CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

ENERGY RESEARCH AND DEVELOPMENT DIVISION

FINAL PROJECT REPORT

Lessons Learned from Energy Commission Microgrid Projects

Best Practices from EPIC PON-14-301 Grant Recipients

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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 EPIC Program is funded by California utility customers under the auspices of the California Public Utilities Commission. 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 increased safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emissions 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 a clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the Energy Research and Development Division at ERDD@energy.ca.gov.

ABSTRACT

Microgrid demonstration and implementation is a major focus for the California Energy Commission and has been supported by funds administered by the commission under the Electric Program Investment Charge (EPIC) program for the past 10 years. Seven EPIC-funded microgrid projects funded in 2015 recently concluded their three-year implementation timelines. These seven projects demonstrated low-carbon-based microgrids for critical facilities and high-penetration, renewable-based microgrids. The microgrid developers and customers were early adopters who experienced many challenges and gained valuable insights about microgrid planning, implementation, and operation.

The California Energy Commission gathered lessons learned during the grant period by interviewing key personnel involved in the projects. Aggregating the lessons and best practices across participants will inform future microgrid deployments in California and additional research and development needs. Together, the lessons and best practices from the seven EPIC-funded microgrid demonstration projects reflect considerable knowledge and experience gained by project participants. These microgrids provided compelling value for their customers and communities, even during the early demonstration phases. Project developers have pursued many new microgrid opportunities armed with the expertise gained from these experiences, and multiple participating customers are expanding or building new microgrids for their facilities. Interviews with participants showed basic best practices related to communication, coordination, and technology integration that are critical for complex, multistakeholder, and multivalue projects in a developing market.

This report describes detailed lessons learned, from up-front planning guidance to actionable interconnection recommendations. Based on the experiences with these seven projects, the California Energy Commission funding added value in several key areas related to advancing microgrids in California. Ongoing public funding support will be important to continue to standardize microgrid technology and provide longer-term performance evaluation for existing and future microgrid demonstration projects.

Keywords: Microgrid, lessons learned, best practices, grant funding, resiliency, renewable integration

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Introduction

The Electric Program Investment Charge (EPIC) program is an electricity ratepayer-funded program that benefits investor-owned utility ratepayers through applied research and development, technology demonstration and deployment, and market facilitation. The California Energy Commission (CEC) administers more than $130 million per year for the EPIC program. Funding is awarded for projects that address climate vulnerability through low-carbon technology implementation and commercial penetration while promoting greater electricity reliability and safety.

A major research area for the EPIC program is microgrid demonstration and deployment. Regulatory agencies and market participants are motivated to expedite the rate of microgrid implementation because of the growing need to integrate and make best use of intermittent renewable electricity generation technologies (for example, wind or solar) while also promoting cost savings, a resilient electricity system with fewer and shorter outages, and reliability. Microgrids can demonstrate unique, multivalue benefits to energy consumers while helping to meet California's clean energy targets.

A microgrid is a localized network of electrical power lines and generators that supplies power to a specific area, such as a single building or a group of buildings, and acts as a single controllable entity with respect to the grid.

Project Purpose and Approach

Of approximately 20 EPIC-funded microgrid projects supported by the CEC over the past decade, seven concluded their grant implementation timelines as of March 31, 2019. The grants to these seven projects in 2015 were under two categories in EPIC PON-14-301:

- Group 1: Demonstration of low-carbon-based microgrids for critical facilities
- Group 2: Demonstration of high-penetration, renewable-based microgrids

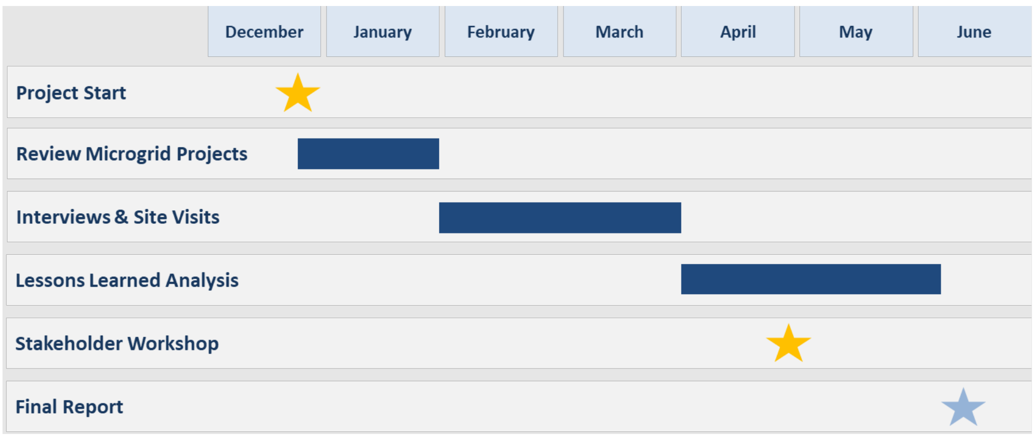
The seven microgrid projects discussed in this report are:

1. Demonstrating a Secure, Reliable, Low-Carbon Community Microgrid at Blue Lake Rancheria
2. Laguna Wastewater Treatment Plant Microgrid
3. A Novel, Renewable Energy Microgrid for a California Healthcare Facility (Charge Bliss)
4. Las Positas College Microgrid Automation Project
5. Solar Emergency Microgrids for Fremont Fire Stations
6. Bosch Direct Current Building-Scale Microgrid Platform
7. Borrego Springs: California's First Renewable Energy Based Community Microgrid

The CEC engaged Navigant Consulting, Inc. (Navigant) to review, interview, and report on the efforts of the microgrid projects awarded under PON-14-301. These microgrid developers and customers were early adopters, experiencing many challenges and gaining valuable insights about microgrid planning, implementation, and operations. It was critical to gather this information near the end of the grant period, while key personnel were still involved with the projects and lessons learned were fresh in their minds.

Navigant's review began in late December 2018 and included a microgrid lessons-learned public workshop hosted by the CEC on April 26, 2019. The project timeline is illustrated in Figure ES-1.

Figure ES-1: Navigant Project Schedule

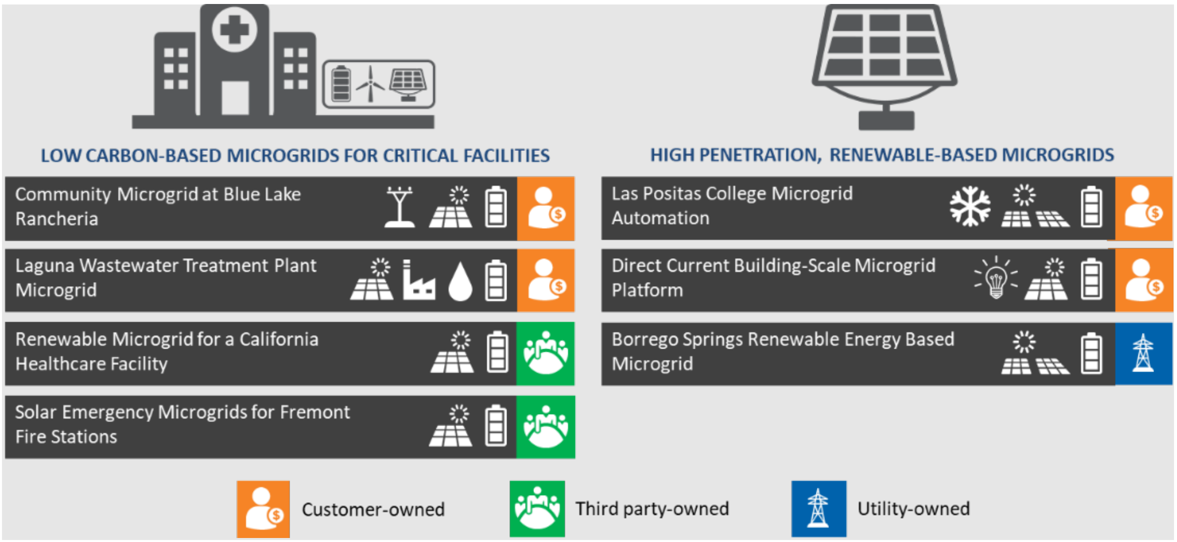


Source: Navigant

Microgrid Projects Funded by the Electric Program Investment Charge

The seven microgrid projects evaluated in this project span a variety of technical configurations and ownership models, as shown in Figure ES-2. Microgrids are divided into two main groups ("low carbon-based microgrids for critical facilities" and "high penetration, renewable-based microgrids"), according to the EPIC grant, but there is significant overlap between the groups, primarily in the universal deployment of low-carbon solar plus battery storage systems.

Figure ES-2: Technical Configurations and Ownership Models



Symbols in the dark grey boxes represent microgrid components of solar photovoltaic arrays, battery storage, electric distribution infrastructure, combined heat and power, pumped water loads, thermal ice storage, and direct current light-emitting diode lighting.

