CALIFORNIA
ENERGY COMMISSION

Energy Research and Development Division

FINAL PROJECT REPORT

Solar Emergency Microgrids for Fremont Fire Stations

Demonstrating Energy Savings and Grid Resilience for Critical Facilities

Gavin Newsom, Governor
September 2019 | CEC-500-2019-054

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PREFACE

The California Energy Commission's (CEC) 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 CEC 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 CEC 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.

*Solar Emergency Microgrid for Fremont City Fire Station*s is the final report for the City of Fremont Fire Stations Microgrid project (EPC-14-050) conducted by Gridscape Solutions. 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 CEC's website at www.energy.ca.gov/research/ or contact the CEC at 916-327-1551.

ABSTRACT

Gridscape Solutions, in partnership with the City of Fremont and funded by California CEC with $1.8 million grant funding, installed solar emergency microgrid systems at three fire stations in Fremont, California. Each of the microgrid systems consists of a microgrid energy management system (EnergyScope™), a parking lot solar photovoltaic canopy system, and a battery energy storage system. The automated microgrid control system optimally manages local energy resources in on-grid and off-grid situations. The system provides energy cost savings when connected to the grid and at least 4-6 hours of clean renewable power during a utility power outage, which might be caused by natural disasters (wildfire or earthquake).

Under a 10-year power purchase agreement/energy savings agreement with the City of Fremont, Gridscape will continue to own, operate, and maintain the microgrid system at the three fire stations. The project is estimated to result in energy cost savings of at least $250,000 over 10 years and about 142,000 pounds of greenhouse gas reduction annually. The project has demonstrated ratepayer benefits ranging from lower energy costs, clean power during outages, lower distribution grid upgrade costs, and many other benefits to the ratepayers as well as city residents.

This project serves as a proof of concept applying a solar emergency microgrid for critical facilities, and also paves the way for mass commercialization of the microgrid technology developed under this grant across many other California cities such as Stockton, Fontana, Richmond, and globally.

Keywords: *solar, microgrid, power purchase agreement, fire stations, energy savings*

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Introduction

California must make better use of locally available renewable energy to increase resiliency in the electricity grid and address climate change impacts, such as increased fires, severe storms, and heatwaves. Critical facilities are especially vulnerable to climate change impacts that disrupt the normal delivery of electricity necessary for their operation. Microgrids, or a combination of localized electricity generation sources, energy storage devices or multiple energy loads that act as a small electric grid that can operate independently or connected from the main electric grid, can help increase the resiliency of critical facilities by maximizing the use of local renewable energy. This project demonstrated how microgrids can improve resiliency at the fire stations, provide power during electricity outages and reduce energy cost by using renewable energy, thereby contribute to achieving state goals of the Renewable Portfolio Standard and other clean energy initiatives.

Traditional microgrid solutions have been complex, customized solutions based on off-grid diesel or some other form of fossil fuel-based electric generation. This project demonstrated how renewable solar energy can be harnessed and stored to form a microgrid at a critical facility that not only provides crucial emergency power during a power outage or disaster situation but also saves energy costs during regular, on-grid operation. Advancing smart inverters, Internet of Things (IoT) technology, and advanced control mechanism, coupled with a decline in prices of solar photovoltaics and battery energy storage systems, has shown positive results to help achieve California clean energy goals.

The City of Fremont has a progressive and aggressive climate action plan. It is the fourth largest city in the metropolitan San Francisco bay area in the Northern California region. It is physically located on top of the Hayward fault line making it earthquake prone. Additionally, it is a major transportation corridor for private and public vehicles in the east bay region. In case of any natural disaster, Fremont city emergency services such as fire, paramedics and police, must be prepared, self-sufficient and fast to respond relying on their own power. The fire stations in the City of Fremont became an obvious choice and desired sites for this technology demonstration project.

It would have been impossible to raise capital investment required for this project from private markets or cash-strapped municipal customers. Private investors are looking for quick return on their investments and cannot quantify the financial value of resiliency provided by such projects. This makes it difficult to raise private capital for such projects. Hence, the ratepayer support was essential for successful completion and to exhibit results and benefits from this project to all stakeholders.

Project Purpose

The Solar Emergency Microgrid Project for the fire stations in the City of Fremont demonstrated reliable and cost-effective integration of distributed clean energy generation, demand-side resources, and smart microgrid components to protect and enable energy-smart critical facilities such as fire stations. This project showed stakeholders that installing a microgrid system using local solar renewable energy can increase the resiliency of a critical facility (fire stations) by providing generation during emergencies and decrease operational energy costs by avoiding high utility demand charges and diesel fuel costs.

This project explored establishing a cost-effective, renewable solar powered emergency microgrid system at critical facilities that was controlled, monitored, and operated remotely from a central cloud-based software system. The project:

- Demonstrated a low carbon-based microgrid that can operate in an islanded (independent) mode for at least three hours at three independent critical facilities (Fire Stations) in the City of Fremont, California.
- Implemented advanced energy visualization software, load control, and management for energy cost savings and participation in future grid ancillary services.
- Produced technical and economic data, including documentation of implementation issues, operational constraints, and performance metrics.
- Reduced greenhouse gas emissions and continues to contribute to the City of Fremont's climate action plan and California's goals of clean energy future.
- Overcome barriers specific to increasing the opportunity for widespread adoption and commercialization of microgrids for the small to medium municipal, commercial, and industrial customer segment.

Project Approach

Gridscape Solutions partnered with the City of Fremont, Delta Products, Sun Light and Power, Microgrid Energy, and Pacific Gas and Electric Company (PG&E) to design and install this project. The CEC EPIC funding provided 75 percent of the capital investment for this project, with Gridscape investing the remaining 25 percent of the capital investment as match funding. The City of Fremont did not want to own, operate and maintain the system and signed a power purchase agreement/Energy Savings agreement with Gridscape Solutions for the company to own and operate the microgrids for 10 years passing the energy savings and clean energy benefits to the city.

The project team carefully selected three fire stations as demonstration sites (Figure ES-1), based on geography, energy use, age of the buildings, minimum disruption to fire operations, ability to replicate and ease of access for research and development purposes. In 2015, the project team installed the first microgrid at Fire Station 11 to ensure that lessons learned, especially technology and cost improvements, from this site can be applied at the remaining two sites. The project team performed exhaustive testing and data collection for a year on the microgrid at Fire Station 11, and then for about four to six months on the remaining two stations. The results of this testing and data collection helped achieve success for this project.

Figure ES-1: Three Fire Station Demonstration Sites in Fremont

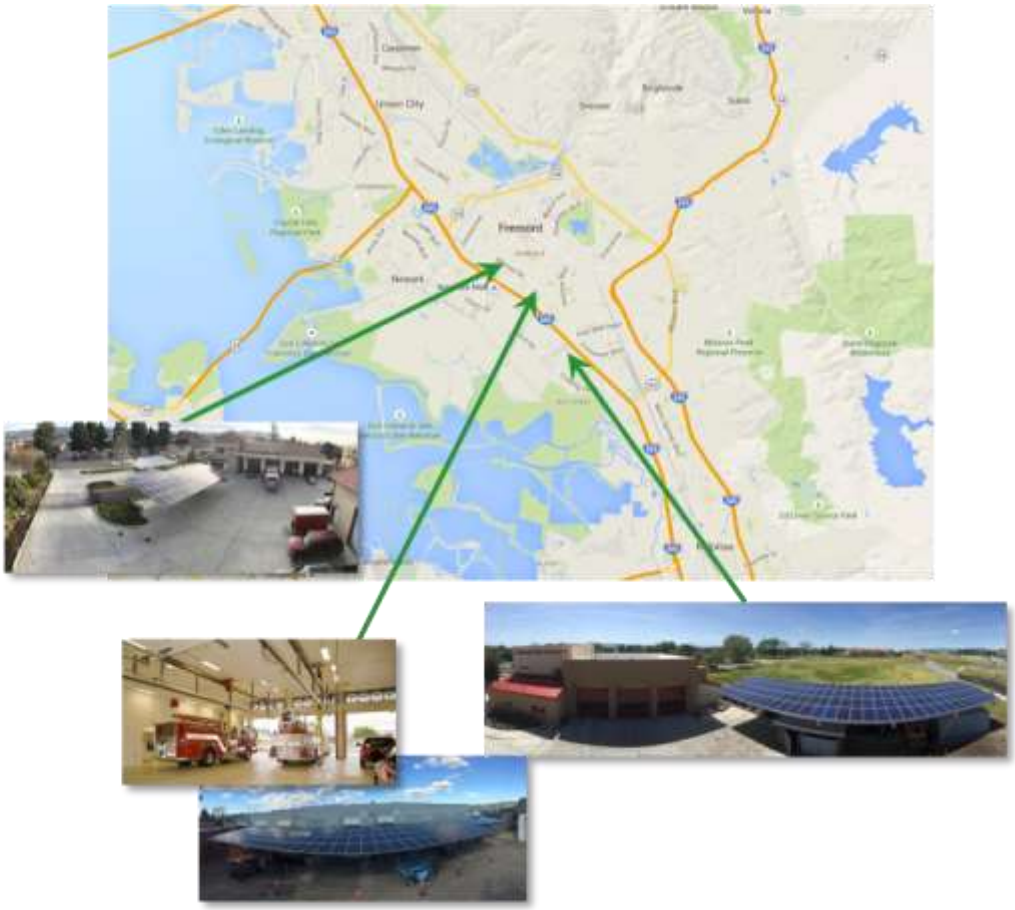

Photo Credit: Google Maps, City of Fremont

Gridscape also undertook an exhaustive design and prototype development upfront to carefully select the right components for the system to meet technology costs, performance attributes and other technical features for the microgrid systems. A technical advisory committee (TAC) was formed to advise the project team on design choices to meet the technology, cost and performance attributes of the system. The TAC team constantly advised the project team on short-term project objectives as well as long-term market traction of these systems during this project.

Project Results

Over past four years, the project involved research, design, deployment, and operations of renewable, solar powered, low carbon-based microgrids at three fire stations in

Fremont, California. Each microgrid consists of an advanced cost-effective microgrid controller, a parking lot canopy solar photovoltaic system, smart inverters, and a battery energy storage system. The automated microgrid controller manages local energy resources and loads optimally. The three sites are managed and controlled by a cloud-based distributed energy resource management system (DERMS). The microgrid intended to provide at least three hours of power a day for critical loads during a utility power outage. The results positively and consistently demonstrate islanding for more than three hours on various occasions. On an on-grid operation, it optimizes the use of clean energy from the solar photovoltaic generation and battery energy storage system to save energy costs to the fire stations.

The project was completed in four years and yielded better than expected results. First and foremost, the project team was able to exceed the anticipated results by a factor of 25 percent across the following metrics.

- The project has saved $7,046 in energy costs over the 12-month demonstration period at Fire Station 11 and is expected to save more than $20,000 collectively for the three fire stations. This result is 25 percent better than original expectations.
- The project team executed four islanding tests during the demonstration period. Each test lasted more than three hours consistently. The last islanding test lasted more than 13 hours. The original goal was to demonstrate at least three hours of islanding.
- The project has also met the greenhouse gas emissions reduction goal of 80,000 lbs/year during the demonstration period and helped the City of Fremont meet its climate action plan objectives.
- The project team achieved a technology cost reduction of more than 30 percent from the first microgrid at Fire Station 11 to the remaining two at Fire Stations 6 and 7, by adopting value-engineering and cost optimization measures.
- The project also supported the design and development of a microgrid controller and cloud-based advanced visualization, control and management platform for distributed energy resources for small to medium critical facility and commercial and industrial market space (Figure ES-2).
- The project also helped pave the way for Gridscape to develop other microgrids with the goal of mass-producing commercial microgrids without state or federal funding in the small to medium municipal, commercial and industrial market in California. Gridscape is now developing other microgrids at critical facilities and with various commercial and industrial customers, using lessons learned from this project.

Figure ES-2: Gridscape EnergyScope^{TM} Visualization Dashboard

Source: Gridscape Solutions

The project team faced several challenges and barriers such as utility interconnection, construction delay and other technical, legal, and regulatory agreement issues. It took more than one year to interconnect the microgrids with PG&E's electrical system at each site, due to lack of a technical and regulatory framework for the net energy metering interconnection agreement used for the battery based renewable systems. The Fire Station 6 and 7 microgrids experienced construction delays due to soil liquefaction issues that affected the carport design and cost. Gridscape overcame most of the challenges with design changes, negotiations, and improvements made throughout the project as described in this report.

Technology/Knowledge Transfer

The results and knowledge gained from this project are being made available to public and stakeholders. Gridscape successfully demonstrated the microgrids and benefits at several conferences, industry trade organizations, and on social media. Highlights of these activities include:

- Local Government for Sustainability published a whitepaper on the Fremont Fire Station Microgrid that is used by several other cities to evaluate the use of this technology and solution and its applicability to their municipal sites.
- The CEC's Energy Innovation Showcase featured the [Fremont Fire Station Microgrids](http://innovation.energy.ca.gov/SearchResultProject.aspx?p=30084) (http://innovation.energy.ca.gov/SearchResultProject.aspx?p=30084).
- Other social media links to this project are:
    - [Creative Partnerships Help Build Critical Infrastructure Resiliency with Microgrids](https://www.engerati.com/blogs/creative-partnerships-help-build-critical-infrastructure-resiliency-microgrids) (https://www.engerati.com/blogs/creative-partnerships-help-build-critical-infrastructure-resiliency-microgrids).

    - California Names 10 Winners for $51.9 Million in Microgrid Grants (https://microgridknowledge.com/microgrid-grants/).
- Gridscape also has presented this project in numerous conferences and industry trade publications such as:
    - Association of Bay Area Governments (https://goo.gl/HRKi6W).
    - Innovation and Impact Symposium 2018 (https://goo.gl/uPTQFi).
    - ACI 4th National Grid-scale Energy Storage Conference (https://goo.gl/YTrz9t).
    - Silicon Valley Energy Summit 2018, Stanford University (https://peec.stanford.edu/sves/2018).
    - EPIC Symposium 2016

Benefits to California

This project demonstrates the replicability and economic feasibility of solar emergency microgrid installations at critical facilities across the state and paves the way for mass use of this technology across the state.

This project led to the design and development of a cost-optimized microgrid controller and value-engineered design for a microgrid targeted for small to medium critical facilities. This invention along with declining prices of solar photovoltaic systems and battery systems opens up a unique market opportunity to companies such as Gridscape to replicate and commercialize these systems for mass adoption. This benefit itself can be considered the greatest achievement of this project.

Gridscape intends to commercialize the microgrid solution developed in this project and market it across various prospects in the small to medium municipal, commercial and industrial markets and university, school and hospital markets in California and globally. Gridscape employed a value-engineering approach in this project to optimize the design, construction, and cost of the microgrid controller and DERMS system to address the specific requirements of this market.

Subsequent to this grant, Gridscape also won a few other grants and projects to deploy more microgrids at municipal facilities such as fire stations and emergency shelters in the cities of Portola Valley, Fontana, and Richmond. Outside of the grant funding, Gridscape has also been in discussions with several private commercial and industrial customers such as food processing plants, warehouses, nutrition centers and other high-energy users who need backup emergency systems. Gridscape plans to deploy these microgrid systems without grant funding.

The following additional results of this project will benefit the state of California as well:

- Reduced annual greenhouse gas emissions in Fremont and California by 141,896 pounds, thereby supporting the goal of Assembly Bill 32 (Nuñez, Chapter 488, Statutes of 2006).
- Contributed 205,000 kilowatt-hours of clean energy generation during the demonstration period and is expected to produce more than 1,750 megawatt-hours of clean power over the 10-year useful life of the project, thereby contributing to achieving California's Renewables Portfolio Standard goal of 33 percent renewable energy sources by 2020 and 100 percent carbon-free energy sources by 2045.
- Will create and maintain clean energy jobs.

CHAPTER 1: Introduction

Problem Statement

Microgrids for Critical Facilities

All critical facilities require emergency backup power. For example, fire stations in every city have a diesel generator that provides power during grid outages caused by earthquakes, wildfires or other emergency situations. Typically, there is a 3-day (72 hours) diesel reserve in the generator, allowing the critical facility to operate for 72 hours without any power from the grid during such events. The fire stations must conserve diesel use during outages to extend emergency services beyond three days. Further, it is also difficult for them to transport additional diesel into the facility especially if the transport routes around the fire station are disrupted due to damage caused by natural event.

It is critical for fire stations to have a capability to generate power locally without relying on diesel supply. The solar emergency microgrid provides this capability to the fire station. It generates clean renewable solar power and saves the excess in the battery that can be used later during evening or night. It also helps the fire operations to extend the amount of diesel beyond 72 hours, as it becomes a secondary source of power after solar energy.

Climate Change

Earth's climate has changed during last 650,000 years. Most of these climate changes, such as the last Ice Age, are attributed to small variations in Earth's orbit that change the amount of solar energy received. However, the current warming trend is particularly significant because most of it is due to human activity during the last 70 years and is proceeding at an unprecedented rate. The evidence for rapid climate change is highly evident, visible, and compelling. It has resulted in a global temperature rise, warming oceans, shrinking ice sheets, glacial retreats, decreased snow cover in the Arctic and Antarctic, rising sea levels, extreme natural events (such as storms or wildfires.), and ocean acidification (Figure 1).

Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time[1]. The main cause of the current global warming is the human expansion of the "greenhouse effect",

1 NASA and Intergovernmental Panel on Climate Change (IPCC) 2007, Summary for Policymakers, in Climate Change 2007, Adaptation and Vulnerability, Cambridge University Press, Cambridge, UK.

generated by the emission of greenhouse gases (GHG) such as CO_2, N_2O, CH_4,and H_2O (vapor)[2].

Figure 1: Global Climate Change Impacts

Photo Credit: Nasa: Global Climate Change

State and Cities – Sustainability Policy and Climate Action Plans

In 2006, the State of California passed Global Warming Solutions Act (AB 32), setting a goal to reduce statewide emissions to 1990 levels by 2020. Under the Global Warming Solutions Act, the California Air Resources Board (CARB) developed a Climate Change Scoping Plan, encouraging local governments to adopt their own greenhouse gas emissions reductions goals. Many California cities developed and adopted various goals and initiatives to meet the challenge. The City of Fremont also adopted a Climate Action Plan on November 13, 2012, setting up an ambitious GHG emission reduction goal of 25 percent from 2005 levels by the year 2020. This document[3] provides a roadmap for the city to achieve a community-wide sustainability.

The city's adopted goal of 25 percent reduction (730,000 million tonnes carbon dioxide equivalent [$MTCO_2e$]) in the city's GHG emissions by 2020, from 2005 baseline (1,660,000 $MTCO_2e$), is more ambitious than the state's goal.

Figure 2 illustrates the "achievement gap" that exists between the emissions level achieved by successful implementation of the state and local actions and the city's aspirational goal. the Climate Action Plan was prepared, it was unclear how the "achievement gap" would be closed. The city hoped for new technology, behavioral

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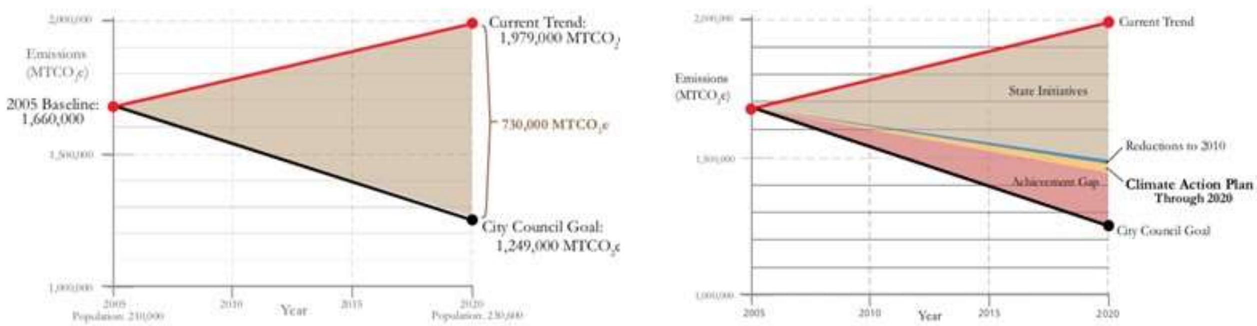
2 IPCC Fifth Assessment Report, 2014.

3 City of Fremont Climate Action Plan, November 2012.

changes, or adoption or both of additional measures to help narrow the gap over several years.

Figure 2: City of Fremont Greenhouse Gas Emissions Reduction Goal



Source: City of Fremont Climate Action Plan, Nov 2012

In 2014, when the CEC announced the grant funding opportunity (PON-14-301) to demonstrate secure, reliable microgrids, and grid-linked electric vehicles to build resilient, low-carbon facilities and communities, Gridscape Solutions approached the City of Fremont with a proposal to install renewable solar-powered emergency microgrid systems at three fire stations in Fremont. The proposal not only addressed the "achievement gap" in the city's GHG emission reduction goal but also met the city's economic development office objective for public-private partnership to assist and develop clean technology businesses in Fremont. Subsequently, three fire stations (critical facilities) were identified that could serve as prospective, renewable, solar powered microgrids to save energy costs, reduce GHG emissions by using clean solar power, and act as an emergency critical facility and response center during natural disasters.

Issues – Funding, Policy, Energy Costs

Many public organizations, including local government agencies such as the City of Fremont, universities, and even corporate businesses do not have funds to justify capital investment for renewable energy projects used only for demonstration purpose. Further, it is also difficult to raise private financing for technologies that are not proven and do not guarantee short-term or long-term return on investment. This is a huge issue hindering development and use of microgrids and coordinated distributed energy resources such as solar photovoltaic (PV) systems, battery energy storage systems (ESS) and electric vehicle (EV) chargers.

Moreover, utility policies and general practices in many cases inadvertently deter microgrid projects, due to perceived risks such as grid stability, safety, reliability, and loss of revenue. Utility interconnection policies have not been amended to accommodate deployment of renewable powered microgrids and distribution of clean energy resources. Many utility system planners and operators do not consider microgrids as a potential resource or asset, capable of addressing system constraints. Many utility executives consider microgrids to be potentially competing, complex, and disruptive. Sufficient data and evidence must be gathered and presented to the policymakers to demonstrate benefits of the renewable powered microgrids.

Lastly, the electricity costs in California has increased over last ten years. In contrast, the price of solar PV panels and battery systems has been steadily falling over last 10 years and is further expected to decline over next ten years as the global production increases from demand. California is at an interesting crossroads where rising utility electricity cost is compelling more residential and commercial customers to seek cheaper energy sources, such as solar PV rooftop and carport systems. Microgrids are technically designed to leverage these cheaper energy sources along with providing the required resilience during utility power outages.

Public-Private Partnership

Cities have a significant opportunity to lead by example, when it comes to innovative energy solutions to solve climate action plan needs that are offered by private enterprises. It's even better for the cities if these types of sustainable energy decisions contribute to the city's economic development strategy. For Fremont, where clean technology is considered one of its largest industry clusters (Tesla, SolarEdge, Delta), public-private partnerships can promote demonstration of new technologies, help its local companies increase production scale, and identify potential sustainability measures for the city's climate action plan and operations.

Market Forces

According to recent United States Department of Energy (USDOE) study and report[4], microgrids can strengthen grid resilience and help mitigate grid disturbances as well as function as a grid resource for faster system response and recovery. Microgrids support a flexible and efficient electric grid by enabling the integration of growing use of distributed energy resources such as renewable solar generation and energy storage systems. The levelized[5] cost of energy with solar PV system has already reached grid parity in various regions in the United States and globally. Similarly, the levelized cost of energy with integrated energy storage system is almost reaching grid parity in various regions worldwide. These market forces are enabling broader use and proliferation of microgrids worldwide.

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4 United States Department of Energy, *The Role of Microgrids in Helping to Advance the Nation's Energy System*.

5 Levelized costs incorporate of the produce all costs over the lifetime including initial investment, operations and maintenance.

Market Segmentation

According to the Navigant Research report on microgrids[6], the microgrid market can be classified into following market segments:

- Campus/institutional microgrids (municipal facilities, critical facilities, universities, schools)
- Commercial and industrial (C&I) microgrids (warehouses, food processing units, industrial units, distribution centers)
- Community microgrids (typically in front of customer meters and downstream of substation feeders)
- Military bases
- Utility distribution microgrids
- Remote microgrids (islands, remote locations)

The first two segments are the markets that represent maximum growth over next 5-10 years as the cost economics and benefits far outweigh the barriers, issues and challenges in installing and operating the microgrids in these market segment. Various business models are also emerging that allow growth in these market segments including energy-as-a-service, government funding (grants, subsidies), owner financing and utility rate base financing.

The Fremont Fire Station Microgrid project serves as a great demonstration for these two market segments and resulted in an evolving business case for repeatable and scalable microgrid systems in the cities and MUSH (municipalities, universities, schools and hospitals) market segments. There are 69,542 fire departments in the United States[7], with 3,041 of those in California. The successful demonstration and technology adaptation from Fremont Fire Station microgrid can lead to successful and broad adoption of these types of microgrids in these market segments.

Solar Photovoltaic Costs and Market Penetration

The installed capacity of global and United States PV systems has soared in recent years, driven by declining PV prices (Figure 3) and government incentives. The reported median installed price in 2011 was $6.13/watt (W) for residential and small commercial systems, and $4.87/W for larger commercial systems[8]. In 2018, the reported median installed price for residential and small commercial rooftop system is $2.75/W and $1.50/W respectively. The equivalent price for small commercial solar carport system is $3.5/W to $4.25/W. These prices are further expected to fall another 30 percent-45

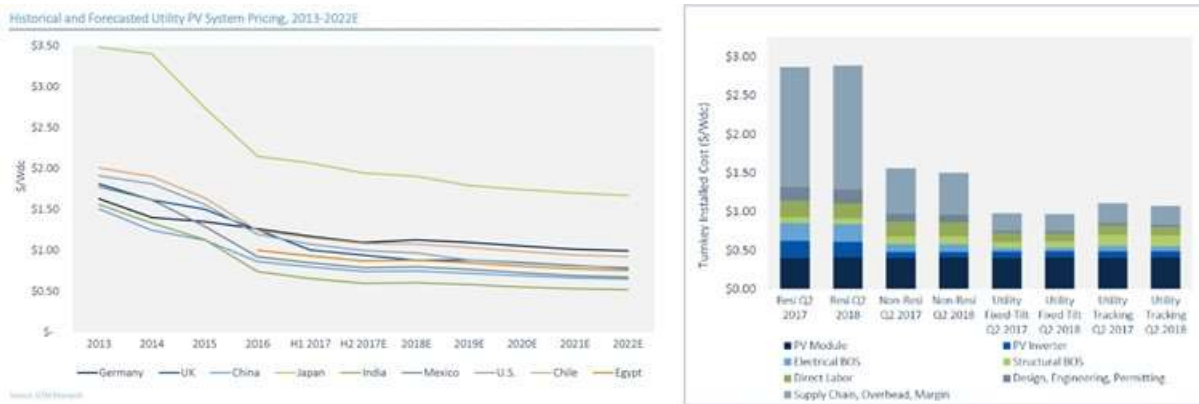
6 Navigant Research: Market Data: Microgrids 3Q 2018.

7 Firedepartment.net website (https://www.firedepartment.net/)

8 SEIA Solar Market Insight Report 2018 Q3.

percent by 2022. The decline in installed solar PV prices is fueling record number of behind-the-meter solar PV installations.

Figure 3: Installed Solar Photovoltaic Price Trend



Source: Greentech Media Research

In the Fremont Fire Station Microgrid project, the installed solar PV carport cost in Fire Station 11, which was constructed in the first quarter 2016 was approximately $5/watt (W) and the installed solar PV carport cost in Fire Station 6 and Fire Station 7 that was constructed in the first quarter 2018 was approximately $4/W. As solar PV prices continue to decline in next five years, Gridscape expects faster market penetration of renewable microgrids in those two market segments.

Energy Storage Costs and Market Penetration

Energy storage systems come in different technologies, chemistries and forms. The most predominant technology is the lithium-ion battery with applications in microgrids and other grid storage options including storage in electric vehicles. The average price of a lithium-ion battery pack in volume is $209/kilowatt-hour (kWh) and set to fall below $100/kWh by 2025.[9]

Energy storage allows distributed solar or other forms of generation to balance the supply and demand by storing the energy when excess is produced and supplying it back to the loads when demand is high. This makes an interesting case and value proposition for microgrids and other solar-storage applications, either behind the meter or in front of the meter.

Energy storage coupled with solar PV generation and intelligent control software makes an excellent case for wide penetration of microgrids in the electric grid. The benefits are significant and as the total cost of system ownership declines in global solar PV and energy storage system, it becomes more attractive for cities, businesses and consumers to install the systems.

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9 Bloomberg New Energy Finance.

Energy storage has another very interesting benefit; it allows off-grid operation. If sized correctly, energy storage can enable 24/7 off-grid power supply when smartly coupled with solar PV generation or other local electric generation.

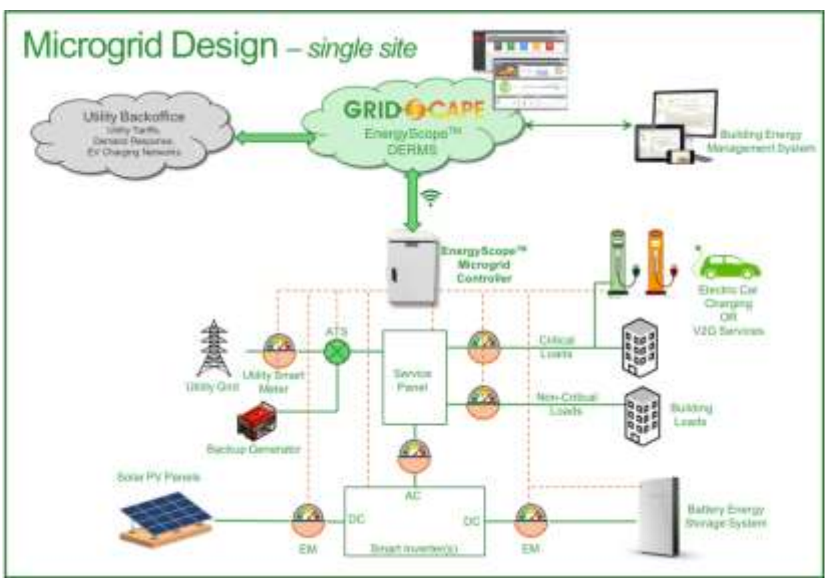
These elements are helping wide adoption and commercialization of microgrid systems in various market segments.

Smart Grid Technology – Internet of Things

The advancements in new Internet-of-things (IoT) technology in power generation, storage, and distribution are opening up vast opportunities to modernize the electric grid into a "smart grid" that is efficient, flexible, reliable, and cost-effective. IoT-enabled faster computing power, universal internet and network availability, precision instrumentation and control, and cloud computing technology is coming to the rescue of grid operators by providing them the necessary information and tools to offer real-time monitoring and control on distributed energy resources. Whether it is solar PV generation, energy storage, demand response, or smart meters, IoT devices coupled with machine learning and cloud computing offer a distributed knowledge base and aggregated information to automatically and swiftly respond to faults, supply and demand, forecast, and issues in the smart grid and microgrids to keep the overall grid balanced and stable.

The Fremont Fire Station Microgrid project showcases a state-of-the-art microgrid design as that uses intelligent cloud software and IoT devices to monitor, visualize, and control all energy resources (Figure 6).

Figure 4: Gridscape's Internet-of-Things-Based Microgrid Design



Source: Gridscape Solutions

This includes solar PV panels, battery ESS system, inverters, meters, and optionally EV chargers, within the microgrid for fine-grained control and smooth operation of the system.

Microgrid Controller Technology

The microgrid controller acts as the brain of the microgrid, whether intentionally islanding from the utility grid or responding to a signal from grid operator in the grid-tied mode to provide ancillary services. It is vital to the success of the microgrid projects whether focused on resilience, renewable energy integration, or economic optimization.

For the past several decades, microgrid control systems were designed and deployed for large utility-scale microgrid applications. The total cost of the control system was quite high. As the microgrid market continues to push small to medium microgrids in MUSH and C&I applications, the incumbent microgrid control systems were no longer cost-effective. When Gridscape started the Fremont Fire Station microgrid project in 2015, the cost of incumbent control systems was approximately 50-100 percent of the total cost of the project. This was a huge cost barrier to design and develop cost-effective solutions for these markets.

As indicated earlier, advancements in IoT technology and cloud computing enabled Gridscape to invent, design, and develop a cost-optimized microgrid controller solution for the small to medium MUSH and C&I market. Gridscape's EnergyScope™ microgrid controller solution is split between the local on-site microgrid controller hardware system and cloud-based distributed energy resource management system (DERMS). The split design optimizes common functions in the cloud and enables a virtual wide area microgrid network that spans multiple sites in separate geographical area.

There are several other large and small microgrid controller vendors in the market today. As the market continues to evolve and grow, the microgrid control technology will continue to advance and become cost-effective for various market segments.

Project Objectives

The objectives of this project are to:

- Design, develop, implement, operate, and support an advanced renewable energy, low-carbon-based microgrid infrastructure at the three fire stations (critical facilities) in the city of Fremont.
- Reduce utility costs by providing energy savings due to local renewable energy generation.
- Display and provide more than three hours of electrical power to the fire stations during a utility outage.

- Implement an advanced microgrid energy management system with accurate forecasting of renewable energy resources and loads to support both day-to-day energy optimization and islanded operation in the event of the utility outage.
- Prevent excess PV generation from being exported at the loss of reduced rate before being consumed on-site.
- Provide technical and economic data, including documentation of implementation issues, operational constraints, and performance.
- Demonstrate reduction in GHG emissions, in line with the City of Fremont's climate action plan.
- Reduce transmission line load to defer system upgrade and reduce power capacity requirements at utility substation.
- Provide off-grid, islanded power to the critical facility that is very close to the Hayward fault line.
- Demonstrate the state goals of grid resiliency.
- Demonstrate use of technological advancement and innovations in energy visualization and management software.
- Overcome barriers specific to microgrid projects in achieving state's statutory energy goals.

