able to cover ‘no vehicle operation’ load during grid outage
2.0	Scenario 2	Base	CPA	Total load = SMCY + Bergamot + Hotel
3.0	Scenario 3	Base	CPA	Total load = SMCY + Bergamot + Hotel + Metro

Table C-12 summarizes the technology sizes for microgrid under different sensitives and scenarios. In the Scenario 1 Design case and for the V2G sensitives, the microgrid is the same size and can support the entire SMCY load during emergency events in island mode. The ZNE sensitivity case tests the cost-effectiveness of a smaller microgrid sizing that meets the Zero Net Energy (ZNE) requirement and can cover critical load when islanding. The additional Bergamot Arts Center, hotel, and Metro load is likely to connect with the microgrid in 2030. Microgrid Scenarios 2 and 3 are sized to minimize the total cost for supporting additional load given the Scenario 1 design.

Table C-12: Microgrid Sizing Under Different Scenarios and Sensitivities

Scenario	Sensitivities	PV (kW)	Storage (kWh)	Fuel Cell (kW)
Scenario 1	Base	1,198	7,204	n/a
	V2G	1,198	7,204	n/a
	ZNE	658	834	n/a
Scenario 2	Base	1,700	7,204	200
Scenario 3	Base	1,700	7,204	200