Source: Navigant

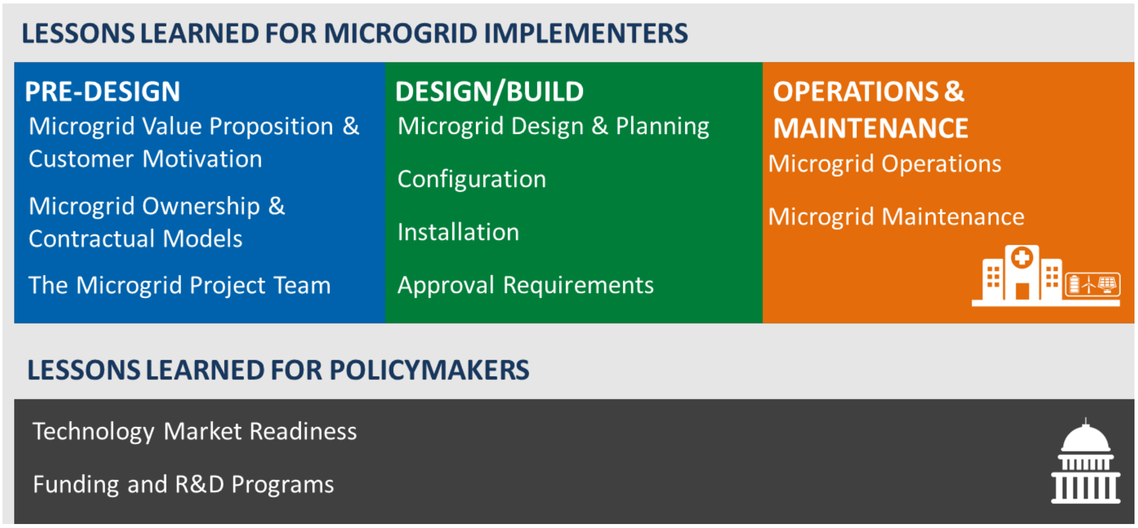
The seven projects benefit facilities and communities of different sizes and include a wide range of generation component sizes. For example, the Borrego Springs microgrid integrated a 26-megawatt third-party-owned solar photovoltaic power plant to serve a community of several thousand residents, while the project at the Fremont fire station had a peak electric load and a solar photovoltaic array of less than 40 kilowatts each. Although most of the microgrids are not sized to cover all the facilities' electric loads, the microgrids reporting at least one year of operation are achieving from 20 percent to nearly 60 percent energy cost savings and over 40 percent demand charge cost savings.

An important objective for each EPIC-funded microgrid was to successfully "island" part of its electric load from the utility grid and operate independently of the grid in case of an outage. The group conducted a variety of test events and operated several microgrids through outages during the demonstration period, gaining real-world experience.

Microgrid Lessons Learned

The EPIC-funded demonstration projects provided valuable lessons learned about the micro-grid project lifecycle and stakeholder use. Figure ES-3 summarizes the high-level lessons-learned categories, based on themes heard during interviews. In addition to increasing public knowledge generally, there are two primary audiences for the lessons learned: microgrid implementers (developers, vendors, and customers/site hosts) and microgrid policymakers (the CEC, state decision-makers, and the California Public Utilities Commission).

Figure ES-3: Lessons-Learned Categories



Source: Navigant

Together, the lessons and best practices from the seven EPIC-funded microgrid demonstration projects represent an enormous amount of knowledge and experience gained by project participants over more than three years. These microgrids provide compelling value for their customers and communities. Developers have gone on to pursue new microgrid opportunities, using the expertise gained from these experiences, and multiple participating customers are expanding or building new microgrids for their facilities.

Many of the lessons and best practices interviewees identified are fundamental to successful microgrid projects and should be considered for future projects. Even the most basic best practices — those related to communication, coordination, and technology integration, for example — carry greater weight for complex, multistakeholder and multivalue stream projects in a developing market.

Key lessons learned for microgrid implementers include the following.

- Customers are motivated by three main benefits: (1) financial (utility bill savings), (2) environmental (low carbon footprint and renewable energy), and (3) resiliency (emergency preparedness and business continuity through outages).
- The microgrid integrator role is especially critical, along with good partnerships between vendors and communication between all stakeholders.
- Testing and thoroughly vetting emerging technology — typically microgrid controllers and energy storage solutions — remain important.
- The design, planning, construction, and operation phases must include an understanding and accommodation of customer needs and site characteristics.
- Permitting and interconnection processes can pose a major challenge to project timelines without considerable upfront preparation and coordination with the permitting agency and utility.

- Operational microgrids are successfully achieving utility energy and demand charge savings.
- Microgrids are successfully running islanding tests and, in some cases, have already islanded through unplanned power outages. However, there are still challenges with eliminating legacy fossil fuel generators from the islanding equation.
- Microgrids typically need long-term, third-party service agreements to support ongoing operation and maintenance needs that are outside the core business of the customer site.

The researchers found that the complexity and functionality of the seven microgrid demonstrations would not have been achievable if they had not received CEC EPIC funding. Interviewees shared that the initial EPIC grant was critical to project success. The CEC has a variety of paths forward to continue to advance microgrids in California. Public funding could contribute to further standardizing microgrid technology, including:

- Controllers, communication protocols, and configurations.
- Advanced and long-duration energy storage solutions.
- Direct current microgrids.

Finally, continued analysis of data from and performance of operating microgrids, including these seven projects, will be needed to continue to provide valuable post-implementation lessons.

CHAPTER 1: California Energy Commission Microgrid Overview

This chapter provides the background and context for the seven microgrid projects examined in this report. It describes the Electric Program Investment Charge (EPIC) program, the California Energy Commission's (CEC) experience with microgrids, the program opportunity notice (PON) for funding related to the seven microgrid projects (PON-14-301), and Navigant Consulting, Inc.'s (Navigant) work authorization to evaluate these projects and share lessons learned.

Electric Program Investment Charge

The EPIC program is a ratepayer-funded program that benefits ratepayers through applied research and development, technology demonstration and deployment, and market facilitation. The program, established in 2011, is administered by the CEC and the state's largest investor-owned utilities (IOUs): Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E).

In 2012, the California Public Utilities Commission (CPUC) established the purpose and governance structure of the EPIC program through Decision 12-05-037 in Rulemaking 11-10-003. Funds for the EPIC program come from utility bill surcharges and are administered by the CEC and the state's three largest IOUs (80 percent and 20 percent of funds, respectively) (CPUC, 2012).

The CEC administers approximately $130 million per year for the EPIC program[1] through solicitations that award funding for projects related to research, development, and demonstration (RD&D) that address climate vulnerability through low-carbon technology deployments and commercial penetration while promoting greater electricity reliability and safety. In other words, the funds enable the CEC to award grants to projects that focus on validating technologies in real-world scenarios that may also facilitate market acceleration.

CEC Microgrid Experience

A major research area for the EPIC program is microgrid demonstration and deployment. The growing need to integrate and optimize intermittent renewable generation while promoting cost savings, resiliency, and reliability has motivated regulatory bodies and market participants to expedite the rate of microgrid adoption. Microgrids can demonstrate unique, value-stacking benefits to energy consumers while helping meet clean energy targets such as those mandated by Senate Bill (SB) 100.[2] Other influential laws and regulations include: Assembly Bill

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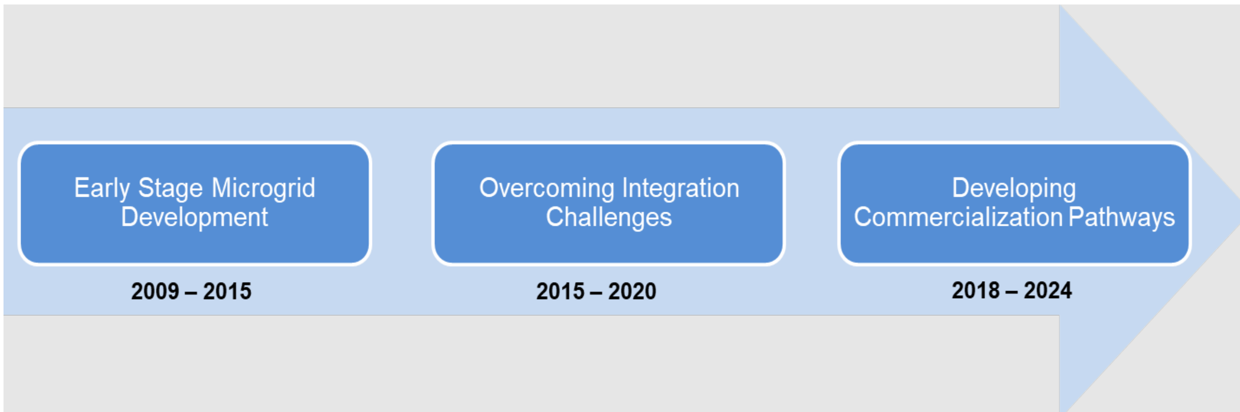
1 The EPIC surcharge yields $162 million per year, with 80 percent administered by the CEC.

2 The 100 Percent Clean Energy Act of 2018, signed by Governor Brown on September 10, 2018, mandates that served electricity be sourced by 100 percent clean energy by December 31, 2045.