Project Phases

This project started in March 2015 and was completed in March 2019 in the following phases:

1. Contract Phase
2. Design Phase
3. Construction Phase
4. Demonstration Phase
5. Operations Phase

Report Structure

Chapter 2 provides an overview of initial contract phase with the city and subsequently design, construction, and operation of the microgrid. It also discusses the various challenges faced and mitigation actions Gridscape design team undertook to overcome them during the course of the project.

Chapter 3 reviews the results of the project and its benefits to the city, California, PG&E, and other important stakeholders.

Chapter 4 discusses Gridscape's activities to spread awareness and transfer knowledge gained in this project to different agencies. It also forms the primary marketing plan for Gridscape to commercialize the technology and solution developed in this project.

Chapter 5 summarizes the report by providing concluding remarks and various recommendations to all stakeholders (CEC, California investor-owned utilities (IOUs), California Public Utilities Commission, cities, and others) for a streamlined policy to allow faster adoption and accelerated growth in the deployment of this technology and solution across the state and beyond.

Chapter 6 analyzes various qualitative and quantitative benefits to the City of Fremont, California, and ratepayers in California IOU territories who contributed to the Electric Program Investment Charge (EPIC) funding for this project.

CHAPTER 2: Project Approach

This chapter provides an overview of the project including agreement with the City of Fremont, design and construction. The microgrid system was installed at three fire stations in the City of Fremont (Figure 5).

1. Fire Station 11, 47200 Lakeview Blvd, Fremont, California 94538.
2. Fire Station 6, 4355 Central Ave, Fremont, California 94536.
3. Fire Station 7, 43600 Grimmer Blvd, Fremont, California 94538.

Figure 5: Three Fire Station Microgrids in Fremont

Source: Google Maps, City of Fremont

Contract and Agreement

The CEC awarded the grant project to Gridscape Solutions in a business meeting on April 8, 2015. Gridscape started initial discussions and negotiations with the city of Fremont on a contract and agreement to deploy the microgrids at the three fire stations named in the grant application. The three original fire stations in the grant application were Fire Station 1, Fire Station 6, and Fire Station 7.

However, during initial discussions and California Environmental Quality Act (CEQA) review, Fire Station 1 had a leak in the underground gas tank that would require substantial repair work and did not meet the CEQA compliance requirements of the project. The city offered Fire Station 11 as a replacement for Fire Station 1. The Fire Station 1 was an old station with numerous trees and vegetation that would impact solar generation at that site. A site change request was requested to replace Fire Station 1 with Fire Station 11, and approved June 9, 2015.

Gridscape worked with several city departments for project and stakeholder approval:

- Sustainability Department (lead champion of the city project)
- Fire Department
- Maintenance Department
- Landscaping Department
- Information Technology Department

The stakeholders insisted that the preliminary design of the microgrids including siting, sizing, energy usage, cost analysis and expected results, should be completed before they can give approval for the project. Since this was a research project and first of its kind in the state, Gridscape did not have the necessary analysis to provide the preliminary design. Therefore, the design team initiated a prototype development in the Fremont lab to demonstrate an operating model to the stakeholders in the city. The prototype was completed in January 2016 and the results of the prototype were presented to the CEC and the city stakeholders in the critical project review meeting on February 24, 2016.

The successful prototype demonstration led to stakeholder approval. A staff report for a Council approval was prepared in July/August 2016. Finally, Gridscape received Fremont City Council approval on September 13, 2016, and an energy savings/power purchase agreement (PPA) contract with the city was signed on November 9, 2016.

Fremont Sustainability and Planning

Fremont Sustainability and Planning department took the lead in championing this project with various stakeholders in the city. The climate action plan for the city was also developed by this department with the value and benefits this project would bring to Fremont evident. The team worked diligently to raise awareness of this project and its benefits to the city, and prepared a comprehensive staff report to secure council approval and sign the final agreement with Gridscape.

Staff Report

The staff report (ID# 2806) was presented to Fremont City Council on September 19, 2016 (see Appendix A).

Council Approval

Fremont City Council approved the project[10] and authorized the city manager or his designee to execute a power purchase agreement with Gridscape for renewable energy microgrid system at the three city-owned fire stations as part of the CEC funded grant demonstration.

Demonstration and Power Purchase Agreement

Under the grant provisions, Gridscape needed to demonstrate the viability of energy savings, increase the electrical infrastructure resilience, and optimize energy use to enable energy-smart critical facilities from the three microgrid systems. The initial agreed grant period was May 8, 2015 through March 31, 2018, that included all system design, construction, interconnection, system testing and grant reporting. In particular, it also required that each of the three microgrid systems undergo a "demonstration period" of at least one year.

The City of Fremont chose to enter into a ten-year PPA with Gridscape, after the demonstration period for continued operation of the system and receive benefits from the system beyond the CEC grant period. The city will not only receive free clean power generated by the solar PV system, included in the microgrids, during the demonstration period, but also continue to save significant energy costs at the fire stations for the next ten years. Table 1 shows the estimated savings during the demonstration period as well as for next 10 years at each fire station, under PPA agreement with Gridscape.

As of this report, the results from each microgrid system have exceeded the expected savings estimated.

10 City of Fremont Council Approval Report.

Table 1: Estimated Savings from Power Purchase Agreement[11]

	Station #6	Station #7	Station #11	Combined
Ave. Annual Electric Usage	97,500 kWh	108,000 kWh	64,500 kWh	270,000 kWh
Ave. Annual Electric Bill	$17,900	$19,000	$12,500	$49,400
Current Electric Costs ($/kWh)	$0.1830	$0.1761	$0.1942	
PV System Size	37.1 kW	43.4 kW	37.2 kW	117.7 kW
PPA Rate Year 1 ($/kWh)	$0.0916	$0.0881	$0.0971	
Est. Production Year 1	52,000 kWh	66,000 kWh	56,000 kWh	174,000 kWh
% Energy Usage Offset	53.3%	61.1%	86.8%	64.4%
"Demonstration Period" Savings	$9,574	$11,604	$10,849	$32,027
PPA Payment Year 1	$4,763	$5,815	$5,438	$16,015
Remaining Utility Payment Year 1	$8,327	$7,396	$1,651	$17,373
New Net Electric Costs Year 1	$13,090	$13,211	$7,088	$33,389
Annual Electric Savings Year 1	$4,810	$5,789	$5,412	$16,011
% Bill Savings Year 1	26.9%	30.5%	43.3%	32.4%
Bill Savings Over 10 Year Term	$60,886	$74,399	$79,559	$214,844
Total Bill Savings (Demonstration Period + PPA)	$70,460	$86,003	$90,408	$246,870

Source: Gridscape Solutions

Microgrid Design

This section describes the breakthroughs, issues and challenges faced during the microgrid design and prototype development phase.

Research and Discovery Phase

The research and discovery phase of this project started in May 2015 through September 2016. An intensive study on various design considerations including

11 Courtesy City of Fremont Staff Report.

selection of right equipment, electrical design, software design and prototype validation of the design concepts was executed during this phase.

Early on during the design phase, the design team determined it will use a direct current (DC)-coupled microgrid system at Fire Station 11 and an alternating current (AC)-coupled microgrid system at Fire Station 6 and 7. This was to ensure that the technical and economic benefits of both type of systems for same-size sites and operations are analyzed and recorded.

Equipment Vendors Technical Selection

Earlier in the research and discovery phase, Gridscape contacted several equipment vendors for smart inverters, battery energy storage system, microgrid controllers, meters and automatic transfer switches (ATS), to study the component specification and its applicability to the project to meet the design objectives. An in-depth, diligent, critical review and prototype testing for each component was completed in the lab and the vendor lab to determine right capability/cost tradeoff for each piece of equipment.

Each smart inverter vendor was measured using four criteria, namely, features/ capabilities, ease of integration, technical support and cost. The design team first engaged with vendor's technical support and engineering team to evaluate the features, capabilities and ease of integration of the product. Based on this interaction, each vendor was given a rank in terms of number of Xs before making a selection. "XXX" indicates most satisfactory and excellent results, while "X" indicates least satisfactory or unfavorable results.

The following subsections show the results of this critical review and prototype testing.

Smart Inverter Evaluation

The result of the evaluation of smart inverters is summarized in Table 2. The cost of the smart inverters from various vendors varied from $4,000 (denoted by XXX) to $15,000 (denoted by X).

Table 2: Smart Inverter Evaluation

Vendor	Features/ Capabilities	Ease of Integration	Technical Support	Cost
Ideal Power	XXX	XXX	XXX	X
Princeton Power	XXX	XX	XX	XX
Schneider Electric	XX	XX	XX	XXX
Delta Electronics	XX	XX	XXX	X
Outback Power	X	XXX	XX	X

Source: Gridscape Solutions

Based on intensive evaluation, Gridscape selected Ideal Power for DC-coupled microgrid at Fire Station 11 and Delta for AC-coupled microgrids at Fire Station 6 and 7. The main reason for selecting Ideal Power and Delta was technical features, capabilities and technical support from vendors.

Battery Energy Storage System Evaluation

The result of the evaluation of battery energy storage system (BESS) is summarized inTable 3. The cost of the BESS system varied from $400/kWh (denoted by X) to $900/kWh (denoted by XXX).

Table 3: Battery Energy Storage System Evaluation

Vendor	Features/ Capabilities	Ease of Integration	Technical Support	Cost
Samsung SDI	XX	XXX	XXX	XX
Tesla	XX	XX	XX	XXX
Delta/LG Chem	XXX	XXX	XXX	X
Imergy Energy	XX	XX	XX	XXX
Octillion Power Sys	X	XX	XX	XX

Source: Gridscape Solutions

Based on intensive evaluation, Gridscape selected Samsung SDI BESS for DC-coupled microgrid in Fire Station 11 and Delta/LG Chem BESS for AC-coupled microgrid systems at Fire Station 6 and 7. Tesla did not have a smaller battery pack (110kWh) at the time of selection. Imergy was a flow battery with a very large space requirement. Tesla and Imergy were expensive as well. Octillion Power Systems did not have all the features necessary for the project.

Microgrid Controller Evaluation

The result of the evaluation of microgrid controllers is summarized in Table 4. The cost of the off-the-shelf microgrid controller varied from $350,000 to $500,000 (denoted by XXX in the table).

Table 4: Microgrid Controller Evaluation

Vendor	Features/ Capabilities	Ease of Integration	Technical Support	Cost
Schneider Electric	XXX	XX	XX	XXX
SEL	XXX	XXX	XX	XXX
Siemens	XX	XX	XX	XXX
Spirae	XX	XX	XX	XXX

Source: Gridscape Solutions

Based on intensive evaluation on available microgrid controllers, Gridscape determined that most the controller products available in the market were too expensive for the small to medium MUSH & C&I market microgrids. The average cost of integrated controller was more than the cost of the installed solar and storage system. These controllers were originally designed for utility scale microgrids with multiple energy sources. They were over-engineered and over-designed for the project need and expensive. Gridscape decided to design and develop a controller for the project with the right features and is cost-optimized for this market.

Smart Meter Evaluation

The result of the evaluation of smart meters is summarized in Table 5.

Table 5: Smart Meter Evaluation

Vendor	Features/ Capabilities	Ease of Integration	Technical Support	Cost
Accuenergy	XX	XX	XXX	XX
Socomec	XXX	XXX	XXX	XX

Source: Gridscape Solutions

Gridscape liked the Accuenergy and Socomec products for this project. Gridscape used Accuenergy in Fire Station 11 and Socomec in Fire Station 6 and 7. Gridscape determined that going forward Socomec offers the right products for metering requirements for microgrids of this size and this market.

Automatic Transfer Switch Evaluation

The result of the evaluation of ATS is summarized in Table 6.

Table 6: Automatic Transfer Switch Evaluation

Vendor	Features/ Capabilities	Ease of Integration	Technical Support	Cost
Eaton	XX	X	X	XXX
Emerson	XX	X	XX	XXX
Deep Sea	XX	XX	XX	XX
Generac	X	X	X	XXX

Source: Gridscape Solutions

The ATS systems for this market are primarily designed to operate backup diesel generators. They are not designed and optimized for integrating solar/storage systems. Gridscape had lot of difficulty testing and prototyping integration of ATS system with the controller. This integration still remains an issue till-date. Gridscape will revisit this topic in detail later in this report.

Constraints and Challenges

This section provides an overview of various constraints and challenges that Gridscape experienced during the early phases of the project.

Design Constraints

The Gridscape design team had no precedence that they can refer to in order to design a most optimal and cost effective microgrid for the fire stations. Since there were three sites to deploy, it was decided to use the first site Fire Station 11, closer to the office and lab as a “live living laboratory” site. The microgrid at Fire Station 11 was designed with a solar canopy structure and a 20 feet container (Figure 6), placed below the canopy, that will house all other microgrid components such as the battery energy storage system, DC-coupled inverter, transformer, etc. Enough space was left for an engineer or technician to work inside the container.

Figure 6: Fire Station 11 Microgrid Container Design

Source: Gridscape Solutions

The other two fire stations (Fire Station 6 and 7), as shown in Figure 7 were cost-optimized and installed with all outdoor rated components, with a goal to modularize and commercialize the system.

Figure 7: Fire Station 6 and 7 Modular, Outdoor Microgrid

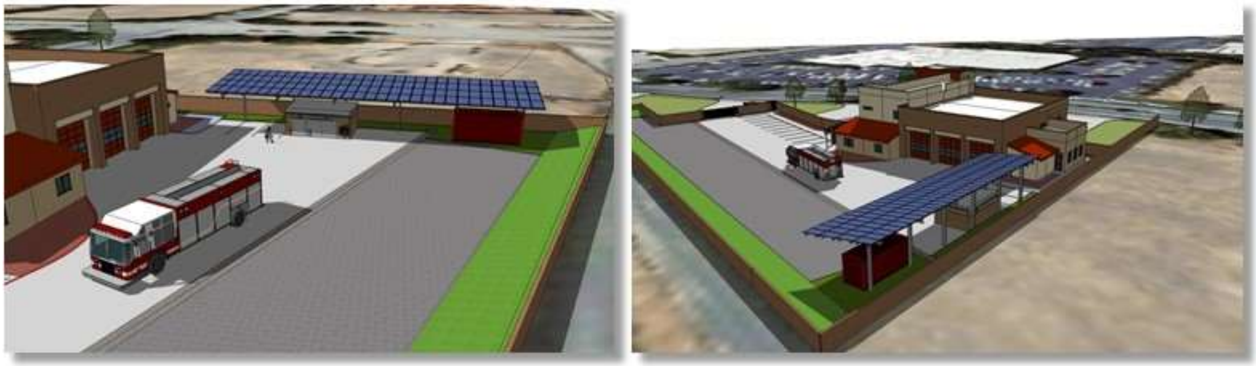
Source: Gridscape Solutions

Fire Station Operations Considerations

Since Fire Station is a critical facility for the city, Gridscape included all requirements and considerations from the Fire Chief and the Fire Operations team in the design of microgrids at each site. The Fire Operations team at the City of Fremont required the research team to include following elements in the design, constructions and operations of the microgrids.

- All load at each fire station need to be treated as critical load. There is no non-critical load at the fire station.
- The fire department and the city required the research team not to design any rooftop solar. All solar PV systems had to be in carport canopy structures.
- The location of the solar carport should not obstruct the fire truck movement in and out of the station as well as should not hinder the fire operations trainings conducted at the fire stations, as depicted in Figure 8.
- The height of the canopy had to be high enough so that it does not come in the way of fire truck arms that carry essential apparatus and personnel, as shown in Figure 8.

Figure 8: Fire Operations Design Considerations



Source: Gridscape Solutions

Size Considerations

The size of the fire station microgrids was determined based on the load analysis at each fire station and available area at the desired location of solar carport canopies.

Solar Sizing

Gridscape design team performed a detailed load analysis from energy use data from past three years at each site. Based on the load analysis, it determined that the optimal size of the solar PV system will be the one that offsets utility use by 75-80 percent. This solar size also matched the area available for placement of solar PV canopy system.

After critical design review with the city, Fire Department and the engineering procurement contractor (EPC) on the project, following solar PV sizes were agreed to for each station:

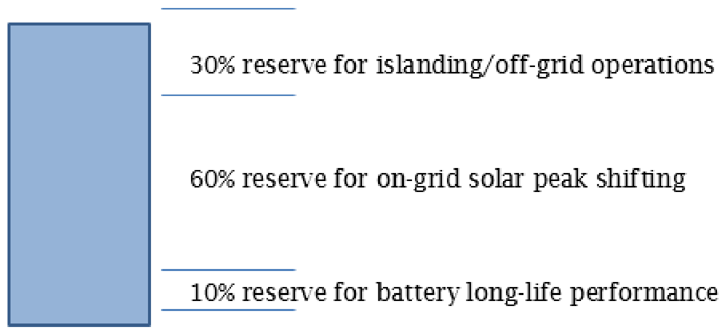
1. Fire Station 11: 38.4 kW DC
2. Fire Station 6: 43.225 kW DC
3. Fire Station 7: 43.225 kW DC

Battery Sizing

The size of the battery was determined by the size of solar PV system and energy (and power) required for at least 3-6 hours of islanding in case of an outage at each site. The fire stations are on a time-of-use (TOU) rate from PG&E. There is no demand charge at the three fire stations and hence the primary requirements for the battery system was islanding (off-grid power source) and peak shifting.