(AB) 32, SB X1-2, AB 785, and AB 2514.[3] The CEC recognizes a microgrid's varied service characteristics and has encouraged innovation in these areas through EPIC program opportunities. The progression of microgrid research, development, and demonstration with the CEC is illustrated in Figure 1.

Figure 1: EPIC Program Microgrid Research Evolution



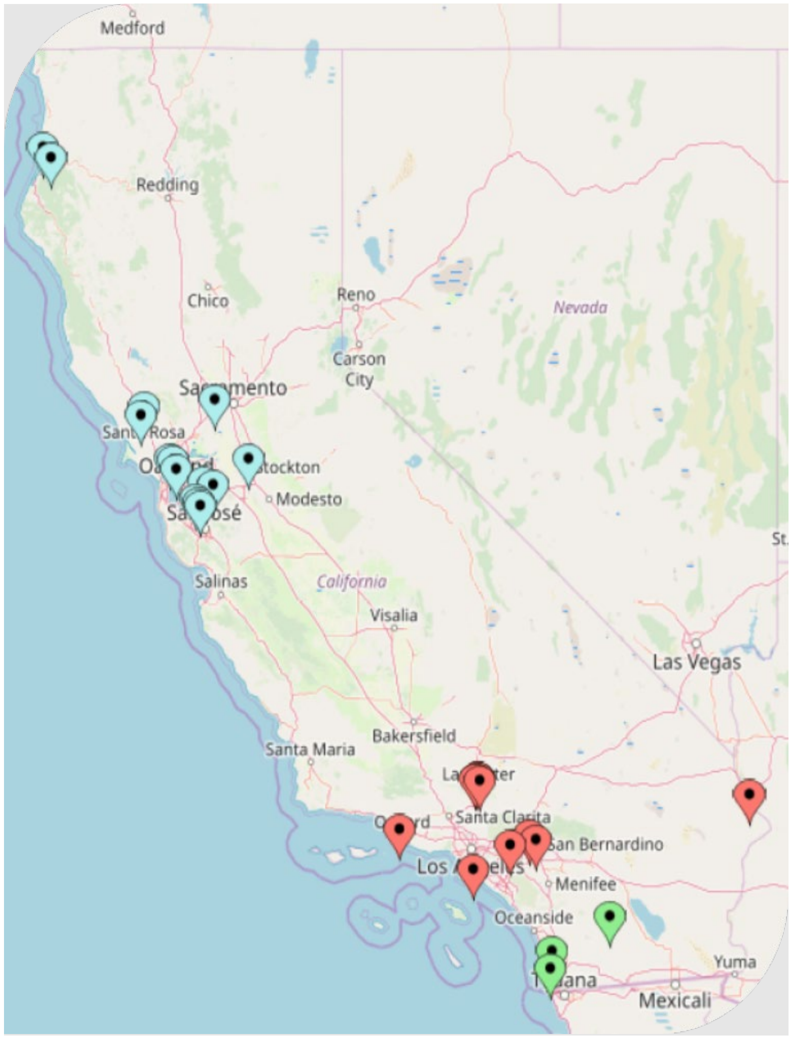
Source: CEC

In the early stages of the CEC's experience with microgrids, five solicitations were awarded, totaling $11.1 million with a cost share of $6.8 million. This period, from 2009 to 2015, addressed research for microgrid controllers and an integrated systems approach. From 2015 to 2020, nine microgrids were awarded totaling $29.5 million with a cost share of $11.6 million, which assisted in identifying and overcoming challenges with multiple distributed energy resource (DER) integration and refining the controller design. Currently, projects developing commercialized pathway microgrids are emphasized, targeting nine microgrids from 2018 to 2024 with approximate funding of $55 million and shared costs of $62 million. To date, the CEC has provided approximately $84.5 to support these project demonstrations (Gravely et al., 2019).

Currently, 20 microgrid projects have been awarded grants through EPIC funding solicitations. Figure 2 illustrates the researched locations and Figure 3 depicts the percentage of IOU service territory distribution of site locations.

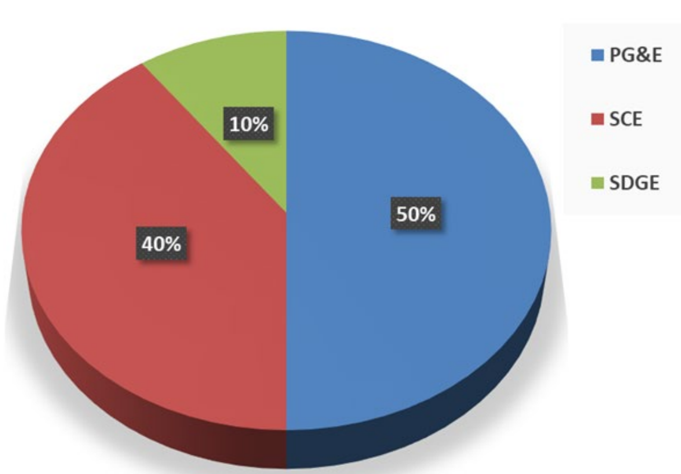
[3] AB 32, The Global Warming Solutions Act; SB X1-2, Renewable Portfolio Standard; AB 785, Building Efficiency; AB 2514, Energy Storage Procurement Targets.

Figure 2: EPIC-Funded Microgrid Sites



Source: CEC

Figure 3: Distribution of EPIC Microgrids in IOU Territory



Source: CEC

Of the 20 EPIC-funded microgrid projects, seven concluded their grant implementation timelines as of March 31, 2019. The following section describes the scope of the solicitations relating to these grants and the application attributes required for selection.

EPIC Program Opportunity Notice 14-301 Awards

Program Opportunity Notice, PON-14-301, issued in July 2014, sought to fund technology demonstration and deployment projects that exhibit the reliable integration of energy efficient demand-side resources, DER integration, and components that enable smart grid controls (CEC, 2014a). The general requirements granted public and private entities and individuals the ability to apply with projects that would lead to technological advancements and breakthroughs in overcoming market barriers and help meet the state's statutory energy goals while benefiting ratepayers.

In 2015, the CEC awarded EPIC grants to seven microgrid projects totaling $25.5 million with project timelines through March 2019. The projects aligned with the following two groups identified in the PON:[4]

- Group 1: Demonstration of Low Carbon-Based Microgrids for Critical Facilities
- Group 2: Demonstration of High-Penetration, Renewable-Based Microgrids

Grant recipients in Group 1 proposed implementing or expanding upon microgrid designs that protect critical facilities from outage or service interruption by providing reliable power. Critical facilities serve residents and community members in times of unforeseen disasters or emergencies (e.g., hospitals, fire stations, police stations, water and wastewater treatment plants, and shelters). Additionally, Group 1 projects would demonstrate energy and cost savings and reductions in end-user greenhouse gas (GHG) emissions.

Following are the requirements for Group 1 (CEC, 2014b).

1. Projects must include generation and controllable loads through advanced monitoring, control, and automation systems.
2. Projects must have the ability to drop any non-critical loads, coordinate generation and load, prevent export of power during excess generation, and limit adverse grid impacts.
3. Projects should have the ability to automatically disconnect from the adjacent electrical grid and operate autonomously as well as change energy storage devices with any excess generation for later dispatch.
4. The microgrid must be able to successfully island for at least three hours.
5. Technologies must be capable of being commercially available after the grant period.
6. Microgrids must meet or exceed the U.S. Department of Energy's 2020 goals for commercial-scale systems to reduce outage duration of required loads by greater than

[4] Group 3, for the "Demonstration of Advanced Smart and Bidirectional Vehicle Charging," did not include microgrids and is not evaluated in this report.

98 percent at the lowest cost while reducing GHG emissions by greater than 20 percent compared to diesel backup.

7. Inverters used must be "smart inverters" that meet the Institute of Electrical and Electronics Engineers (IEEE) 1547a and IEEE 1547.8 requirements.
8. Projects must comply with IEEE 1547.4, IEEE 1547.8, and CPUC Rule 21.
9. Projects must reduce consumption through energy efficiency and demand response whenever appropriate.
10. Wherever feasible, on-site generation must be from renewable resources integrated with energy storage and demand response.
11. EPIC funds are to be used for activities on the customer side of the meter but can cover engineering and interconnection infrastructure.

Group 2 recipients sought to demonstrate the viability of microgrids in managing high amounts of renewable energy, up to 100 percent and with a minimum of at least 51 percent of the facility or community total annual load. Group 2 projects involved the use of advanced controllers and energy management systems.

The Group 2 technical requirements addressed specifications similar to those of Group 1, as follows (CEC, 2014a).

1. Technologies must be capable of being commercially available after the grant period.
2. Projects must include generation and controllable loads through advanced monitoring, control, and automation systems.
3. Projects must have the ability to drop any non-critical loads, coordinate generation and load, prevent export of power during excess generation, and limit adverse grid impacts.
4. Projects must be able to successfully island, consistent with the IOU's requirements.
5. Microgrids must meet or exceed the U.S. Department of Energy's 2020 goals for commercial-scale systems to reduce outage duration of required loads by greater than 98 percent at the lowest cost while reducing GHG emissions by greater than 20 percent compared to diesel backup.
6. Inverters used must be "smart inverters" that meet IEEE 1547a and IEEE 1547.8 requirements.
7. On-site renewable DERs must supply more than 51 percent of the facility or community's total annual electricity requirements.
8. Wherever feasible, on-site generation must be from renewable resources integrated with energy storage and demand response.
9. EPIC funds are to be used for activities on the customer side of the meter but can cover engineering and interconnection infrastructure.