After detailed review the team designed same battery system size of 110 kWh at the three fire stations and determined to reserve 30 percent of the battery for off-grid/islanding purpose, 60 percent for solar peak shifting and remaining 10 percent reserve to optimize battery performance for a long period (Figure 9).

Figure 9: Battery Size Consideration



Source: Gridscape Solutions

Interconnection Considerations

Utility interconnection has been the biggest design and operational challenge in this project. During the design phase, Gridscape discussed the best interconnection options with PG&E (local utility to the fire stations). In 2015, PG&E had options for AC-coupled solar PV and battery energy system but did not have any option for DC-coupled system. After a discussion with the city, the design team decided to apply under Net Energy Metering (NEM) interconnection option for Fire Station 11, and subsequently for Fire Station 6 and 7. The city desired to interconnect under the NEM option so that it can receive credits for the excess solar PV output from these three systems.

After several months of discussions, process delays and lengthy process, PG&E approved following interconnection permits for the systems.

- Fire Station 11: DC-coupled microgrid: Interconnected under Non-Export Energy Agreement, with an addendum to allow for inadvertent export
- Fire Station 6 and 7: Net Energy Meter Multiple Tariff (NEMMT) agreement

A detailed description of challenges faced in the interconnection process is provided later in the report.

Cost Considerations

One of the important considerations in the microgrid design was to keep the overall cost of the whole system as low as possible. The team prepared a detailed value engineering design approach, selecting low cost components in the market, streamlining the design process and developing a modular approach to scale mass use of these types of microgrids in the future.

During the design phase, the design team realized that the cost of microgrid controller relative to other system components was high. All the other components for 40kW solar PV system with 100kWh battery system microgrid would cost approximately $500,000, while the cost of available microgrid controller in the market was approximately $400,000. This made the project not feasible since Gridscape had to develop and install three microgrids. This constraint led to design and development of a cost-optimized microgrid controller for this market segment.

The microgrid at Fire Station 11 (Figure 10) was more expensive since it was the first microgrid and played an important role of a living laboratory for Gridscape, PG&E and the city to ensure that it is designed and operating in a fashion that is non-intrusive and cost-effective. In general, Gridscape spent approximately $1,000,000 in design, development and operations during the demonstration time. The microgrids at Fire Station 6 and 7 were more cost-optimized taking shorter time to design and construct as well. Gridscape spent approximately $500,000-$600,000 each on Fire Station 6 and 7 during the the project.

Figure 10: Aerial View of Fire Station 11 Microgrid

Source: Gridscape Solutions

Design Optimization

To design and develop a cost-optimized microgrid controller for this market, Gridscape took a radical approach to split the controller functions into two computing boards, namely, the local controller and cloud based distributed energy resource management system (DERMS). In doing so, Gridscape aggregated common functions such as energy profile design, load dispatch aggregation, visualization and utility back office interface to the cloud server. The local common functions such as load dispatch, equipment and meter interface and instrumentation were concentrated on the local controller. This optimization reduced the cost of the microgrid controller considerably, in the order of

10-20 percent of commonly available microgrid controllers in the market. The dashboard portal of the cloud based DERMS system is shown in Figure 11.

Figure 11: Gridscape EnergyScope Dashboard

Source: Gridscape Solutions

Prototype Development and Testing

The prototype development and testing was carried out at the Gridscape office lab in Fremont, California. Gridscape design team developed a small portable solar PV system of approximately 8KW (Figure 12). Gridscape installed a battery energy system of about 30kWh and setup the prototype lab with transformers, switchgear, controller and ATS system. The engineering team iteratively tested the design from July 2015 to May 2016.

Figure 12: Prototype Testing and Demonstration at Gridscape Lab

Source: Gridscape Solutions

Final Design

Fire Station 11 Final Design

Gridscape engaged Microgrid Energy as the EPC for design and construction at Fire Station 11. The container buildout was completed by August 2016. Gridscape worked with Microgrid Energy for 4-6 months in detailing every aspect of the microgrid at Fire Station 11. Finally, the final permit ready design for Fire Station 11 was completed on 9/1/2016 and submitted to the City on November 1, 2016 after the agreement with the city was completed. The city approved the permit for construction at Fire Station 11 on January 2017.

Fire Station 6 and 7 Final Design

The sites at Fire Station 6 and 7 were not suited for cantilever style Solar PV carports because of soil liquefaction. Because of these design constraints, Gridscape selected Berkeley-based Sun Light and Power (SLP) as the EPC for Fire Station 6 and 7. They provided a spread-footing solar PV carport designed by Schletter for the project that will withstand the liquefaction at these two sites.

Gridscape engaged with SLP to finalize the modular microgrid designs at Fire Station 6 and 7. The final permit ready design for Fire Station 6 and 7 was completed on July 31, 2017 and submitted to the city the next month for permit. The city approved the permit for construction for Fire Station 6 and 7 on November 30, 2017.

Major Equipment Procurement

Solar Photovoltaic Panels and Carports

Gridscape leveraged experience of the EPC partners at all sites to provide best-in-class solar PV panels and carports for the microgrids. The basic specification and performance expectation were provided to them and then they recommended the PV panel and carport vendors. For Fire Station 11, Gridscape selected Boviet Solar PV panels and Baja Carports as a carport vendor (Figure 13).

Figure 13: Baja Carport Design

Photo Credit: Baja Carports

For Fire Station 6 and 7, Canadian Solar PV panels and Schletter carports were selected. The Schletter carports at Fire Station 6 and 7 (Figure 14) were designed with spread-footing base at both sites.

Figure 14: Schletter Carport Design

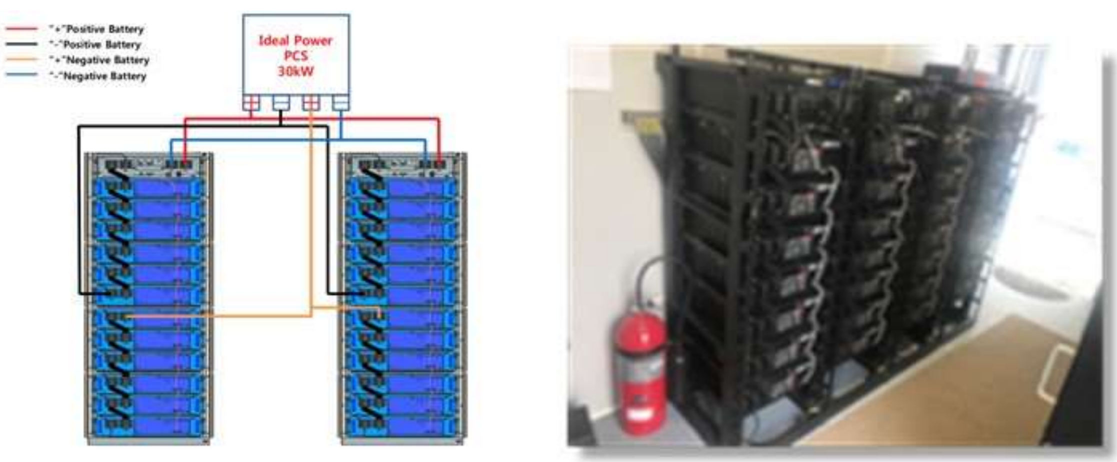
Photo Credit: Solar Electric Supply

The Boviet and Canadian Solar PV modules were similar in type, efficiency (18 percent) and cost.

Battery Energy Storage System

Gridscape tested at least two different battery ESS vendors for the project to learn which works best for this application. Gridscape selected Samsung SDI ESS system for Fire Station 11. Figure 15 depicts Samsung ESS system design and actual battery installed in the Fire Station 11 container. Samsung SDI ESS is an indoor rated battery system and well suited for the container application at Fire Station 11.

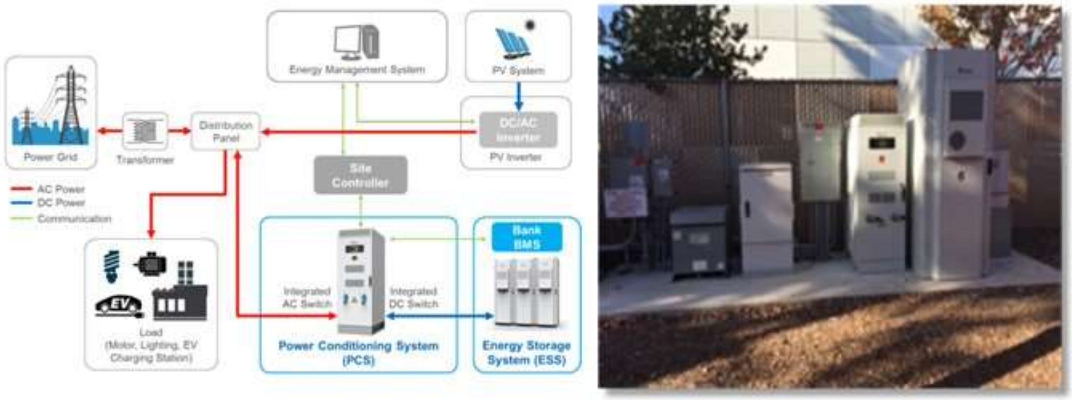
Figure 15: Samsung Energy Storage System Design



Source: Gridscape Solutions

Delta/LGChem system was selected for Fire Station 6 and 7 (Figure 19) . Delta/LGChem is a fully outdoor rated battery ESS system that suited the modular microgrid design at Fire Station 6 and 7.

Figure 16: Delta/LGChem Energy Storage System System Design



Source: Gridscape Solutions

The ESS specifications of the battery vendors were similar in terms of power, energy and efficiency. The main difference was indoor-rating versus modular outdoor-rating. Since the design team's prime requirement in Fire Station 6 and 7 was to seek cost reduction and modular design, it opted for Delta/LGChem ESS system in Fire Station 6 and 7 instead of indoor-rated Samsung system.

Meters

The meters used in this project are embedded in the microgrid controller designed by Gridscape. Gridscape used Accuenergy AC and DC meters in Fire Station 11 microgrid controller, while Gridscape used Socomec meters in Fire Station 6 and 7 microgrid controllers. Both meters are certified with utility-grade accuracy (0.5 percent) (Figure 20).

DC meters are required to measure the Solar and Battery circuits as these are DC sources and loads, while AC meters are required to measure inverter AC output port as well as utility lines.

Figure 17:Accuenergy Acuvim II Meter (L) and Socomec B30 and D50 Meter (R)

Photo Credit: Accuenergy and Socomec

EnergyScope™ Microgrid Controller

Gridscape designed and developed a microgrid controller (EnergyScope™) for this project. The primary function of the microgrid controller is to meter, monitor and control the various power sources in the microgrid such as solar PV system and battery ESS, and execute load dispatch in both on-grid and off-grid modes based on the pre-set energy profile provided by the EnergyScope™ DERMS. The first generation of the controller was developed by a local electronic component manufacturer and used at the Fire Station 11 (Figure 18).

Figure 18: First Generation EnergyScope™ Microgrid Controller, Fire Station 11

Source: Gridscape Solutions

Subsequently, Gridscape developed a second generation outdoor-rated controller with various cost optimizations for Fire Station 6 and Fire Station 7 (Figure 19).

Figure 19: Second Generation EnergyScope™ Controller, Fire Station 6 & 7

Source: Gridscape Solutions

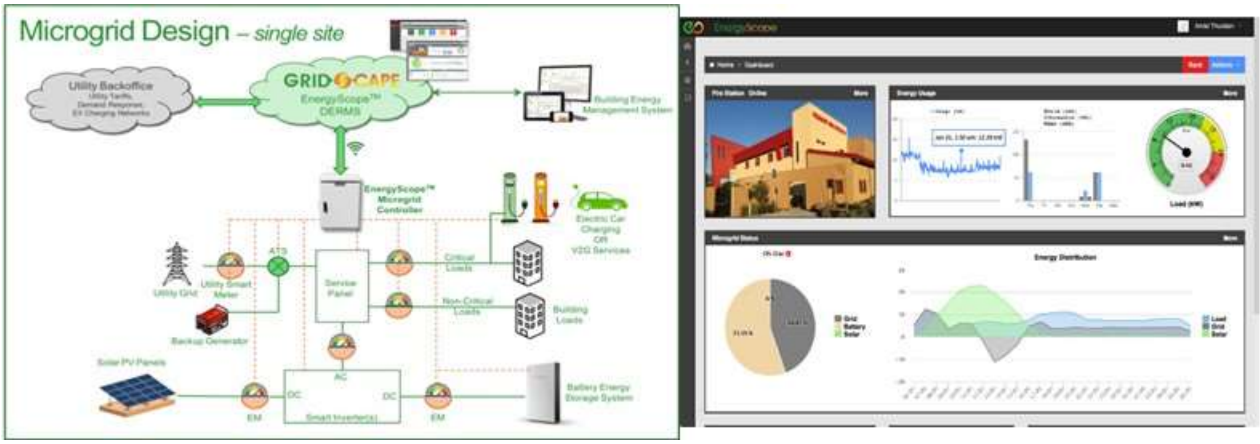
Both versions of the controller underwent a rigorous industrial and performance test at the contract manufacturer sites as well as Gridscape lab, prior to installation. During the demonstration phase after the controllers were commissioned, Gridscape team executed detailed functional and performance tests on the controllers. The Fire Station 11 controller was tested for 12 months, while the Fire Station 6 and 7 controllers were tested for 3-6 months.

EnergyScope™ Distributed Energy Resource Management System

Gridscape also designed and developed a cloud-based distributed energy management system that will communicate with EnergyScope™ microgrid controllers at each Fire Stations remotely over a secure cellular data connection. The main function of the DERMS is to perform aggregated common functions such as energy profile design, load dispatch aggregation, economic energy optimization, visualization and utility back office interface to the cloud server. Figure 20 depicts a single site design of EnergyScope™ DERMS and Fire Station 11 portal dashboard.

The EnergyScope™ DERMS was also installed and tested with the microgrid controller at each site. Gridscape design team is continuously testing and upgrading the DERMS from the point of deployment date.

Figure 20: EnergyScope^{TM} Site Design and Dashboard



Source: Gridscape Solutions

Microgrid Construction

Engineering Procurement Contractor Selection

As indicated earlier, Gridscape selected Microgrid Energy as the EPC for Fire Station 11 and Sun Light and Power (SLP) as the EPC for Fire Station 6 and 7. Both EPCs provided Solar PV design, panel procurement, permit ready drawings and construction. Gridscape undertook the design and purchase of inverters, battery ESS and microgrid controller system.

Microgrid Energy, subcontractor, completed Fire Station 11 microgrid design and construction successfully. Their quote, however for Fire Station 6 and 7 was considerably higher and more than the allocated budget, therefore, Gridscape selected SLP for Fire Station 6 and 7 design.

Schedule and Cost Considerations

The construction phase for Fire Station 11 microgrid started in November 2016 and was completed by April 2017. The construction phase for Fire Station 6 and 7 microgrids started in December 2017 and was completed by April 2018.

On average, it took both EPCs similar amount of time to complete the design and construction for the microgrids.

There were some special considerations that the design team adhered to from fire station operations during the construction phase. None of the construction activities were allowed in the main area of fire operations. Also, the fire department insisted on minimum amount of trenching and quick turnaround. Gridscape project manager coordinated all activities with fire personnel as well as city maintenance personnel during construction phase.

The design team coordinated one planned outage with the fire department, city maintenance department and IT department to interconnect the system with the main grid at each fire station that lasted no more than 30 minutes. .

Planning and Permit Approvals

The permit ready drawings for Fire Station 11 were prepared by Microgrid Energy and submitted to the City for permit approval. The permit ready drawings for Fire Station 6 and 7 were prepared by SLP and submitted to the City for permit approval. City of Fremont Planning office took approximately eight weeks to approve the Fire Station 11 design. The design team quickly responded to the single request for clarification.

Because of the liquefaction issue at Fire Station 6 and 7, Gridscape engaged the city planning department early before submit of drawings to ensure that they are aligned with the design approach for spread-footing structure. In general, Gridscape received cooperation from the city planning department in permit approvals for all microgrids. It took approximately five weeks to approve the Fire Station 6 and 7 designs. Since the permit review team at the city was familiar with the Fire Station 11 project and were involved early in the design phase, it took considerably less time to issue permits for Fire Station 6 and 7.