Table 1 and Table 2 list the grant recipients awarded under PON-14-301.

Table 1: Revised Notice of Proposed EPIC-Funded Awards
Group 1: Demonstration of Low Carbon-based Microgrids for Critical Facilities

Rank	Project Applicant	Title	EPIC Funds (in Millions)	Matching Funds (in Millions)
1	Humboldt State University	Demonstrating a Secure, Reliable, Low Carbon Community Microgrid at the Blue Lake Rancheria	$5.0	$1.3
2	Gridscape Solutions	City of Fremont, Fire Stations Microgrid	$1.8	$0.6
3	Trane U.S., Inc.	Laguna Wastewater Treatment Plant Microgrid	$5.0	$2.2
4	Charge Bliss, Inc.	Charge Bliss Renewable Microgrid	$4.8	$2.1

Source: Notice of Proposed Award (NOPA), California Energy Commission, September 2015 (available at https://web.archive.org/web/20150905093906/https://www.energy.ca.gov/contracts/PON-14-301_NOPA_revised_2.pdf).

Table 2: Revised Notice of Proposed EPIC-Funded Awards
Group 2: Demonstration of High-Penetration, Renewable-based Microgrids

Rank	Project Applicant	Title	EPIC Funds (in Millions)	Matching Funds (in Millions)
1	Robert Bosch LLC	Direct Current Building Scale Microgrid	$2.8	$1.8
2	Chabot-Las Positas Community College District	Las Positas College Microgrid Automation	$1.5	$0.5
3	SDG&E	Photovoltaic Based Microgrid	$4.7	$1.2

Source: Notice of Proposed Award (NOPA), California Energy Commission, September 2015 (available at https://web.archive.org/web/20150905093906/https://www.energy.ca.gov/contracts/PON-14-301_NOPA_revised_2.pdf).

The CEC selected awardees through a comprehensive evaluation process for each proposal. Grant recipients met the requirements and described goals that aligned with the criteria in the Microgrid Pre-Application Workshop on July 29, 2014, and the program opportunity notice instructional guide.

Navigant Work Authorization

The purpose of Navigant's work authorization was to review, interview, and report on the efforts of the microgrid projects awarded under the EPIC Program PON-14-301. These microgrid developers and customers were early adopters, experiencing many challenges and gaining valuable insights across microgrid planning, implementation, and operations. Gathering this information near the end of the grant period (March 2019) became critical because the key personnel were still involved with the projects and lessons learned were fresh in their minds. Once these projects complete their required grant activities, key personnel may move on in their careers and it would become more difficult to obtain this information.

Navigant's review began in late December 2018 and featured a Microgrid Lessons Learned public workshop hosted by the CEC on April 26, 2019. Overall, Navigant's tasks included:

- Task 1: Project Administration.
- Task 2: Review Microgrid Projects.
- Task 3: Interviews with Microgrid Project Managers.
- Task 4: Stakeholder Workshop.
- Task 5: Final Report.

The goal of Task 2 (Review Microgrid Projects) was to review available material on the microgrid projects under PON-14-301 to identify commonalities and provide a baseline for developing interview questions. Under the EPIC program requirements, each grant recipient was required to submit a final report with extensive technical detail on the project. For Navigant's review, project fact sheets and five of the seven final technical reports were made available. The technical reports will continue to be posted publicly by the CEC as they are finalized and approved (see References).

The goal of Task 3 (Interviews with Microgrid Project Managers) was to contact and interview the primary project participants in the seven microgrid grants awarded under PON-14-301 to obtain firsthand knowledge of the lessons learned, best practices, and recommended improvements. These interviews collected key findings across the seven projects to serve as digestible, actionable insights. Navigant visited each microgrid project in person to interview grant awardees, project developers, and site hosts, in order to understand perspectives from multiple critical project roles.

Additionally, Navigant interviewed representatives from the three IOUs that were involved in interconnecting the microgrid projects to the utility grid:

1. PG&E: Blue Lake Rancheria, City of Fremont, Charge Bliss, Laguna Wastewater Treatment Plant (Laguna WWTP), and Las Positas College.
2. SCE: Bosch Direct Current Building-Scale Microgrid Platform.
3. SDG&E: Borrego Springs.

Several questionnaires were created to facilitate the conversational interviews. The objective of these interview guides was to enable in-depth discussions with the primary stakeholders involved in each of the microgrid projects. Navigant modified the foundational interview questionnaires to meet the unique, known characteristics related to each project. The questions addressed each interviewee's dedicated role and experience throughout the project timeline. The interview and data gathering portion of the report development included discussions with grant recipients, facility hosts, end-users, developers, and utility interconnection representatives.

The questions directed participants in sharing valuable outcomes during the studied project timeline. Responses supported the documentation of the project's complete lifecycle and comprehensively communicated existing information to record new knowledge and insights. Discussing the unique conditions faced by each project provided the foundational background in constructing the lessons learned surrounding the successes, challenges, and overall impact of each microgrid deployment.

Interview Topics

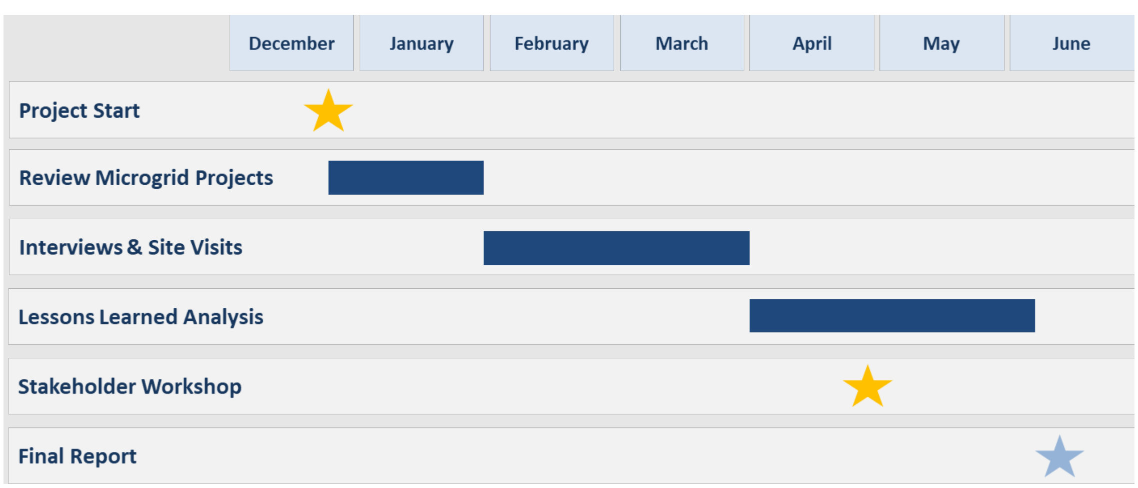
1. Project Motivation and Design
2. Project Implementation
3. Microgrid Operations and Performance Assessment
4. Stakeholder Engagement
5. Looking Forward
6. Funding and Administration

See Appendix A for complete interview questionnaires.

The goal of Task 4 (Stakeholder Workshops) was to present the findings of this work authorization, at a CEC sponsored workshop or workshops. The CEC and Navigant held the workshop on April 26, 2019, in Sacramento, California called "Lessons learned & best practices from 7 EPIC-funded microgrids."

The high-level project timeline for these tasks is illustrated in Figure 4.

Figure 4: Navigant Project Schedule



Source: Navigant

CHAPTER 2: EPIC-Funded Microgrid Projects

This chapter provides an overview and comparison of the seven EPIC-funded microgrid projects under PON-14-301 as a group; it is followed by individual sections summarizing each project's design, unique characteristics, and interviews with Navigant. The brief interview summaries describe areas in which there were key findings, which are then aggregated in the next chapter into lessons learned.

Overview of Awarded Projects

The awarded microgrid projects were:

1. Demonstrating a Secure, Reliable, Low-Carbon Community Microgrid at Blue Lake Rancheria
2. Laguna Wastewater Treatment Plant (WWTP) Microgrid
3. A Novel, Renewable Energy Microgrid for a California Healthcare Facility (Charge Bliss)
4. Las Positas College Microgrid Automation Project
5. Solar Emergency Microgrids for Fremont Fire Stations
6. Bosch Direct Current Building-Scale Microgrid Platform (DCBMP)
7. Borrego Springs: California's First Renewable Energy Based Community Microgrid

These seven microgrids are located throughout California, as shown in Figure 5.

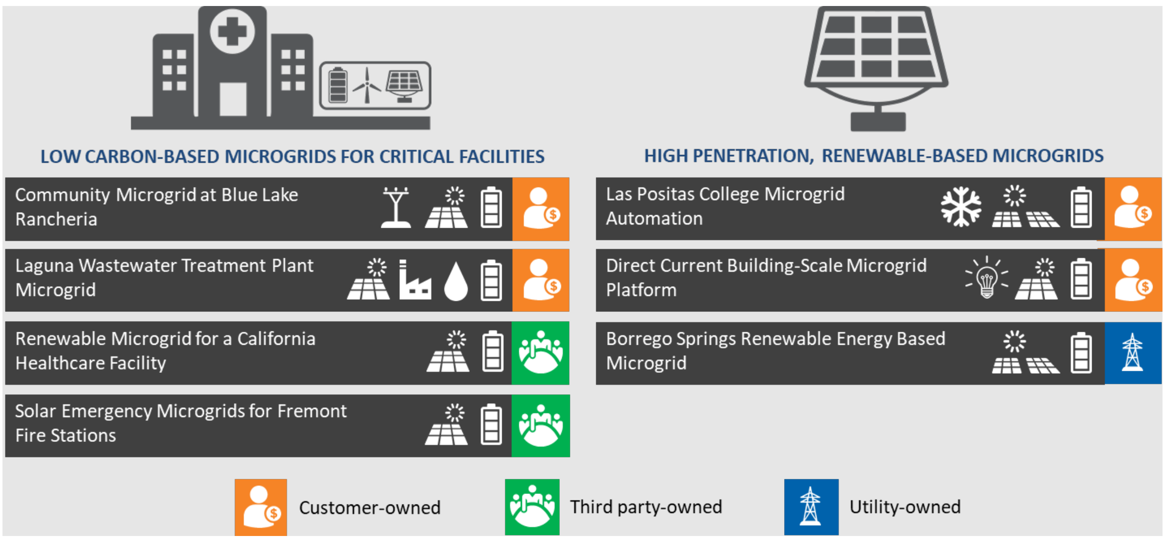
Figure 5: Microgrid Site Locations

Source: Navigant

As shown on the map, the projects are geographically dispersed from north to south, although all are in the western half of the state. Some of the projects are located in major population centers, such as the several San Francisco Bay Area microgrids, while others serve much more remote communities (e.g., Blue Lake, California; Borrego Springs, California).

In addition to geography, the seven microgrids span a variety of technical configurations and ownership models, as shown in Figure 6. Although the microgrids are divided into two main groups ("low carbon-based microgrids for critical facilities" and "high penetration, renewable-based microgrids"), according to the EPIC grant structure, there is still significant overlap between both groups, primarily in the universal deployment of low carbon solar + battery storage systems.

Figure 6: Technical Configurations and Ownership Models



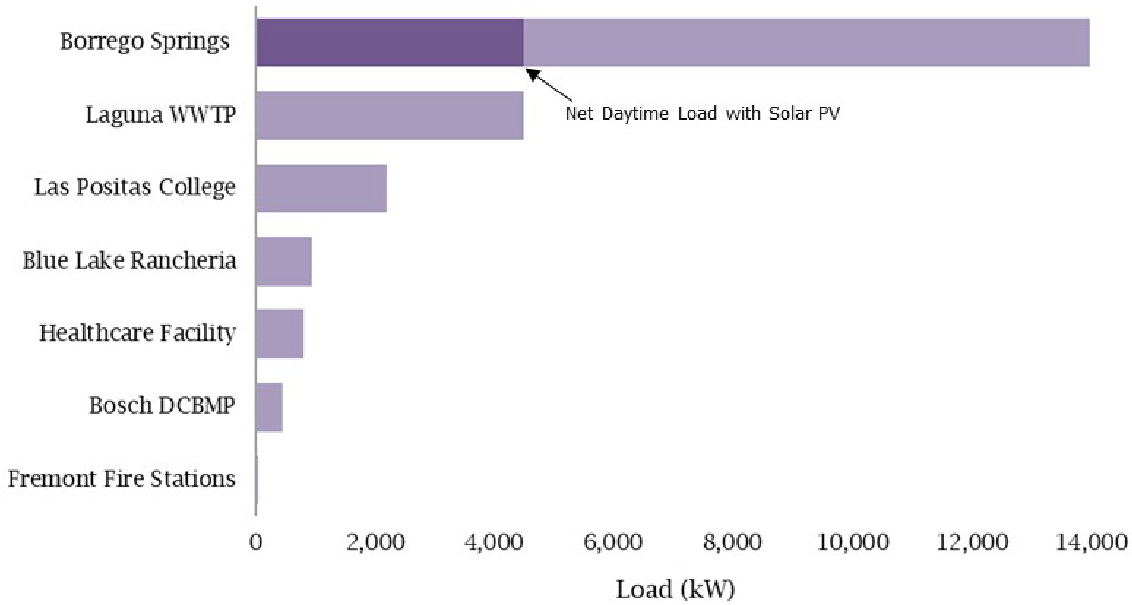
Symbols in the dark grey boxes represent microgrid components of solar PV arrays, battery storage, electric distribution infrastructure, combined heat and power (CHP), pumped water loads, thermal ice storage, and direct current light-emitting diode lighting. Additional information on each microgrid may be found in the following sections of this chapter.

Source: Navigant

The most common ownership structure is the customer-owned model used in four of the seven projects. Two of the projects are third party-owned with a power purchase agreement and/or service agreement between the developer and customer, and one project is utility-owned. Almost all the best practices identified in this report are common across all three ownership types, with a few lessons that may be more or less critical, depending on the type.

The seven projects benefit facilities and communities that are very different sizes (as measured here by peak load) and include a wide range of generation component sizes. For example, the Borrego Springs microgrid integrates a 26-megawatt (MW) third party-owned solar photovoltaic (PV) plant to serve a community of several thousand residents, whereas a single Fremont fire station has a peak electric load and solar PV array of less than 40 kilowatts (kW) each. These ranges are depicted in Figure 7 and Figure 8.

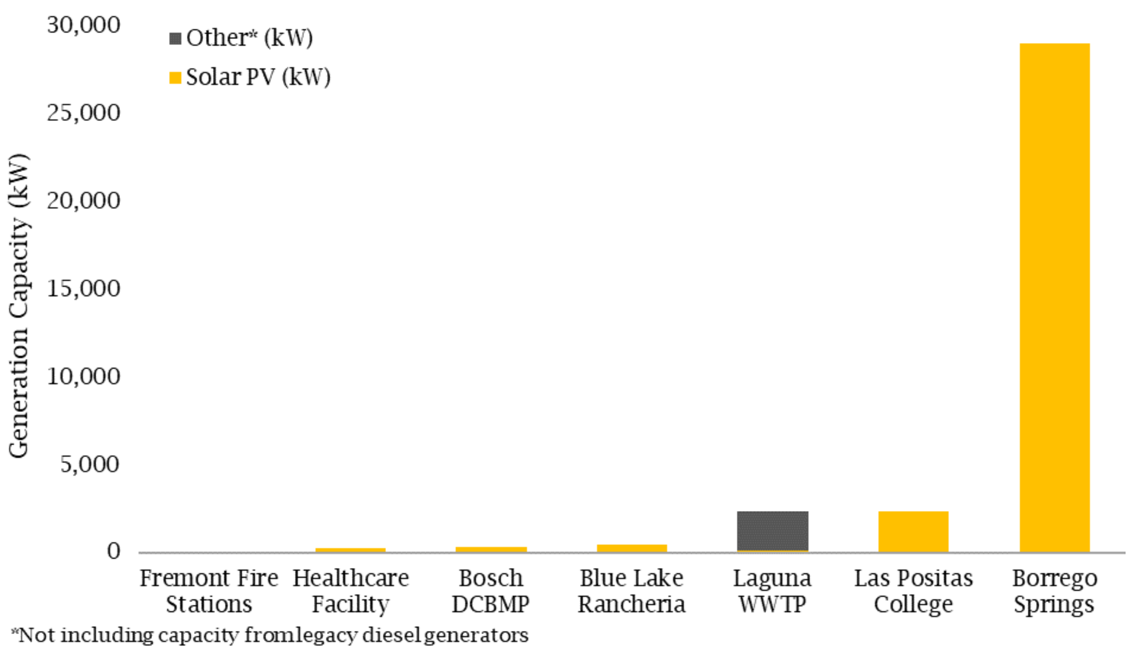
Figure 7: Approximate Facility Peak Load (kW)



Note: One of three Fremont fire station microgrids depicted

Sources: Interviews and final reports for Bosch, Charge Bliss, Blue Lake, Blue Lake Rancheria, and Borrego Springs, and interviews with Santa Rosa Water

Figure 8: Microgrid Generation Capacity (kW)



One of three Fremont fire station microgrids depicted. "Other" generation at the Laguna WWTP consists of CHP units. Borrego Springs incorporates a 26-MW third party-owned solar PV plant and several MW (and growing) customer rooftop solar PV.

Sources: Interviews and final reports for Bosch, Charge Bliss, Blue Lake, Blue Lake Rancheria, and Borrego Springs, and interviews with Santa Rosa Water and Las Positas Community College

In addition to solar PV, all seven microgrids leveraged battery energy storage systems (six using lithium-ion battery technology, one using flow battery technology) (see Table 3). Except for one microgrid project (the Laguna WWTP), the batteries are intended to charge primarily using solar energy and operate for relatively long durations (several hours).