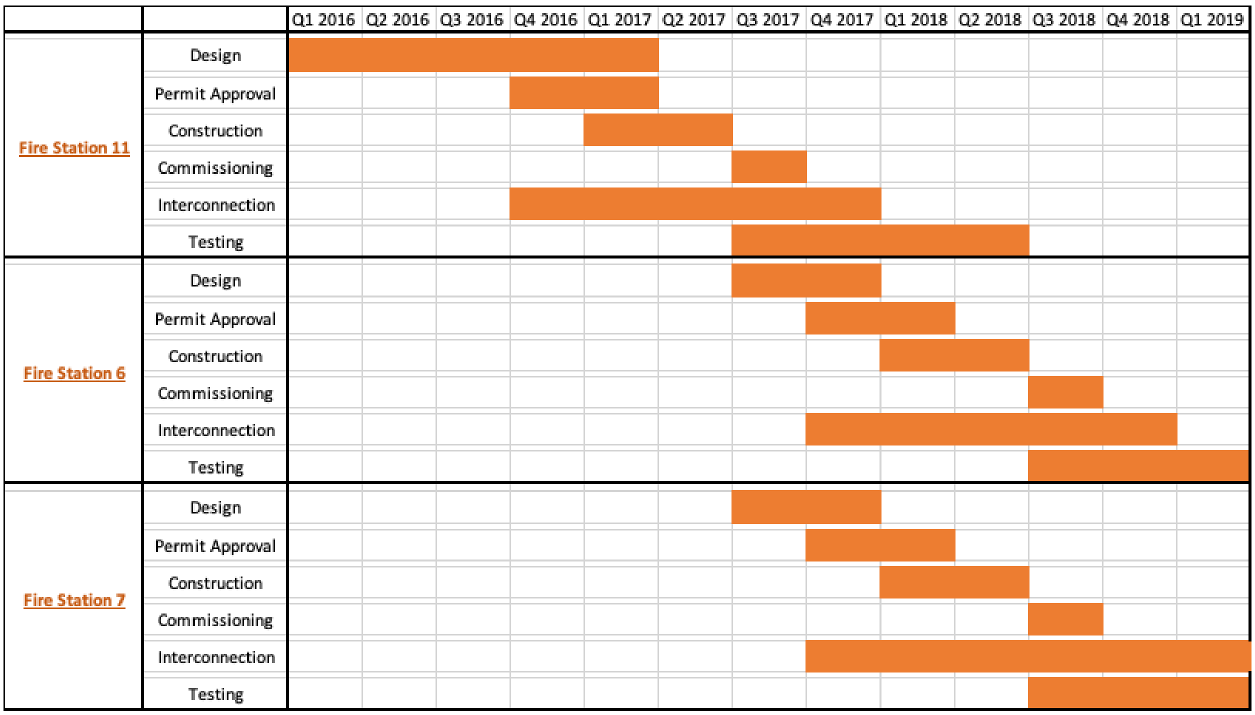
Schedule Delay and Extension

Gridscape had to ask for an extension of 12 months on this project to the CEC due to following three reasons that took more time than expected.

1. City Council Approval and Agreement: It took the City of Fremont almost 10-11 months to get a council approval and signed agreement for this project. The City of Fremont had signed a 20-year PPA agreement with SunEdison for few other projects in the city and Gridscape used that as a template for this microgrid project. This first step was initiated in December 2015. After series of back-to-back discussions with the city, the project was finally approved by the council on September 13, 2016, and an Energy Savings/PPA contract with the city was signed on November 9, 2016.
2. Liquefaction Issue: Gridscape discovered a liquefaction issue at Fire Station 6 and 7 that triggered a swap out and selection of a new EPC (SLP). This process took almost 5-6 months before Gridscape could engage SLP for Fire Station 6 and 7.
3. PG&E Interconnection: Fire Station 11 microgrid is a DC-coupled microgrid and intended to be a Net Energy Meter tariff (NEMMT) interconnection agreement with PG&E. However, the DC-coupled design triggered an engineering design review process at PG&E that took almost 8-9 months to complete. This issue is discussed in greater details later in this report.

Figure 21 shows a detailed actual schedule that this project followed despite several delays as explained above. Fire Station 11 was completed within 30 months (10 quarters), starting from June 2016 until June 2018. Fire Station 6 and 7 were executed in parallel and they took 7 quarters (21 months) to complete.

Figure 21: Detailed Schedule



Source: Gridscape Solutions

Construction Challenges

The biggest issue Gridscape faced during design and construction was the liquefaction issue at Fire Station 6 and 7. Because this was discovered after Fire Station 11 was completed, Gridscape swapped out Microgrid Energy with SLP as the EPC on the project. This process led to an agreement change at the end, taking additional time.

As Gridscape progressed with commercialization efforts on these microgrid systems, it is evident from this experience to pay special attention to soil reports at the sites. Depending upon results of the soil report, the design team can select the appropriate carport structure (cantilever deep pier or spread footing structure) for the solar PV system at the site.

Interconnection Challenges

Fire Station 11 Interconnection Challenges

Fire Station 11 microgrid is a DC-coupled microgrid. The solar PV output and the storage system are connected on the same DC plane using a hybrid inverter from Ideal Power.

The original intention for the City of Fremont was to apply and interconnect with NEMMT agreement, so the city could receive credits for the excess solar output to the grid. However, PG&E did not approve the NEM-MT interconnection agreement for this project as per California Public Utilities Commission (CPUC) ruling 14-05-033.

The CPUC ruling 14-05-033 states that if the customer intends to interconnect with NEM-MT provision, then the customer-generator must 1) install a non-export relay on the non-NEM generator(s), specifically a battery Energy Storage System (ESS); 2) install Net Generation Output Metering (NGOM) for the NEM-eligible generation (Solar PV output), meter the load, and meter total energy flows at the point of common coupling; or 3) install interval NGOM directly to the NEM-eligible generator(s).

However, in a DC-coupled system, PG&E did not have any approved DC NGOM meter at the time of this request plus it was expensive to install a hardware non-export relay on the battery ESS port.

Gridscape design team explained to PG&E that it can control the battery ESS output circuit and port with the controller software since each battery ESS system comes in-built with a contactor switch that can be controlled externally via software.

After series of discussions with PG&E's design team, it was agreed that PG&E will interconnect this system after an onsite test by PG&E engineers. This test was scheduled at Fire Station 11 during the week of July 14, 2017.

Once the PG&E technical team approved the design, the team was faced with a regulatory issue. PG&E agreed it will interconnect Fire Station 11 by a non-export energy agreement with an addendum to allow for inadvertent export, however will not compensate the city for the export of the solar power. PG&E also indicated that it will file an advise letter with the California Public Utilities Commission (CPUC) to allow NEM agreement on DC-coupled microgrids and once approved, then the Fire Station can reapply for a NEM agreement at a later date.

The PG&E Advice letter to CPUC is available at: https://goo.gl/8Gbg6V.

As of writing of this report, Gridscape has not received any indication from PG&E that it can reapply for NEM interconnection with PG&E. The system is still interconnected with non-export agreement. The design team views this as an issue that impedes mass proliferation of these types of microgrids in the state.

Fire Station 6/Fire Station 7 Interconnection Challenges

Fire Station 6 and 7 are AC-coupled microgrids. The solar PV system and the battery ESS system have separate inverters (power conversion system) and are combined on an AC plane before interconnecting with PG&E.

As per CPUC ruling 14-05-033, Gridscape could interconnect these two microgrids by using NGOMs on the solar PV AC output. However, during the application process, PG&E indicated that it is running a pilot that allows software-controlled microgrids such as these to interconnect with a NEMMT tariff.

Gridscape applied for interconnect application for Fire Station 6 and 7 with PG&E on September 1, 2017. PG&E indicated this will take anywhere from 30-45 days to receive interconnection permits for both the fire stations after permit application. Gridscape received interconnection agreement for Fire Station 6 on August 1, 2018.

However, for Fire Station 7, there was mistake in the meter ID on the application. PG&E redacted the application and a new application was submitted with Gridscape receiving the interconnection agreement for Fire Station 7 on January 21, 2019.

The PG&E interconnection process is very lengthy, cumbersome and complex. Gridscape asks the CEC, CPUC and PG&E to simplify the process to make it easier for developers to receive interconnection permits quickly and diligently.

Final Installation and Use

Fire Station 11 Microgrid Final Installation

The fire station 11 microgrid was put into service on September 15, 2017 and has been operating as a demonstration since then. Figure 22 on the following page shows the progress made over several months from January 2017 to July 2017 to complete the microgrid.

Figure 22: Fire Station 11 Microgrid Construction and Final Deployment

Source: Gridscape Solutions

Fire Station 6 Microgrid Final Installation

The Fire Station 6 microgrid was put in service on September 20, 2018 and has been operating in demonstration phase since. Figure 23 shows progress made from January 2018 to June 2018 to complete the microgrid.

Figure 23: Fire Station 6 Construction Progress and Final Deployment

Source: Gridscape Solutions

The carport structure in Fire Station 6 (Figure 23) is spread footing design allowing the carport to carry the load without deep piers. The carport at Fire Station 6 is also divided into two; one is inside the gated wall and one is over visitor parking outside the gate. The design team developed this structure due to space limitations at Fire Station 6 and based on considerations from the Fire Department.

Fire Station 7 Microgrid Final Installation

The Fire Station 7 microgrid began service on January 21, 2019. Figure 24 shows progress made from January 2018 to January 2019 to complete the microgrid construction.

Figure 24: Fire Station 7 Construction Progress and Final Deployment

Source: Gridscape Solutions

The Fire Station 7 carport structure is a continuous structure mounted on a spread footing base. The diesel generator set at the Fire Station 7 is housed below the carport and the design team left an open vent in the carport for the diesel genset exhaust.

Microgrid Operation

Fire Station 11 Microgrid Operation

The Fire Station 11 microgrid began service on September 15, 2017 and has now been operating since then, completing its demonstration period on September 15, 2018. The microgrid is officially rolled into the PPA/Energy savings agreement contract with the City of Fremont.

On-Grid Operation

During the demonstration period, the microgrid system continuously ran 24/7 without a single power outage or interruption in service to the fire station. Gridscape engineers remotely monitored the microgrid via EnergyScope DERMS system 24/7 throughout this time.

The microgrid battery ESS system was controlled by the Gridscape EnergyScope™ microgrid controller so it will charge the battery ESS daily when solar power is generated. The solar power the fire station first and the excess solar power will be used to charge the battery ESS. When the battery ESS is full, the excess solar power will be exported to the grid. During evening hours and when the solar production stops, the battery ESS is discharged to power the fire station until late evening or early night hours when the utility rate changes to off-peak low rates. The fire station is powered with low cost off-peak energy at night hours.

Gridscape team also collected data of solar PV output, battery ESS charge and discharge cycles and load consumed by the fire station with detailed discussion in the next chapter.

Off-Grid/Islanding Operation

During the demonstration period, the Fire Station 11 microgrid never had an unplanned power outage, however, to test the system in islanding mode, Gridscape team executed three planned outages at the fire station to ensure that the microgrid operates as desired in the islanding mode.

During normal operations, if the microgrid controller detects a grid outage, specifically a loss of voltage and frequency on the utility service line, it will disconnect the site from the utility and operate in the islanded mode.

Fire Station 6 Microgrid Operation

The Fire Station 6 Microgrid was put into service on September 20, 2018 and has been operating 24/7 without any issues. Similar to Fire Station 11, the Gridscape team is remotely monitoring this site 24/7. After March 31, 2019, this microgrid went into 10-year PPA/Energy Savings agreement with the City of Fremont.

The Gridscape design team executed two planned off-grid mode testing on this microgrid in January and February 2019. The results of these tests are provided in the next chapter.

Fire Station 7 Microgrid Operation

The Fire Station 6 Microgrid began service on January 21, 2019 and Gridscape continued demonstrating until March 31, 2019. After that, the facility went into a 10-year PPA/Energy Savings agreement with the city, similar to Fire Station 6.

The Gridscape design team executed one planned off-grid islanding test on Fire Station 7 on May 29, 2019. The islanding test was similar to the tests performed on Fire Station 6. The research team successfully islanded the fire station for a period of more than 6 hours during this test. The test started at 11am PDT and lasted until 5pm PDT. The battery SOC was still at 52% when the test ended. The team had to end the test as Fire Operations had only given a time window of six hours for the test.

CHAPTER 3:
Project Results

This chapter provides detailed results of this CEC-funded project. Gridscape have collected and analyzed all data pertaining to Fire Station 11 and Fire Station 6 microgrids.

Microgrid Performance Results

Fire Station 11 Data Analysis (On-Grid Performance)

The Table 7 provides an overview of the data collected and analyzed for Fire Station 11 in on-grid mode for a year, starting from September 15, 2017.

Table 7: Fire Station 11 Data Collection and Analysis (One Year)

Fire Station 11 On-Grid Mode	Energy in kWh	% of Total Energy Supply (106,020 kWh)	Energy Cost ($$) to the Fire Station (Fremont City)
DC Solar PV Output	61,493	58%	$0 (during demo period)
Total Fire Station 11 Power Consumption	86,484	82%	
AC Solar Output of Microgrid	56,084	53%	$0
Supplied by Grid	49,936	47%	$5,472[12]
Net Solar Energy Exported	16,798	15%	$0[13]
System Loss	2738	3%	

Source: Gridscape Solutions

As shown, 53 percent of the total power consumption at Fire Station 11 was supplied by the microgrid and remaining 47 percent was consumed from the grid. However, net load supplied to the facility is 82 percent and 2 percent of energy is lost in system loss. The system loss is calculated as follows:

12 Based on an average of 18c/kWh of PG&E blended rate.

13 The facility has Non-export agreement with PG&E. Once it shifts to NEM agreement, there will be some solar credits.

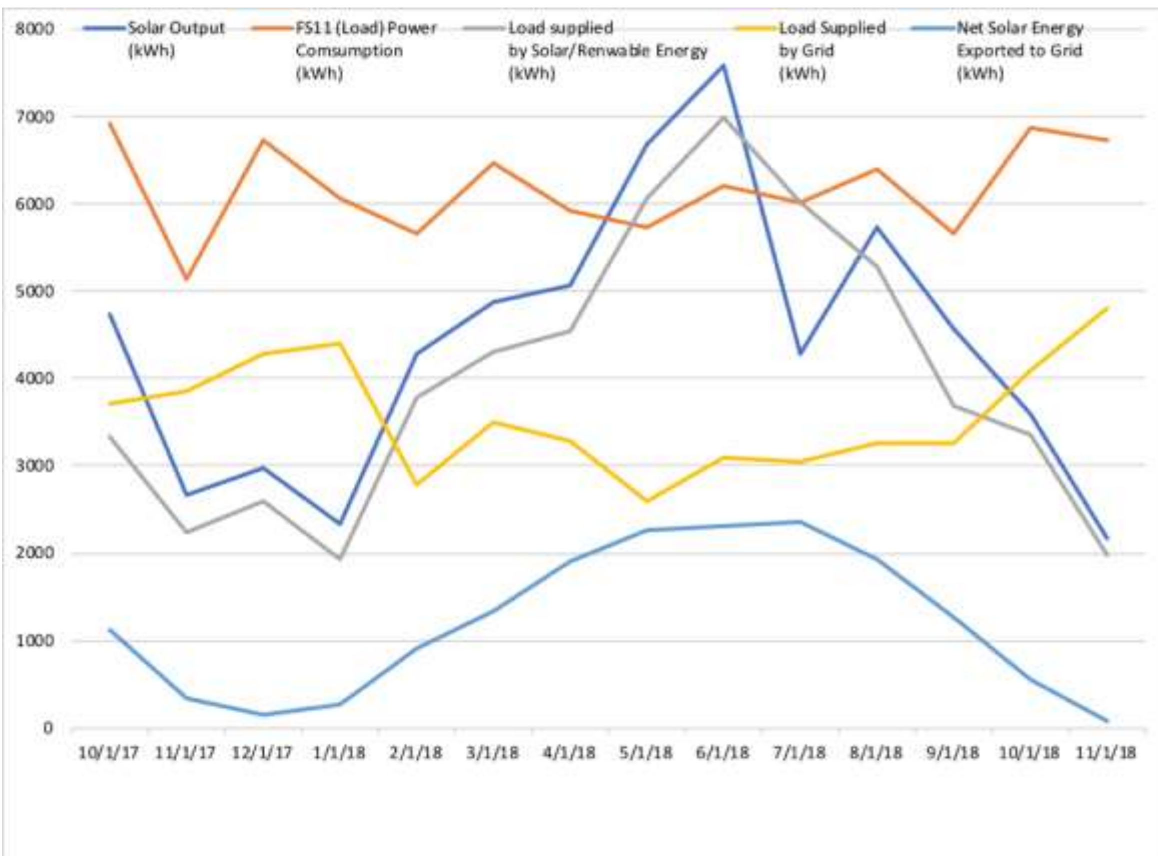
AC Solar Output of Microgrid + Energy Supplied by Grid = Fire Station Consumption + Net Solar Energy export + System Loss

The system loss can be attributed to step down transformer (480V AC Microgrid output to 240V AC main service panel connection). The system loss can be eliminated in future by using a 240V AC output inverter instead of 480V AC output inverter.