Table 3: Microgrid Battery Energy Storage and Capacity

	Battery Capacity (kW)	Battery Storage (kWh)
Fremont Fire Stations	30	110
Laguna WWTP	2,000	167
Bosch DCBMP	180	540
Blue Lake Rancheria	500	950
Las Positas College	200	1,000
Healthcare Facility	250	1,000
Borrego Springs	1,500	4,500

Note: One of three Fremont fire station microgrids depicted. Not included: the approximately 11,000 kilowatt-hours (kWh) ice storage system at Las Positas College. The Laguna WWTP battery is designed for short-duration applications.

Sources: Interviews and final reports for Bosch, Charge Bliss, Blue Lake, Blue Lake Rancheria, and Borrego Springs, and interviews with Santa Rosa Water and Las Positas Community College

Several of the operating demonstration projects have reported significant bill savings in the first year, from both energy savings and peak demand shaving using the solar plus storage microgrid assets. Although most of the microgrids are not sized to cover all the facilities' electric loads, the microgrids reporting at least one year of operation are achieving 20 percent to nearly 60 percent energy cost savings and over 40 percent demand charge cost savings.[5]

An important objective for each EPIC-funded microgrid was also to successfully island part or the entirety of its electric load from the grid. The group conducted a variety of test events and several microgrids operated through real-world outages during the demonstration period. Figure 9 below shows a comparison of islanding objectives and measured islanding duration.

The Bosch DCBMP, the Fremont Fire Stations, and the Healthcare Facility (Charge Bliss/Kaiser) originally aimed to island microgrid loads for between three and four hours. The measured islanding durations shown here are based on limited tests, which were conducted to collect data and generally ended before the system would have failed in a true outage situation.

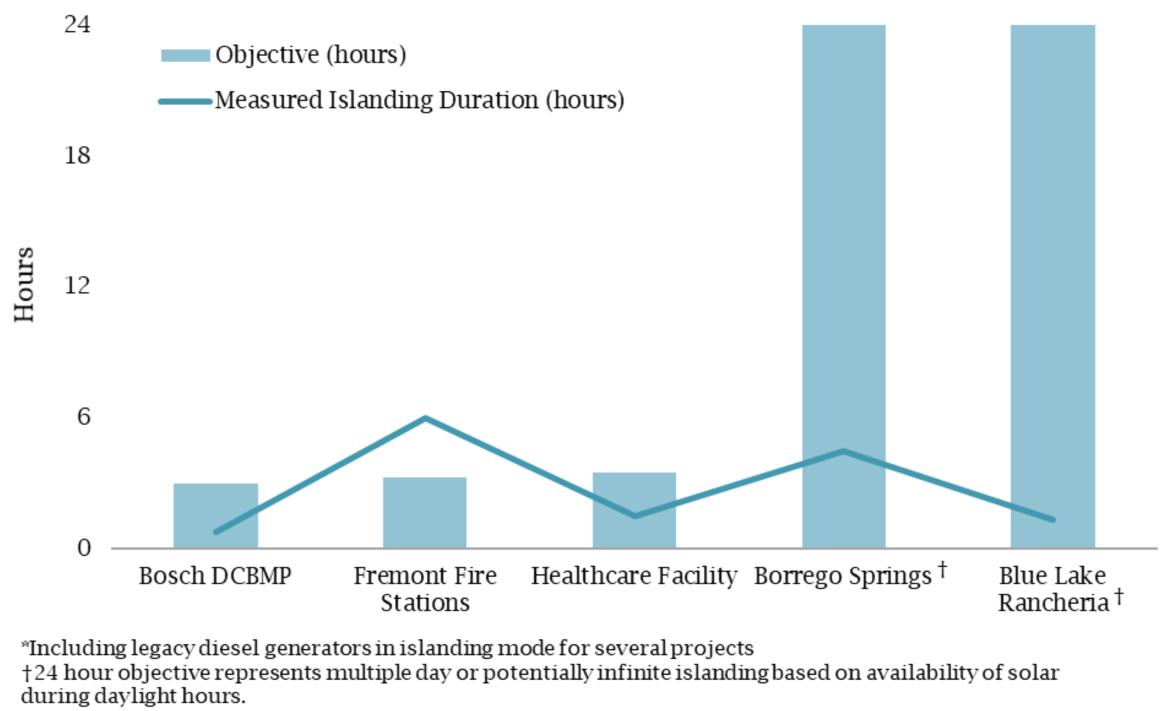
The 24-hour-plus objective represents achieving a long-term island in a severe outage situation. For Borrego Springs, the goal is to carry all loads during the day on renewables and drop down to critical loads at night, first with energy storage and then with legacy diesel generators. For Blue Lake Rancheria, the goal is to provide up to seven days of islanding capacity, enabled in part by a load shedding sequence. Blue Lake Rancheria is also doubling

[5] Estimated 20% bill savings for Kaiser Permanente Richmond Medical Center, 26.9-43.4% bill savings range for the Fremont Fire Stations, and 58% energy cost savings and 42% demand charge savings for Blue Lake Rancheria.

the battery size of its system to reach its long-range goal. Both microgrids recorded successfully islanding during real-world outages, providing the measured islanding duration in Figure 9. For the Fremont Fire Stations and the Healthcare Facility (Charge Bliss/Kaiser), an indefinite islanding situation is also possible with a combination of load shedding, solar, battery, and onsite fuel storage for the diesel generators. However, the objective cited in the technical reports is at least three to four hours.

The microgrid at the Laguna WWTP is not depicted here because it is designed for a different use case. Specifically, the battery system can carry a 2 MW load for five to seven minutes, acting more like a capacitor to ramp up and down as other plant functions come online to carry load during a loss of power from the grid. Islanding duration information for Las Positas was not provided at the time of this report but will be included in the project's final technical report.

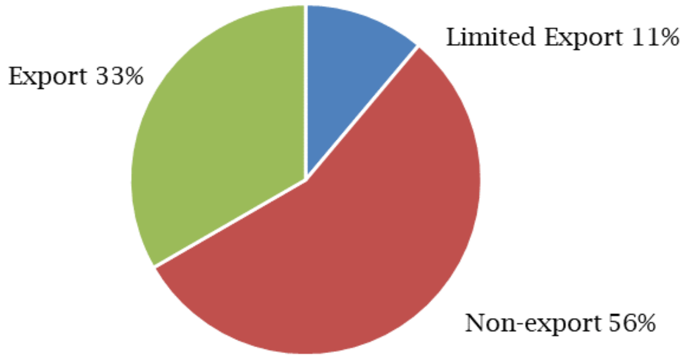
Figure 9: Islanding Objectives and Measured Islanding Duration



Sources: Interviews and final reports for Bosch, Charge Bliss, Blue Lake, Blue Lake Rancheria, and Borrego Springs, and interviews with Santa Rosa Water and Las Positas Community College

Electric Rule 21 governs most microgrid interconnections, with requirements for exporting (including net energy metering) systems and for non-exporting systems. The interconnection process, Rule 21, and related lessons learned are discussed in detail later in this report. Figure 10 shows a high-level comparison of the different interconnection types obtained by the projects, related to the export of electricity from the microgrid to the utility grid.

Figure 10: Comparison of Export Policy for Excess Power

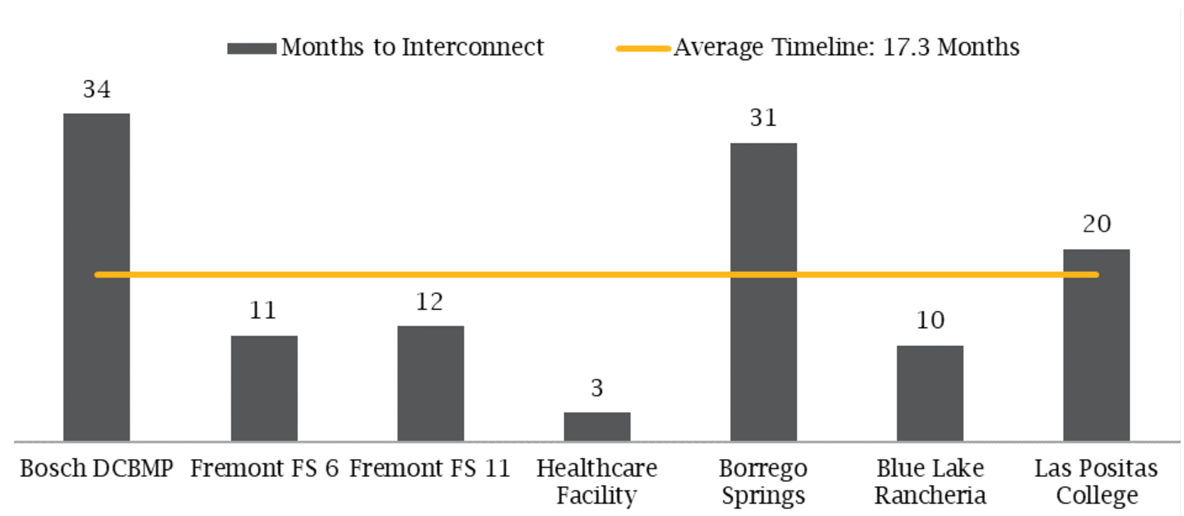


Note: Two of the three Fremont Fire Stations export power while one is under a non-export agreement; therefore, they are considered separately for a total of nine microgrids rather than seven. "Limited export" refers to the Blue Lake Rancheria microgrid with a 100-kW export limit.

Sources: Interviews and final reports for Bosch, Charge Bliss, Blue Lake, Blue Lake Rancheria, and Borrego Springs, and interviews with Santa Rosa Water and Las Positas Community College

Several grant recipients experienced delays in the interconnection process; these challenges and some solutions are discussed in the lessons learned. Overall, the interconnection timelines varied due to different design elements, exporting restrictions, and IOU technical studies required. On average, it took approximately 17 months from application to receiving permission to operate from the utility, a range of three months to three years.[6] The shortest three-month timeline was the result of the only successful fast track process.

Figure 11: Interconnection Process Duration (in Months)



Note: Laguna WWTP submitted a final design to interconnect in late 2018 and, at this writing, is in the process of receiving permission to operate. Fremont Fire Station 7 is awaiting interconnection.

Sources: Interviews and final reports for Bosch, Charge Bliss, Blue Lake, Blue Lake Rancheria, and Borrego Springs, and interviews with Santa Rosa Water and Las Positas Community College

[6] This average excludes the Laguna WWTP and Fremont Fire Station 7, as they are still going through the process.

Low-Carbon Community Microgrid at Blue Lake Rancheria

The Blue Lake Rancheria microgrid was designed and implemented by the Schatz Energy Research Center (SERC) team affiliated with Humboldt State University. The microgrid provides renewable energy to Blue Lake Rancheria (a federally recognized Native American tribal government) community resources. It is the first deployment of the Siemens Spectrum Power 7 microgrid management system and the first multi-inverter Tesla battery energy storage system used in a microgrid application. The grant allowed SERC to design, build, and demonstrate a low-carbon microgrid that integrates solar plus storage and pre-existing backup diesel generation.

Microgrid Design

- Solar: 420-kW alternating current (AC) PV ground-mounted array
- Energy Storage: 500-kW/950-kWh lithium-ion (Li-ion) battery storage
- Software and Controls: Siemens Spectrum Power 7 Microgrid Management System and Schweitzer Engineering Laboratories Protection Relays
- Other Infrastructure: Purchased distribution system infrastructure to create a new point of common coupling with the grid, integrating six buildings into the microgrid behind one electric meter
- Technology Integration: SERC at Humboldt State University

Unique Project Aspects

- Critical facility serving as an American Red Cross designated shelter
- Successfully islanded during several unplanned utility outages due to weather and nearby wildfires. The microgrid can deploy five levels of load shedding, depending on the outage and system conditions.
- Achieving energy cost savings of 58 percent and demand charge savings of 42 percent
- Plans to double the battery storage system, add solar PV, integrate more electric vehicle charging stations, and participate in demand response programs.

> *"With our project partners, primarily [SERC], we have proven the effectiveness of microgrids at the community scale in terms of cost, performance, and climate action. The Blue Lake Rancheria low-carbon community microgrid, powered by a solar photovoltaic array paired with battery storage, has vastly improved continuity of operations across the lifeline sectors — energy, water, food, transportation, and communication/IT."*
>
> *- Jana Ganion, Blue Lake Rancheria*

Figure 12: Photovoltaic Array at Blue Lake Rancheria

420-kW AC PV ground-mounted array at Blue Lake Rancheria

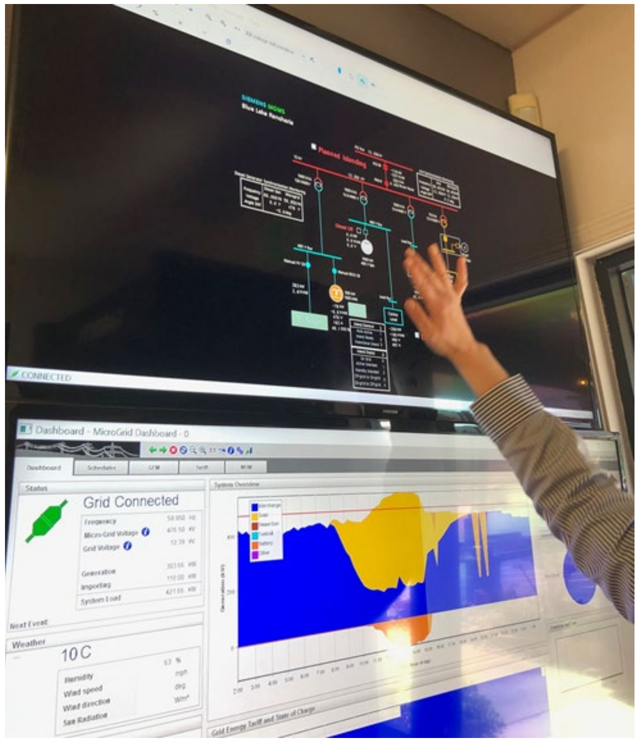
Source: Blue Lake Rancheria

Figure 13: Switchgear Enclosure

Point of common coupling (PCC) switchgear enclosure housing the PCC breaker, PCC battery system, and communications system

Source: Blue Lake Rancheria

Figure 14: Siemens Microgrid Management System (MGMS) Dashboard Screen



Blue Lake Rancheria representatives explaining the Siemens MGMS dashboard screen for system monitoring

Source: Navigant

Interview Summary

Navigant conducted interviews with the grant recipient and developer SERC and representatives from Blue Lake Rancheria (BLR).

SERC and BLR already had a good foundation for local partnership when the grant solicitation was issued, and SERC realized that BLR was the perfect site for the microgrid demonstration. The two organizations had established a working relationship in part through the work of Humboldt State University students evaluating distributed energy resources at BLR for their capstone projects, and through collaboration on a previous EPIC grant for a biomass-powered fuel cell (which ultimately did not go into operation but had been planned to be part of the later microgrid project).

As discussed in the interview, BLR is focused on ensuring continuity of operations for its government offices, hotel and casino business, and critical infrastructure in the event of an emergency. Underpinning the microgrid demonstration were BLR's fundamental goals related to resilience, decarbonization, conservation and preservation of natural resources, and self-reliance. Due to the threat of natural disasters (the region is a high-risk tsunami zone), the BLR campus is a designated American Red Cross shelter. In a major disaster event, BLR does not want to rely solely on available diesel fuel, despite having significant fuel storage capacity. With solar PV and battery storage, BLR can extend its power supply for a much longer period using renewable resources, using a five-level load shedding approach in the microgrid control system. In addition to the resilience aspect of the demonstration microgrid, SERC designed the system to perform demand charge reduction in response to grid pricing, resulting in significant bill savings for BLR.

> *"After almost two years of performance, the microgrid continues to provide stacked benefits, including new jobs, energy savings of approximately 30%, and seamless transfers to and from islanded operation in three wildfire outages. This effectiveness has prompted expansion, and with our partners SERC, PG&E, and the California Energy Commission, the Tribe is doubling the storage and solar PV within its community microgrid and building a separate solar plus storage microgrid at its fuel station convenience store complex."*
>
> *- Jana Ganion, Blue Lake Rancheria Tribe*

The BLR microgrid project encountered several unique challenges related to interconnecting the system to the utility grid but it was able to establish effective working relationships with the utility and regulators and experienced a high degree of support overall. Specifically, BLR had to purchase a segment of the utility distribution circuit in order to establish a point of common coupling for the microgrid system. This process required CPUC approval and additional specialized electrical testing. Although this extended the overall interconnection process, project participants understood the need for extensive safety testing.

Collaboration between SERC, subcontractors (such as the experienced local electrical firm), technology vendors, and BLR was a key factor in the success of the project and, importantly, this collaboration began early in the planning and design phase. Early testing with the Idaho National Laboratory was key to developing new microgrid controller functionality and resolving issues later in the project. This technical collaboration ultimately resulted in a better commercial microgrid controller product. Although the project timeline was constrained due to some design changes and unanticipated utility requirements, project commissioning was successful and the microgrid is currently operational.

Through an additional grant from the CPUC's Self-Generation Incentive Program (SGIP), future microgrid enhancements will double the size of the battery storage system for additional energy arbitrage benefits, load shifting, and optimal cycling of the battery. Eventually, BLR will integrate the campus electric vehicle (EV) charging stations. In parallel, BLR is constructing a second, smaller microgrid project on the neighboring gas station. Inspired by the demonstration project, BLR has developed a "lifeline sector" framework to meet community goals for sustainability, resilience, and independence, including concepts around water (such as a smart water grid or resilient regional water microgrid), food, transportation, and communications.

> *"The Blue Lake Rancheria microgrid project has been critically important in informing progress in microgrid design for us at Schatz Energy Research Center and for our utility partner PG&E. The lessons learned at BLR — where a single customer owns both the generation and distribution assets — led to our next and more complex microgrid project at the Redwood Coast Airport."*
>
> *- Peter Lehman, Founding Director, Schatz Energy Research Center*

Laguna Wastewater Treatment Plant Microgrid

The Laguna WWTP Microgrid project was led by Trane U.S., Inc. to create an advanced, renewable-integrated microgrid for a wastewater treatment plant in California.