The City of Fremont spent $5,472 during the year to power this facility from the grid. Rest of the power was supplied by the microgrid.

Figure 25 depicts the data collected during the demonstration period on a monthly basis. The solar output is in AC and it is low during winter months but high during summer months as shown by dark blue line. The solar export (light blue line) also follows the solar generation and is low during winter months and high during summer months.

Figure 25: Fire Station 11 Monthly Data Collection and Analysis Graph



Source: Gridscape Solutions

The graph shows that the site load is constant throughout the year. Since the solar production is high during summer, less energy is consumed from the grid during summer and coincidently more solar power is also exported during summer. A larger battery system than 110kWh used in the project can potentially reduce the solar export and supply more renewable energy to the site load.

Dashboards

The seasonal dashboards shown in Figure 26 depict the performance of the Fire Station 11 microgrid on few specific dates of the year. The upper right section of the dashboard shows real time load at the site in the power meter - historical load for last 12 hours on the site. The middle section of the dashboard shows the power source mix over last few minutes and a rolling window of energy distribution at the site. For example, green envelope shows the solar production, blue envelope shows battery performance and gray envelope shows energy imported from the grid. The lower section shows solar and battery performance.

Figure 26: Seasonal Fire Station 11 EnergyScope™ Dashboards

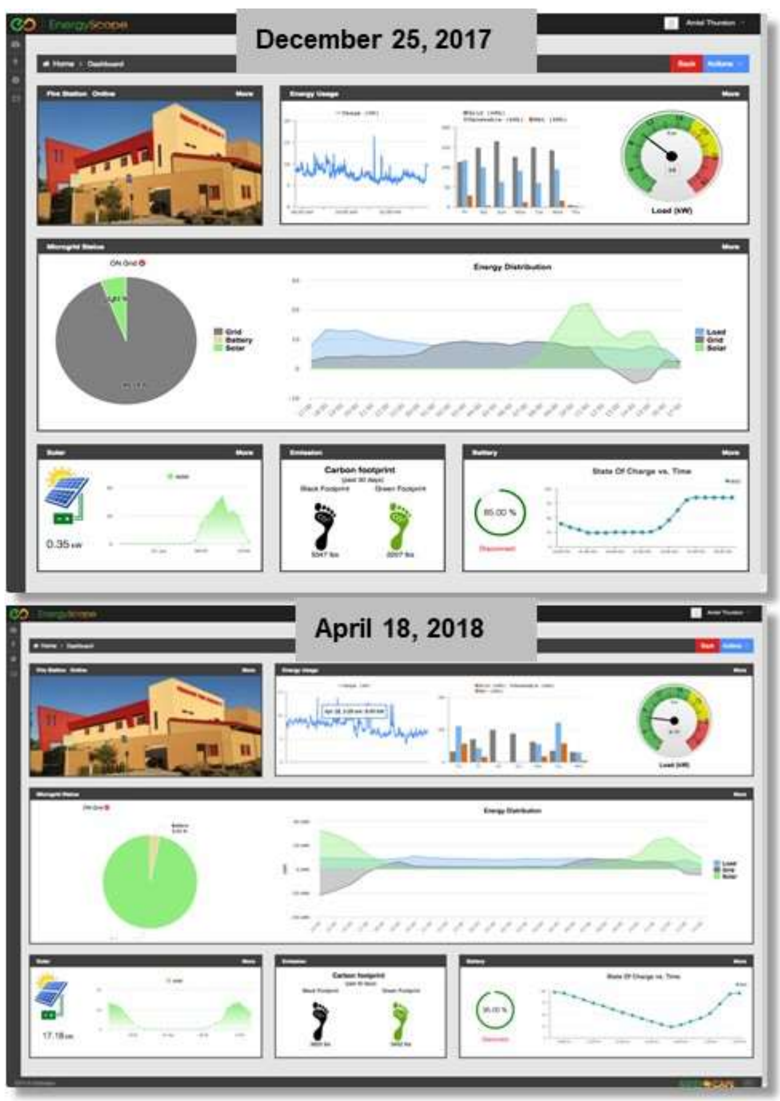
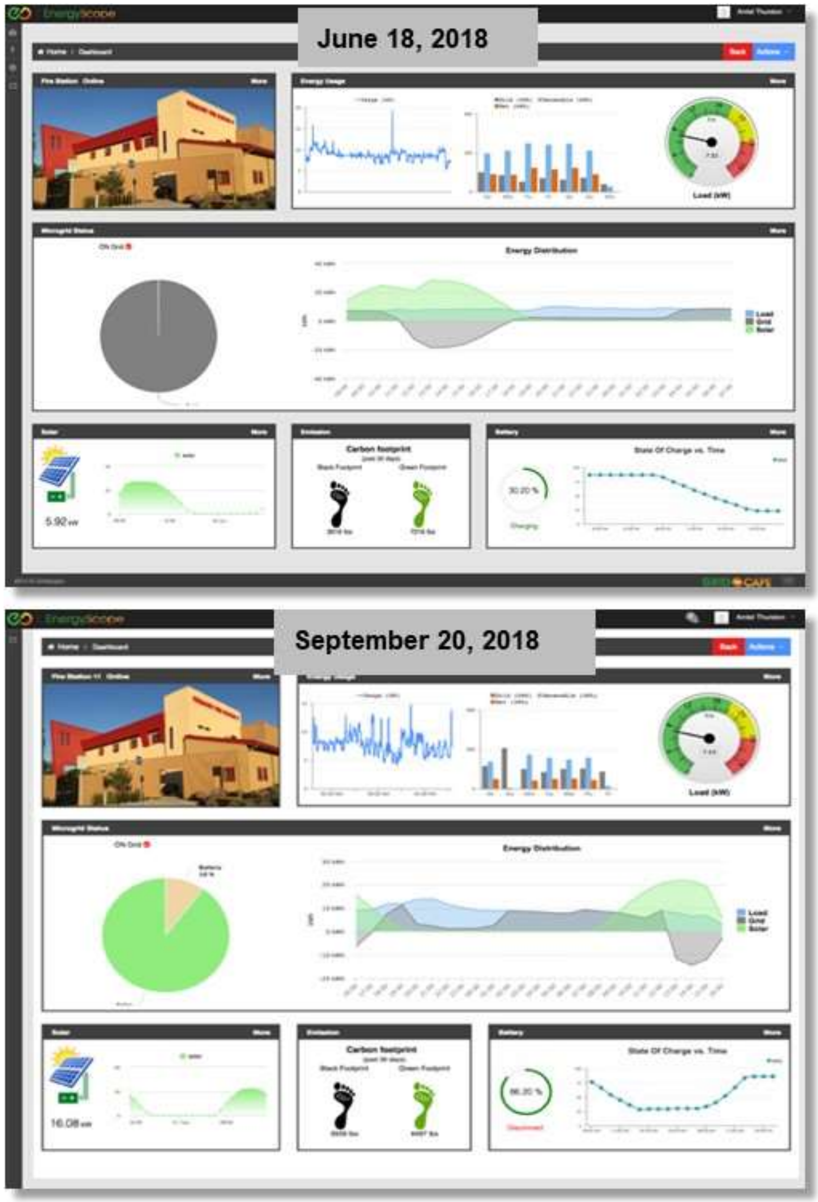


Figure 26 (cont'd): Seasonal Fire Station 11 EnergyScope^{TM} Dashboards



Source: Gridscape Solutions

The seasonal dashboards also attest to the fact that there are longer solar days during summer months and higher solar export than winter months. These dashboard images are snapshots from Gridscape EnergyScope^{TM} DERMS system.

Fire Station 11 Data Analysis (Off-Grid/Islanding Mode Performance)

Gridscape design team performed two islanding tests at the Fire Station 11 during the demonstration period with the results summarized in the following sections.

First Islanding Test

The first off-grid islanding test at Fire Station 11 was performed June 2, 2018 and lasted for three hours and 15 minutes. Gridscape coordinated the off-grid test with City of Fremont and Fire Department as Fire Station 11 is a critical facility.

Gridscape test team islanded the facility completed off-grid from PG&E. The team switched off the main breaker of the facility at a specified time. Once islanded, the microgrid controller switched the Ideal Power inverter into a grid-forming mode and ran the entire facility on the solar and storage microgrid. There was no disruption in any fire station operations during the island test and clean, renewable power was provided to the facility during the islanding test period.

A few minor software issues were uncovered in the microgrid controller and the Ideal Power inverter. The design team resolved all the software issues in the controller and are working with Ideal Power inverter for long term resolution of the issues in the inverter. One of the issues reported during this test was that the Ideal Power inverter was not able to handle in-rush currents generated by few reactive loads (HVAC and motor for fire station doors) and it would exit the island mode. Gridscape design team collaborated with the Ideal Power team to resolve this issue by identifying and setting the appropriate configuration parameter in the inverter so that it will not exit the island mode.

Second Islanding Test

The second off-grid islanding test at Fire Station 11 was performed June 27, 2018, lasting two hours and 30 minutes. Again, Gridscape coordinated the off-grid test with the City of Fremont and Fire Department.

Similar to first test, the Gridscape test team islanded the facility off-grid from PG&E's main feeder by turning off the main breaker. During this test, Gridscape observed that the Ideal Power Inverter went down three times due to a problem with inrush currents emanating from AC motor loads. Gridscape collected the results and shared with Ideal Power. The inverter 30B3 used in Fire Station 11 microgrid has less tolerance for inrush currents. Ideal Power suggested upgrade to their newer 30C3 inverter.

Fire Station 6 Data Analysis (On-Grid Performance)

Table 8 provides an overview of the data collected and analyzed for Fire Station 6 in on-grid mode for five months, starting October 1, 2018 to February 28, 2019.

Table 8: Fire Station 6 Data Collection and Analysis (Five Months)

Fire Station 6 On-Grid Mode	Energy in kWh	% of Total Energy Supply (23,250 kWh)	Energy Cost ($$) to the Fire Station (Fremont City)
AC Output of the Microgrid	9,615	23%	$0 (demo period)
Total Fire Station 6 Power Consumption	40,457	95%	
Supplied by Grid	31,911	77%	$5,744[14]
Net Solar Energy Exported	1,322	3%	$119[15]
System Loss	831	2%	

Source: Gridscape Solutions

The table shows 23 percent of the total power consumption at Fire Station 6 was supplied by the microgrid and remaining 77 percent consumed from the grid. Three percent of energy was exported to the grid and the system loss was 2 percent. Since this data is collected during fall and winter months when the sun is low, the solar production is considerably less. The system loss is attributed to the loss in transformer during conversion of 480V AC to 240V AC.

The City of Fremont spent $5,744 during this period (October, 2018 – February, 2019) to power this facility from the grid. Rest of the power was supplied by the microgrid. It is expected that as solar production increases during summer months, the City of Fremont would save more in upcoming months. It is expected that it will cost the city not more than $9,000 on an annual basis in utility energy costs after full year of production.

Dashboards

The following seasonal dashboards depict the performance of the Fire Station 6 microgrid on specific dates of the month (Figure 27).

14 Based on an average of 18c/kWh of PG&E blended rate.

15 Based on NEM Rate of 9c/kWh of PG&E blended rate.

Figure 27: Fire Station 6 EnergyScope^{TM} Dashboards

Source: Gridscape Solutions

Fire Station 6 Data Analysis (Off-Grid/Islanding Mode Performance)

The Gridscape design team performed two islanding tests at the Fire Station 6 in January and February 2019.

First Islanding Test

The first off-grid islanding test at Fire Station 6 was carried out on January 9, 2019 lasting four hours. Gridscape test team islanded the facility completed off-grid from PG&E. The team switched off the main breaker of the facility at a specified time. Once islanded, the microgrid controller switched the Delta PCS inverter into a grid-forming mode and ran the facility on the battery. Since this is an AC coupled system, solar energy was not used during the test only the battery power was used to serve all loads. Overall the test was successful with no reported issues or problems.

Second Islanding Test

The second off-grid islanding test at Fire Station 6 was carried out on February 20, 2019 and lasted 13 hours. Gridscape test team islanded the facility completed off-grid from PG&E at around 9:30 am. Solar and battery power were used to island the facility since it was a relatively cloudy day and there was not maximum solar production. Nevertheless, the Fire Station stayed in islanded mode until 10 pm.

This test was also successful with no reported problems. Figure 28 shows EnergyScope dashboard indicating 13-hour island test at Fire Station 6.

Figure 28: 13-Hour Islanding Test at Fire Station 6

Source: Gridscape Solutions

Challenges and Lessons Learned

This section details the challenges and lessons learnt during this project. Gridscape faced five main challenges:

1. Capital investment for mass use of microgrids.

2. Microgrid controller technology and cost.
3. City contract process including council approval.
4. PG&E interconnection process.
5. Liquefaction issue at two fire station sites.

Capital Infrastructure Cost

This is perhaps the most important financial challenge in proliferating and using this technology at a mass economic scale.

The financial analysis on this project shows that with current prices of solar PV systems, battery ESS system and microgrid controller solution, it will take 12 years for private financiers to receive a return on investment (ROI) on their capital investment on such projects.

For example, the total capital cost in using Fire Station 6 was approximately $425,000. Given solar incentive tax credit of 30 percent, Self-Generation Incentive Program (SGIP) on energy storage system and Federal Accelerated Depreciation program on qualified solar projects, the investor can receive approximately $260,000 back as incentives over the first five years of operation. The remaining $165,000 can be recovered from the energy cost savings over 12 years. The microgrid system at Fire Station 6 will save approximately $14,000 annually to the City of Fremont.

However, the economic results of this project do show a promise to realize reasonable ROI of 5-7 years in future on private funding for capital investment requirement. Gridscape believes that the solar PV module prices and the battery ESS system cost will decline considerably over next 5-10 years and the private financiers should be able to shorten the ROI on such projects.

Microgrid Controller Technology and Cost

For small to medium municipal and commercial and industrial customers, initial research showed there was no cost-effective microgrid technology solutions for similar applications. After rigorous review of existing products and technology, Gridscape realized it will be best to develop a microgrid controller technology and product that fits this market and its needs.

The funding provided was immensely helpful for this product and solution development. Gridscape developed EnergyScope™ microgrid controller and DERMS software from this funding and its own match funding sources. The technology is now at Technology readiness Level 8 level after use at the Fire Station 6 and 7. Gridscape intends to receive Underwriter’s Laboratory certification on the controller in 2019 for mass commercial use.

Lack of Interface Standardization

There are no leading standards for integrating communication protocols between microgrid controllers with various smart inverters and battery management systems. The current technology depends upon Modbus and CANbus style interfaces. However, these are customized as per individual vendors. There must be a uniform standard to access all common elements across these products.

IEEE 2030 has started the process of standardizing microgrid controls; however, it is not complete and ratified. The IEEE 2030.7 discusses overall standardized microgrid architecture while IEEE 2030.8 discusses overall standardized microgrid test environment and process. There is currently no effort to standardize the communication interface between the microgrid controls and all DERs including solar inverters, battery energy management system and smart inverters.

City Contract Approval Process

Since this project was first of its kind in the state without any precedence, it took some time for Gridscape and City of Fremont to receive city council approval and contract agreement.

Gridscape anticipates, however, a much smoother process going forward. Other cities such as Stockton, Fontana, Atherton, and Menlo Park have been using this process created and adopted by the City of Fremont for using critical facility microgrids in their jurisdictions.

Pacific Gas and Electric Company Interconnection Process

This is perhaps the most time consuming and overly complicated process in using solar emergency microgrids or DERs in the PG&E area. As discussed earlier, it took more than one year to be interconnected with the PG&E grid at all fire stations. The CEC can perhaps help CPUC and IOUs streamline and accelerate the interconnection process for more microgrid installations.

Liquefaction Issue at Two Fire Stations

Gridscape was surprised when the liquefaction issue was discovered at Fire Station 6 and 7 during the design and installation phases. The lesson learned from this experience is to ensure that proper soil tests are performed by certified geological firms at each site to avoid unnecessary project delays.

Value Engineering and Production

In this project, Gridscape has advanced value engineering of microgrids by shifting to low-cost standardized components to solve key cost challenges. Through an intensive and iterative engineering effort in research and design phase, Gridscape has achieved breakthrough deep cost reductions in transfer switching, grid synchronization, and enabled broad plug-and-play functionality with a wider range of less expensive components through enhanced software drivers and communications protocols.

Gridscape undertook a comprehensive value engineering effort on key elements of a critical facility microgrid system, including equipment, design, engineering, installation, commissioning and operations. This helped reduce costs 30 percent to 50 percent across the board for future installations, while delivering the same level of benefits to the customer as custom-designed microgrid solutions.

These standard components are now entering the commercialization pipeline through Gridscape and its partner network. The Fremont project, specifically Fire Station 6 and 7, will be one of the first in which this technology is being commercially used with standardized components, and the first time a microgrid with these comprehensive capabilities will be integrated with a larger cloud-based EnergyScope™ DERMS system to unlock additional grid and customer benefits. The project evaluates the economies of scale achieved via this newly engineered open interfaces and control algorithms that enable plug-and-play configuration of components (rather than loose integration of systems). Through these interfaces, Gridscape will be able to achieve lower-cost procurement of essential microgrid components, as illustrated Table 9.

Table 9: Value Engineering Productization and Cost Reductions

Component/ Service	Avg. Cost / Leading Incumbents	Gridscape Cost	Cost Reduction Strategy
Controller	$250K-$400K	$40K-$75K	Standardized operational use cases and control algorithms
Transfer Switch	$75K-$100K	$50K-$75K	Standardized deployment approach reducing onsite configuration
Engineering (per site)	$100K-$300K	$50K-$150K	Use of engineering design templates
Systems Integration	$100K-$300K	$50K-$150K	Productization of several custom built components
Interconnection (BTM generation)	$10K-$15K	$5k-$10K	Standard application template (NEMMT)
Commissioning	$50K-$100K	$25K-$50K	Standard Operating Procedure for Commissioning

Typical Size: 50kW-250kW Solar PV / 100kWh-500kWh BESS

Source: Gridscape Solutions

Conclusion

This project has been a successful demonstration of emerging technology to use renewable resources such as solar PV systems and battery ESS systems to power critical facilities during off-grid/power outage systems. It displaces the need for diesel generators. In addition, the microgrid saves energy costs and provide clean fuel to the facility in on-grid mode.

This project paves way for cleantech companies like Gridscape to commercialize the solution across many customers and opens up new market entrants.

More importantly, the project helps achieve California's goals to meet renewable energy goals by deploying clean energy infrastructure on municipal critical facilities.

CHAPTER 4: Technology/Knowledge/Market Transfer Activities

This chapter provides an overview of the various technology and knowledge transfer plan and activities during this project.

Technology/Knowledge Transfer Plan

Gridscape intends to commercialize the solar emergency microgrid solution using the CEC funding to all other critical facilities in the California as well as other states in the US. The goal of the Technology and Knowledge Transfer Plan was to reach out to the following stakeholders during this project as well as in the future to proliferate awareness of this technology and project results:

- City and county governments in California and other states in the United States.
- Industry Associations.
- City and county government associations.
- Commercial and industrial trade associations.
- Electric utilities.
- Universities and academic groups.
- Non-profit entities with special interest in clean energy and clean technology.
- International energy companies and foreign governments.

The knowledge gained from this project and the results were made available to the public and stakeholders in following ways during the project:

- Gridscape marketing documents
    - Presentation materials
    - Project fact sheet
    - Solutions brief
    - Datasheets
- Third party outreach and marketing documents
    - ICLEI report
    - City of Fremont staff report
    - Other market research firm reports and documents
- Press releases
- Public and private conference and seminar presentations

- Social media and web sites
    - Gridscape website and social media outreach
    - City of Fremont website and social media outreach
    - The CEC website and media outreach
    - Third party websites and social media outreach
- Future publications including this final project report
- Other channels

Gridscape Marketing Documents

Gridscape developed several marketing documents that are being used to educate and market the benefits of this microgrid system to other critical facilities in the state as well as others in the country. Gridscape's sales and marketing team uses these documents on a regular basis:

- Presentation materials: various presentation material has been developed, distributed and presented at various conferences, discussions and meetings as listed.
- Project Fact Sheet: the Project Fact Sheet was distributed and presented at various meetings listed.

- Gridscape EnergyScope Solutions Brief (https://goo.gl/Vzgx5y)
- Gridscape Datasheets:
    - EnergyScope Overview (https://goo.gl/DXWmTF)
    - EnergyScope Operating System (https://goo.gl/h9AsC7)

Third Party Outreach and Marketing Documents

Several third parties including City of Fremont and others have developed extensive outreach and marketing documents used to discuss and spread the project results and benefits to the community at large and include:

- Local Governments for Sustainability Publication (http://icleiusa.org/publications/)
- Fremont Fire Station Case Study (https://goo.gl/QQYZGU)
- Fremont Green Challenge (https://goo.gl/s2ZMBQ)
- City of Fremont Staff Report for 10-year PPA Approval (https://goo.gl/hq2v4y)
- Smart Grid Library (http://www.smartgridlibrary.com/tag/smart-city/)

Gridscape and the City of Fremont met with various stakeholder groups on a periodic basis (quarter to quarter) to discuss this project and its benefits.

Press Releases

Over the last two years, various press releases on this project and its benefits were posted and used by several agencies in outreach and awareness programs. Some of these press releases are listed:

1. Fremont Sustainability Award (https://goo.gl/9suWhp)
2. Microgrid Energy (subcontractor) Press Release (https://goo.gl/9Uz35p)
3. GreenBiz Press Release (https://goo.gl/37JdWJ)
4. Tricity Voice Release (https://goo.gl/cnFHBd)
5. Connectivity Week (http://www.connectivityweek.com/2011/#news_14)
6. Microgrid Knowledge (https://goo.gl/fPz6LC)

Public and Private Conference/Seminar Presentations

Gridscape and its partners, including City of Fremont are also very active in various public and private conferences and seminars where they talk about the project, its results and benefits to the community. Some of these conferences and the presentations are listed:

1. Association of Bay Area Governments (https://goo.gl/HRKi6W)
2. Innovation and Impact Symposium 2018 (https://goo.gl/uPTQFi)
3. ACI 4th National Grid-scale Energy Storage Conference (https://goo.gl/YTrz9t)
4. Silicon Valley Energy Summit 2018, Stanford University (https://peec.stanford.edu/sves/2018)
5. EPIC Symposium 2016 (https://goo.gl/ZqHDBN)

Social Media and Websites

Gridscape is actively promoting the microgrid solution on social media i.e. LinkedIn, Twitter and Facebook. Gridscape is also in the process of upgrading its website to discuss benefits of the solar renewable microgrids at critical facilities.

Gridscape is using CEC posts on Fremont Fire Station Microgrid project (CEC Energy Innovation Showcase, http://innovation.energy.ca.gov/SearchResultProject.aspx?p=30084) to promote the project.

Future Publications

In 2019, Gridscape intends to promote and market the microgrid project and its results and benefits to the industry by attending various conferences and online marketing campaigns.

Final Project Report

This final project report will also serve as an important marketing document for Gridscape and the City of Fremont to discuss this project, its benefits and distribute its results to various industry stakeholders.

Other Channels

Gridscape has also started working with leading market research firms such as Navigant Consulting, Microgrid Energy, and GTM research to promote the results and benefits of this project to the industry.

Summary

Gridscape believes 2019 will be a breakout year for Gridscape to discuss and promote the results and benefits of the Fremont Fire Station Microgrid project to the industry. Gridscape will continue outreach to various customers and stakeholders through conferences, seminars, webinars, social media, press releases as well as market research firms for efficient technology and knowledge transfer of this project.

CHAPTER 5: Conclusions/Recommendations

Path Forward

Gridscape intends to commercialize the solution developed in this project and market it across various prospects in the MUSH market in California and globally. Subsequent to this grant, Gridscape also won the GFO-17-302 award to install five more microgrids at municipal facilities such as fire stations and emergency shelters in cities such as Fontana and Richmond. Gridscape will capitalize on this win to further refine the solution and sell it to multiple locations and sites. In addition to the additional grant funding, Gridscape also secured private project financing that will allow it to scale and use this solution on a mass scale in the next five years.

Recommendations

#1: Simplify Interconnection Process for DC-Coupled Microgrids

The project team strongly recommends the CEC, and other policy stakeholders, streamline and simplify the grid interconnection process. To achieve the state goals of decarbonizing the grid as well as using 100 percent renewable power in the future, it is imperative that the behind-the-meter microgrid installations are easily interconnected.

Specifically, the interconnection rules must be relaxed to allow seamless and trouble-free battery storage use in microgrids. Without battery storage systems, renewable microgrids are not possible and the critical facilities in the state will not be able to receive all the benefits described in this report.

For NEM interconnection applications where DC-coupled storage systems are employed in microgrids, it is increasingly difficult to interconnect. The DC-coupled storage systems have less losses than the AC-coupled systems and more benefits. However, the current interconnection rules do not allow easy NEM interconnection for DC-coupled systems.

#2: Simplify Interconnection Application and Process

The project team suffered a huge setback due to a meter mistake in the Fire Station 7 interconnection application. After working with PG&E, the error was corrected in the meter ID and the application was approved in February 2019.

The project team recommends the CEC and all other policy stakeholders simplify the interconnection application process so that common mistakes can be acknowledged and resolved quickly rather than restarting the whole application process.

#3: Simplify City Approval Process

Most cities in California have procurement processes that are time-consuming and lengthy. To speed up installing microgrids in the state, the project team recommends the CEC and other policy stakeholders give special consideration and fast-track approvals for renewable microgrid projects for critical facilities in the cities and counties.

Even though the City of Fremont is more progressive in sustainability than other cities, it took more than nine months for the City of Fremont to approve this project. Current experiences with other cities such as Portola Valley, Stockton, Richmond, and Fontana have been difficult when it comes to approval of these types of projects.

Again, if California is to achieve 100 percent renewable power goals by 2030, then the project approval process for solar emergency microgrid systems at critical facilities must be given special consideration and fast track approval.

#4: Standardize Distributed Energy Resources Communication Interface Protocols

The project team recommends the industry standards organizations, such as IEEE or IEC, act swiftly to standardize the communication interface protocols for DERs within the microgrid. The integration time required to test and use microgrid DER resources will be substantially reduced if these interfaces are standardized.

Currently, IEEE is leading the 2030.7 standard, however, more work remains to be done, and quickly, to help states achieve their goals. The project team urges the CEC to push IEEE or other standards bodies to expedite the communication protocol standardization process.

#5: Simplify Distributed Energy Resource Installation Building Codes

Although the project team did not face any substantial challenges in the permit approval process, it seems that several building codes at various cities are still not updated with distributed energy resources (DER). The project team recommends the CEC continue to help cities and counties to simplify building codes for DER installation for commercial and municipal locations where solar emergency microgrid systems can be sited in future.

Conclusion

This project has demonstrated substantial, tangible benefits to the city, State and private companies such as Gridscape Solutions, to solve energy and sustainability issues. It allowed a path for startups like Gridscape to commercialize the microgrid technology and offer great innovative solutions to critical facilities that not only reducing energy costs, but also providing important grid resilience to a changing electricity system.

CHAPTER 6: Project Benefits

The Solar Emergency Microgrid project at the Fremont Fire Stations has been a successful project and produced numerous benefits for the City of Fremont, its fire department, California, ratepayers, local communities, PG&E, and other beneficiaries. The project has also provided benefits to Gridscape and its team who are now embarking on commercializing this technology based on the project results.

City of Fremont

The solar emergency microgrids at the three fire stations in Fremont will save about $250,000 over the 10 years of the microgrid operation of the microgrids. This is a substantial energy savings for the city as a PG&E ratepayer. The energy savings are produced from the local renewable power generation at each site, coupled with reducing demand charges at each site. The residents of the city, who are also ratepayers, will also benefit indirectly from this project as they could pay less taxes for better critical services.

For example, the City of Fremont received the Fire Station 11 microgrid benefits shown in Table 10 during the demonstration period.

Table 10: Benefits to the City of Fremont

Benefit	Amount
Annual Energy Cost Without the Fire Station 11 Microgrid	$15,567
Annual Energy Cost With the Microgrid	$5,472
Annual GHG Emissions Reduction	141,896 lbs*

*** GHG Reduction Calculator, United States Environmental Protection Agency**

Source: Gridscape Solutions

In addition to the tangible benefits provided, the city will also receive these intangible benefits from the project:

- This project will help City of Fremont protects its critical facility (Fire Station 11) against power outages.
- This project will help reach city's GHG reductions goal by reducing about 141,896 lbs/year based on the United States Environmental Protection Agency's GHG reduction calculator, as stated in its Climate Action Plan, especially the "achievement gap" as described on the Page 5 of this report.
- The project also helps meet the city's goal to support local cleantech company's advancement and innovation with a strong tie to the economic development goals of the city.

- The fire station will receive clean, renewable power of its own during emergency situation and not rely solely on the onsite diesel generator. In addition, it can preserve the 72-hour "reserve" diesel fuel for a much longer time during outage situation. It will also save diesel fuel cost for the City of Fremont and Fire Department.
- The fire station personnel receive free shading for their cars from solar PV canopies.

State of California

The results of this project benefits the state of California by:

- Contributing to reduced peak demand during peak hours based on California Independent System Operator (CAISO) duck curve analysis.
- Reducing GHG emissions in California by 141,896 lbs on an annual basis, thereby supporting the goals of Assembly Bill 32 (AB32), the California Global Warming Solutions Act of 2006.
- Producing more than 1,750 MWh of clean (solar) energy during the next 10 years.
- Helping to achieve California's Renewables Portfolio Standard goal of 33 percent renewable energy sources by 2020 and 50 percent renewable energy sources by 2045.
- Creating and maintaining clean energy jobs.
- Demonstrating replicability and economic feasibility of solar emergency microgrid deployments at critical facilities across the state.

Reduced Peak Load Demand

This project will reduce peak load in critical areas by producing local clean renewable energy to power the critical facilities. This will help in meeting the demands for ramp up and ramp down periods.

The battery energy storage system in the microgrid can even be used to assist in ramp up and ramp down periods in the future when needed by CAISO.

Avoided Transmission and Distribution Infrastructure Upgrade Costs

The three solar emergency microgrids are strategically located in substation circuits that are almost reaching their capacities. This project will help reduce capacity stress on those circuits avoiding transmission and distribution infrastructure upgrade costs for PG&E. The PG&E ratepayers will, in turn, benefit since they will not have to fund expensive upgrades. The City of Fremont is a fast-growing city and its energy demand is also increasing year to year. This project will help defray or possibly eliminate utility infrastructure upgrade costs necessary on those circuits.

Uninterrupted Critical Services During Outages

The Fremont Fire Chief quoted recently in an interview that the biggest benefit to the fire services is that they have locally generated clean power during disasters or outages. They do not have to rely on diesel generated power during outage. Further, the critical services do not have to compete for the diesel fuel with the general population during disaster situation as well. This is a huge benefit to the ratepayers as they could receive uninterrupted critical services from the fire stations, which are powered by clean renewable power, during disasters such as wildfires or earthquakes.

Path for Future Commercialization

This project paves the way for companies like Gridscape to commercialize this microgrid technology and market this solution at all critical facilities in the state and the country. The project team received overwhelming support and numerous inquiries from other cities to use similar solutions in their critical facilities.

Gridscape intends to fully commercialize the EnergyScope™ microgrid controller and DERMS solution for various market segments including municipalities, government, commercial and industrial customers. In the municipal government vertical, Gridscape is working with several California cities including Portola Valley, Fontana and Richmond to design and install solar emergency microgrids at fire stations and other municipal buildings such as city halls, police headquarter buildings, and community centers. In the commercial and industrial market, Gridscape is working with various food processing plants, warehouses and data center buildings to potentially use this system.

This project has allowed Gridscape design to test and install two generations of microgrid controllers for favorable cost optimization. Gridscape is now developing a third generation controller and DERMS solution with further cost optimization and more features. Table 11 summarizes how this project enabled Gridscape to shorten the return on investment for future projects and market commercialization. Overall, the technology will benefit California and other states with mass use, resulting in job growth.

Table 11: Return on Investment for Market Commercialization

	Fire Station 11	Fire Station 6 or 7	Future Sites (2019-2020)
Project Cost	$800K	$450K	$300k (with Incentives: $180k)
PPA Payment	$17,385	$18,253	$15,000
ROI	46 years	24 years	8 years

Source: Gridscape Solutions

GLOSSARY AND ACRONYMS

Term/Acronym	Definition
AC	Alternating current
ATS	Automatic transfer switch
BESS	Battery energy storage system
CAISO	California Independent System Operator
CARB	California Air Resource Board
C&I	Commercial and Industrial (customers)
CPUC	California Public Utilities Commission
DC	Direct current
DER	Distributed energy resources
DERMS	Distributed Energy Resource Management System
EPC	Engineering Procurement Contractor (Licensed contractor hired to perform structural, mechanical, electrical design, equipment procurement, construction, and installation)
EPIC	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.
ESS	Energy storage system
EV	Electric vehicle
GHG	Greenhouse gas (emissions)
IoT	Internet of Things
IOU	Investor-owned utility
kW	kilowatts (unit of electrical power)
kWh	kilowatt-hour (unit of electrical energy)
Microgrid	A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A

Term/Acronym	Definition
	microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected and island-mode.
MUSH	Municipal, universities, schools, hospitals (Market segment)
NEMMT	Net Energy Meter – Multiple Tariff (Interconnection Agreement)
PG&E	Pacific Gas and Electric (Largest independently owned utility in Northern California)
PON	Program Opportunity Notice
PPA	Power purchase agreement
PTO	Permit to Operate
PV	Photovoltaic
ROI	Return on investment
Smart Grid	Smart grid is the thoughtful integration of intelligent technologies and innovative services that produce a more efficient, sustainable, economic, and secure electrical supply for California communities.
TAC	Technical advisory committee
USDOE	United States Department of Energy

REFERENCES

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2. IPCC Fifth Assessment Report, 2014
3. City of Fremont Climate Action Plan, November 2012
4. United States Department of Energy *The Role of Microgrids in Helping to Advance the Nation's Energy System.*
5. Levelized costs incorporate of the produce all costs over the lifetime including initial investment, operations and maintenance.
6. Navigant Research: Market Data: Microgrids 3Q 2018
7. Firedepartment.net website
8. SEIA Solar Market Insight Report 2018 Q3
9. Bloomberg New Energy Finance.
10. City of Fremont Council Approval Report.
11. Courtesy City of Fremont Staff Report
12. Based on an average of 18c/kWh of PG&E blended rate
13. The facility has Non-export agreement with PG&E. Once it shifts to NEM agreement, there will be some solar credits
14. Based on an average of 18c/kWh of PG&E blended rate
15. Based on NEM Rate of 9c/kWh of PG&E blended rate
16. GHG Reduction Calculator, United States Environmental Protection Agency

APPENDIX A:
Fremont Staff Report

Fremont City Council
3300 Capitol Avenue
Fremont, CA 94538
DRAFT

Meeting: 09/13/16 07:00 PM
Div/Dept: Community Development
Category: Agreements and Contracts

Sponsors:
DOC ID: 2806

STAFF REPORT (ID # 2806)

MICROGRID PROJECT AT CITY FIRE STATIONS - Public Hearing (Published Notice) to Consider Adoption of a Resolution Authorizing the City Manager or His Designee to Execute Power Purchase Agreements with Gridscape Microgrids, LLC for Renewable Energy Microgrid Systems at Three City-Owned Fire Stations as Part of a California Energy Commission Funded Microgrid Demonstration Project for Low-Carbon, Resilient Communities.

Contact Persons:

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Executive Summary:
Gridscape Solutions, Inc. (Gridscape), a Fremont-based clean technology firm, is the recipient of a California Energy Commission (CEC) grant award to support the demonstration of Microgrid Systems consisting of solar photovoltaic panels paired with battery energy storage units and smart controllers at three City of Fremont Fire Department Stations. The CEC grant requires Gridscape to design, construct, and demonstrate the viability of the systems for a period of no less than one year, whereby all energy produced by the systems would be provided to the City at no cost. At the conclusion of the grant demonstration period, the City can choose to leave these systems intact and purchase the clean energy generated by the systems. Gridscape has provided the City with pricing for both a direct purchase of the Microgrid Systems and for a Power Purchase Agreement (PPA). Based on the more favorable terms associated with the PPA option, staff recommends that Council authorize the City Manager to enter PPAs for three City-owned locations.

BACKGROUND:

On February 3, 2015, the California Energy Commission (CEC) awarded a grant of $1,817,925 to Gridscape Solutions, Inc. (Gridscape), a Fremont-based clean technology firm, to demonstrate a secure, reliable, and low-carbon based microgrid energy management system (Microgrid System) at three City of Fremont Fire Department Stations. As a Bay Area clean technology hub, this public-private partnership not only promotes new technology and potential sustainability measures for the City, but also supports a local company's efforts to scale and demonstrates the City's commitment to the industry.

The entire CEC-funded Microgrid System demonstration project is valued at $2,475,185, with matched funding provided by Gridscape in the amount of $657,260. The City of Fremont is providing in-kind support to the combined value of $80,000 in the form of staff time and leveraged energy efficiency improvements as its cost-share contribution.

The proposed Microgrid System at each of the three Fire Stations will consist of a battery energy storage system, smart inverters, a solar photovoltaic carport structure for renewable power generation, and energy visualization and control software that will monitor, collect, and display energy data. These systems will provide greenhouse-gas free electricity to the facilities and reduce power demand from the grid, thereby reducing utility bill costs while at the same time reducing greenhouse gas emissions.

All energy generated by solar panels in the Microgrid Systems will first be supplied directly to the facilities for onsite use. Any additional energy generated will be then stored in the batteries. Once the batteries are full and cannot accept additional energy, the Microgrid Systems will export power to the grid, generating utility credits through net energy metering. When solar energy production slows or stops due to lack of sun, the facilities will draw power from the batteries until the batteries reach a minimal 3-hour supply of charge needed for a potential off-grid/islanding mode in the event of a power outage. When the facilities are unable to draw upon energy from either the solar or battery systems, they will receive power directly from the grid, drawing on net energy metering credits from excess solar generation.

For the purposes of the CEC grant, Gridscape is tasked with demonstrating the viability of energy savings from the Microgrid Systems, increasing electrical infrastructure resiliency, and optimizing energy use to enable energy-smart critical facilities. Gridscape's grant agreement with the CEC covers the period of May 8, 2015 through March 31, 2018, during which time all system design, construction, interconnection, system testing, and grant reporting must be completed. In particular, this requires that each of the three Microgrid Systems undergo a "Demonstration Period" of no less than one year. During this Demonstration Period, the City would receive all energy generated by the Microgrid Systems at no cost, resulting in an expected utility savings in the first year of about $32,000.

At the end of the Demonstration Period of this project, the City can benefit from reduced utility costs by continuing to utilize the Microgrid Systems. After considering two different options (direct purchase of the Microgrid Systems or purchasing the power generated by these systems under Power Purchase Agreements (PPAs)), staff is recommending Council authorize execution of the PPAs with Gridscape Microgrids, LLC (a subsidiary of Gridscape Solutions, Inc).

The purchase of power from these systems by the City of Fremont is allowable under California Government Code 4217.10 et seq, which authorizes public agencies to enter into an energy service contract when the anticipated cost of the conservation services provided by an energy conservation facility will be less than the anticipated marginal cost of energy that would have been consumed in the absence of the project.

DISCUSSION/ANALYSIS:

<u>Facilities to be Installed</u>

The Microgrid Systems are to be installed at the following City of Fremont Fire Department Stations:

- Fire Station #6 at 4355 Central Ave., Fremont, CA 94536
- Fire Station #7 at 43600 South Grimmer Ave., Fremont, CA 94538
- Fire Station #11 at 47200 Lakeview Blvd., Fremont, CA 94538

Gridscape will install carport structures supporting solar panels plus energy storage equipment within existing parking lots at Fire Stations #6, #7, and #11.

The attached files show approximate layouts of the carports at each site.

The design at Fire Station #11 is the permit-ready design, while the designs at Fire Station #6 and #7 are still in the design process.

PPA Terms

Length of Agreement:
The PPAs have a 10-year term with a provision for two additional five-year renewals.

Purchase Option:
The City can exercise an option to buy the systems from Gridscape for fair market value (as determined by a mutually-agreed-upon appraiser) after the first five years of operation.

Production Guarantee:
Gridscape is required to deliver at least 80% of the expected annual power output from the system; failure to do so would result in cash payments by Gridscape to the City to offset the City's costs in replacing the lost power. This provision provides additional incentive to Gridscape to maintain the systems in good working order.

Removal Fund:
Gridscape is required to fund a Removal Fund reserve on an annual basis. The Removal Fund will be held in escrow and could be used by the City to remove the panels and carport structures if Gridscape were to go bankrupt and the City wanted the structures removed.

Pricing:
Each PPA has a different base price, equal to one half (50%) of the current cost of electricity at each respective facility.

	PPA Price ($/kWh)	Annual Escalator
Fire Station #6	$0.0916	2.5%
Fire Station #7	$0.0881	2.5%
Fire Station #11	$0.0971	2.5%

The annual 2.5% escalator in pricing is less than the historic average PG&E price increases of 4% annually.

Project Benefits

A. *Protection of Facility from Service Disruption through Energy Islanding*

   The location of City of Fremont over the Hayward fault and proximity to the San Andreas fault make it highly vulnerable to earthquakes. This project helps protect the three fire stations from service disruption during seismic events by isolating them from the grid and allowing them to independently operate using solar energy and advanced energy storage technologies.

With the Microgrid Systems, during a utility outage, the power distribution will be isolated from the utility at the point of service by a microgrid inter-tie protection relay. An uninterruptible power supply will continue to provide electricity to mission critical telecommunication equipment. Using advanced load controls and automation, the Fire Stations' essential loads will have power for at least 3 hours. The three hour "islanding" from the grid and real time views of the energy data will demonstrate a technological advancement from the current fire station operational procedure with respect to clean energy generation, independence from the grid and reduction in carbon dioxide emissions.

B. *Reduced Utility Cost (Energy Savings) through Onsite Energy Production & Storage*

The Microgrid Systems will enable the City of Fremont to reduce utility bill costs and demand charges as power from a renewable source and battery would be used to offset supply from the grid. The Microgrid Systems will be designed to control when each Fire Station uses energy supplied from the solar photovoltaic system, the energy storage unit, or from the grid. The renewable generation would provide power to the fire station for up to 5.5 hours daily with peak renewable generation from solar between 10am – 2 pm. The battery system would be charged from excess solar generation at a low cost and utilized to offset expensive peak demand without having to draw energy from the grid.

Currently, the three Fire Stations combined are using approximately 270,000 kWh of electricity annually from the grid, costing the City $49,400 in utility bill payments.

Under the proposed agreement, the City would save approximately $32,000 during the Demonstration Period (when the City is receiving the renewable energy and battery power at no cost). Subsequently, in the first year of the PPA, since the City would be paying for the energy generated by the Microgrid at half the current cost of electricity, utility bill savings are estimated at $16,000. Over the 10 year PPA term, the City is projected to save about $215,000.

Estimated Savings from Power Purchase Agreements

	Station #6	***Station #7***	***Station #11***	***COMBINED***
Ave. Annual Electric Usage	97,500 kWh	108,000 kWh	64,500 kWh	270,000 kWh
Ave. Annual Electric Bill	$17,900	$19,000	$12,500	$49,400
Current Electric Costs ($/kWh)	$0.1830	$0.1761	$0.1942	
PV System Size	37.1 kW	43.4 kW	37.2 kW	117.7 kW
PPA Rate Year 1 ($/kWh)	$0.0916	$0.0881	$0.0971	
Est. Production Year 1	52,000 kWh	66,000 kWh	56,000 kWh	174,000 kWh
% Energy Usage Offset	53.3%	61.1%	86.8%	64.4%
"Demonstration Period" Electric Savings	$9,574	$11,604	$10,849	$32,027
PPA Payment Year 1	$4,763	$5,815	$5,438	$16,015
Remaining Utility Payment Year 1	$8,327	$7,396	$1,651	$17,373

New Net Electric Costs Year 1	$13,090	$13,211	$7,088	$33,389
Annual Electric Savings Year 1	$4,810	$5,789	$5,412	$16,011
% Bill Savings Year 1	26.9%	30.5%	43.3%	32.4%
Bill Savings Over 10 Year Term	$60,886	$74,399	$79,559	$214,844
Total Bill Savings (Demonstration Period + PPA)	**$70,460**	**$86,003**	**$90,408**	**$246,870**

C. *Reduction in Carbon Dioxide Emissions through Use of Renewable Energy Technologies*

The City of Fremont's Climate Action Plan sets forth a goal of reducing community greenhouse gas emissions by 25% by the year 2020. Using the combination of renewable generation and battery technologies, the Microgrid Systems will reduce greenhouse gas emissions by 74,646 pounds (34 metric tons) of carbon dioxide annually. Also, during utility outage, the power from the battery would be used to provide backup power thus reducing or eliminating the use of a backup diesel generator, which would further reduce greenhouse gas emissions.

D. *Reduction in Transmission Line Load to Avoid Power Capacity at Substation*

The utility substation serving the three Fire Stations where the Microgrid Stations will be implemented is reaching near maximum load capacity. To avoid power failure due to over capacity, the substation needs to increase capacity or reduce loads. With the Microgrid Systems, the City will be able to reduce energy from the grid and contribute in reducing the load at the substation.

E. *Demonstration of State of California Goals of Power Grid Resiliency*

The Microgrid Systems will offer enhanced grid resiliency and flexibility by mitigating the impact of power outages resulting from severe weather, earthquake or other disruptions. During high demand periods, the battery energy system will be used to offset supply from the grid that will further reduce load on the grid and utility substations.

F. *Support of Technological Advancement and Innovation by the City and by Fremont-Based Cleantech Companies*

Clean tech startups face a relatively long horizon before commercialization and ultimately, profitability. Often critical to their product development cycle and fundraising effort is the ability to demonstrate their technology on existing, operational infrastructure. This gives companies the ability to evaluate and refine new concepts before large-scale deployment can begin. Government operations are a particularly attractive candidate for these types of demonstrations, given the substantial market potential they present, especially in facilities and fleets.

Gridscape Solutions, a Fremont-based clean technology firm, will demonstrate how solar energy paired with energy storage and advance load control and automation solutions, can save energy, reduce greenhouse gases, optimize building operations, reduce grid demand, and result in enhanced community resiliency. The partnership between the City and Gridscape Solutions could result in this technology potentially being replicated at other commercial, industrial, and institutional facilities throughout the City and beyond.

Power Purchase Agreement (PPA) vs. Direct Purchase

Because of the possibility of future cost savings through continued use of the Microgrid Systems beyond the Demonstration Period, the City asked Gridscape to provide quotes for two options for continued utilization of the Systems: a Power Purchase Agreement, where Gridscape continues to own and maintain the systems and the City purchases the power that is generated; or a direct purchase agreement, where the City would buy the systems up-front and then pay nothing for the electricity generated by the systems (although the City would need to continue to pay for maintenance and monitoring/management of the Microgrid Systems). The terms proposed by Gridscape for each option and the reasons for staff's recommendation of the PPA option are provided below.

- Power Purchase Agreement option. As noted previously, the terms of the Power Purchase Agreements are very favorable to the City, offering the electricity produced by these systems at a rate one-half the cost of the City's current electric rates at each facility, resulting in positive cash flow in the first year of operation. Gridscape would furthermore provide all system support (monitoring and maintenance), plus would include the extended 10-year warranty on the energy storage battery units (compared to the 2-year manufacturer warranty) at no additional cost. The total utility bill savings resulting from the 10 year PPA term would amount to approximately $215,000 for all three systems.

- Direct Purchase Agreement. Gridscape also provided a quote for a direct purchase equivalent to the matched funding amount of $657,260. Based on this purchase price alone, the utility bill savings would not result in a positive cash flow until year 15. In addition, due to the complex nature of these Microgrid Systems, the City would also require a contract for monitoring and maintenance support. Gridscape has estimated an annual support fee for the three facilities combined to be approximately 15% of the proposed purchase amount, or $98,580. This support fee would also vary annually depending on the wear and tear of the system, potentially increasing an additional 5-20% after the first year. Finally, a purchase would not include the extended 10-year warranty on the system batteries, instead carrying only the 2-year manufacturer warranty.

Because the annual support fee alone would exceed utility cost savings in the Direct Purchase Option, staff rejected that option. The PPA option proposed by Gridscape, however, results in significant cost savings to the City, and is therefore recommended for approval. It should be noted that Gridscape staff stated that a PPA relationship with the City could benefit Gridscape in future grant applications and business development efforts more than the direct purchase option, which contributed to Gridscape's more aggressive pricing for the PPA option.

It should also be noted that under the PPAs the City has the ability to purchase the systems at fair market value after five years, so if terms were more favorable at that time, the City could reconsider a purchase.

Government Code Section 4217.12

In accordance with California Government Code Section 4217.12, staff has concluded that the total cost of the solar power generation systems provided under the PPAs will be less than the anticipated cost of electricity that would have been consumed at these three locations in the absence of the project. A Resolution incorporating the necessary findings is attached.

FISCAL IMPACT:

Payments under the PPAs will be more than offset by the reduction in payments to PG&E for electricity usage at the three solar sites. As the cost of electricity has been included in the 2016/17 Adopted Budget, no additional allocations are needed.

ENVIRONMENTAL REVIEW:

The project is exempt from the California Environmental Quality Act (CEQA) per CEQA Guidelines Section 15303 consisting of construction and location of limited numbers of new, small facilities or structures; installation of small new equipment and facilities in small structures, specifically, the installation of solar energy systems on existing parking lots.

ATTACHMENTS: None. (Do not list attachments here, the uploaded attachments will automatically be added here when an agenda is generated.)

LINKS: (Paste hyperlinks here. Do not use the "Click here to view Link information" button).

ATTACHMENTS:

- Fire Station 6 Layout
- Fire Station 7 Layout
- Fire Station 11 Layout
- Draft Resolution-Microgrid Systems

RECOMMENDATION:

1. Find that the installation of Microgrid Systems at three City Fire Department Fire Station facilities (Fire Station #6, #7, and #11) is categorically exempt under the California Environmental Quality Act;
2. Adopt the attached resolution making findings necessary to authorize the Power Purchase Agreements under Government Code section 4217.11, including a finding that the PPAs' total cost will be less than the anticipated cost of electricity that would have been consumed by the facilities in the absence of these systems and that the terms of the award are in the best interest of the City of Fremont.
3. Authorize the City Manager or his designee to execute Power Purchase Agreements with Gridscape Microgrids, LLC for Fire Station #6, #7, and #11, consistent with the terms described in the staff report.