Microgrid Design

- Solar: 126-kW carport solar PV array
- Energy Storage: 2-MW Li-ion battery storage
- Software and Controls: Trane microgrid management software programmed with California Independent System Operator's (CAISO) market participation scenarios
- Other Infrastructure: Onsite substation and two 1.1-MW CHP units, each with a selective catalytic reduction unit to reduce emissions (Figure 15) on these previously unused CHP units
- Technology Integration: Trane

Unique Project Aspects

- Flow equalization basins enable the wastewater treatment plant to modify power usage through operations to participate in different CAISO market scenarios, with plans to participate in the CAISO Proxy Demand Resource (PDR) program specifically.
- Battery storage provides short duration dispatch — it performs like a capacitor (Figure 16).
- The project is still in the interconnection process, with additional testing to be completed, and therefore is not yet operational.

Figure 15: SRC Units on CHP Units

SRC units on CHP units (1.1 MW each) to reduce emissions

Source: Navigant

Figure 16: Laguna Wastewater Treatment Plant

Aerial photo of Laguna WWTP, including the 126-kW carport solar array

Source: Trane

Interview Summary

Navigant conducted interviews with the grant recipient and developer Trane and representatives from the City of Santa Rosa and Laguna WWTP management together at the site.

When the EPIC grant solicitation was published, Trane sought a demonstration facility among more than 50 WWTPs before partnering with the City of Santa Rosa. The Laguna WWTP is a critical facility for the City of Santa Rosa and is responsible for treatment services for surrounding communities in Sonoma County. Additionally, it supplies water to the Geysers geothermal power plant through the Geysers Recharge Project. The Laguna WWTP was the best site for the project for several reasons, including its size, existing on-site generation assets in the form of a CHP plant, and a city government proactive on energy and sustainability.

This microgrid demonstration project had a unique design because of several important characteristics of the Laguna WWTP. A key aspect of the design was using two existing CHP units (of four total) that were previously unable to run because of air quality restrictions. The grant-funded demonstration project installed two selective catalytic reduction units on the unused CHP units that allowed them to run. In addition to the existing CHP assets, the facility has unique flow equalization basins that enable the plant to adapt its operations via flow diversions to participate in demand response programs.

Trane designed the microgrid to enable the facility to participate in the CAISO day-ahead market through the PDR program to improve its revenue stream. Trane's software works with the microgrid controller and the pre-existing plant's supervisory control and data acquisition (SCADA) systems to perform different market participation scenarios based on the operational needs of the plant, as determined by on-site staff. The 2-MW battery system is a short duration storage application, functioning more like a capacitor for five to seven minutes so that the CHP plant can ramp up to the needed capacity over a longer period.

City permitting and utility interconnection processes posed several major challenges for the project, impacting the overall timeline and cost. Interviews with Trane and the City of Santa Rosa discussed these challenges, providing several key lessons learned related to navigating these processes. Because of delays, the project is not yet operational but, at the time of the interview, will soon be operating for testing purposes for the next month. Based on the software and business model developed during this grant-funded demonstration project, there may be significant microgrid opportunities at other WWTPs and large industrial facilities.

Renewable Energy Microgrid for a California Healthcare Facility

The Charge Bliss Renewable Microgrid was the first renewable-integrated microgrid in California supporting the critical loads of an acute health facility, the Kaiser Permanente Richmond Medical Center (Figure 17). At the time of commissioning, it was among approximately four similar projects in the nation.

Microgrid Design

- Solar: 250-kW top-level parking garage solar PV array
- Energy Storage: 250-kW/1-MWh Li-ion battery storage (Figure 18)
- Software and Controls: Charge Bliss microgrid controller and Princeton Power Systems Energy Management Operating System
- Other Infrastructure: LED lighting in solar canopies
- Technology Integration: Charge Bliss and CONTECH-CA

Unique Project Aspects

- Demonstrated the first renewable-integrated microgrid supporting an acute, critical health facility in the state.
- The Office of Statewide Health Planning and Development (OSHPD) regulates facility requirements and served as an active partner, approving connections to both normal power and the life and safety circuit (through a manual transfer switch).
- Estimated 20 percent bill savings from mitigating high summer demand charges.
- Additional microgrid opportunities for healthcare facilities were identified, for example: (1) with increased utility wildfire disruptions, the need for additional, longer-duration emergency power systems, and (2) numerous opportunities with medical office buildings that are not OSHPD-regulated.

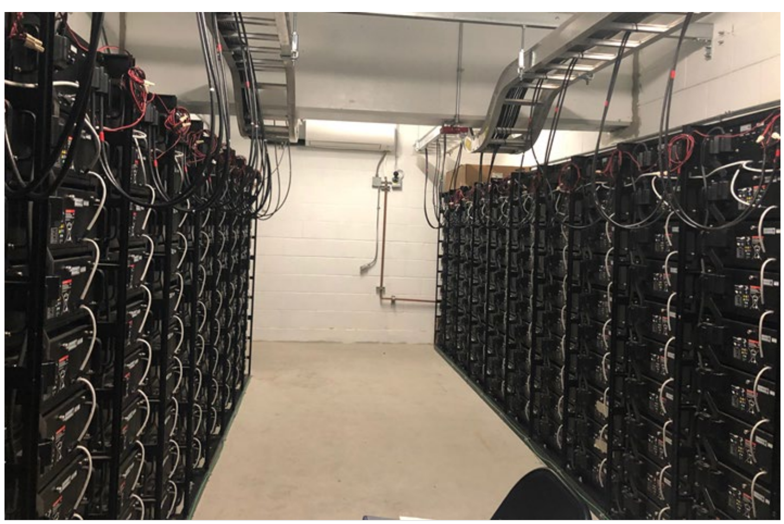
Figure 17: Kaiser Permanente Parking Garage

Aerial photo of the parking garage adjacent to Kaiser Permanente, including the 250-kW top-level solar array

Source: Charge Bliss

> *"Since this project was implemented and publicized around the Kaiser Permanente network, we've gotten more than a half-dozen inquiries from our facilities around California and beyond, including Hawaii, asking if we could do there what we did in Richmond. We're going through the same process of technical assessment for these interested facilities as we did for the Richmond Medical Center. […] We'll have a sense in the coming year or so about exactly how fast and in what ways we'll be able to replicate the Richmond project. It's certainly going to be replicated in one way or another, but it's still early days."*
>
> *- Seth Baruch, Kaiser Permanente*

Figure 18: Battery Energy Storage System



Shipping container-sized 250-kW/1-MWh battery energy storage system

Source: Navigant

Interview Summary

Navigant interviewed grant recipient Charge Bliss and key partner CONTECH-CA, and conducted follow-up calls with Kaiser Permanente representatives.

Charge Bliss' original grant proposal identified John Muir Medical Center in Walnut Creek as the site host for the project. However, this hospital withdrew from participation after the grant was awarded. Charge Bliss worked with the CEC to substitute a new site, the Kaiser Permanente Richmond Medical Center, to implement the project. This caused an early project delay of approximately six months, but highlighted good collaboration between the grant recipient, the CEC, and OSHPD. OSHPD's assistance helped identify a list of possible hospital locations, which were then vetted by the CEC.

From the perspective of Kaiser Permanente, the proposed microgrid project aligned with the nationwide corporate goal for carbon neutrality. The project benefited from the support of the corporate energy and utilities team, executive leadership of the Kaiser Permanente Richmond Medical Center, and the local facility management team. In addition to supporting renewable energy at its facilities generally, the Richmond Medical Center is an important critical care facility in an underserved community, had previously experienced some issues with power reliability, had physical space available for microgrid components, and would benefit from peak demand management savings.

In addition to incorporating renewable energy and mitigating peak demand charges (on the order of 20 percent bill savings by discharging the battery system to mitigate summer demand peaks), the microgrid design focused on providing resilient power for emergency services in the event of a grid outage. This is a significant challenge for a high-occupancy life and safety facility and it necessitated close collaboration with OSHPD. This was groundbreaking work for OSHPD, resulting in a better understanding of backup power systems other than the required traditional diesel generators and of a microgrid design that connects directly to the emergency power system. Although the microgrid currently operates with the existing diesel generation as the "master" island, in the future, hospitals may be able to connect to the solar plus storage system as the first option when islanding. OSHPD was an active partner in engineering this project, and it even proactively suggested that the microgrid connect to the emergency branch of the hospital.

During design and installation, Charge Bliss and CONTECH-CA encountered several siting and construction challenges that informed lessons learned for the project. Permitting, physical space planning, land ownership, and other steps required significant attention from the project team. Additionally, the technical requirements and the sequence of operations for the microgrid controller were relatively complex, particularly in relation to the redundant diesel backup system and islanding. Despite challenges, the microgrid installation and operations never disrupted hospital patients.

Charge Bliss' experience with a critical healthcare facility during this demonstration project positioned the company to pursue additional healthcare customers in California, as well as other customer sectors going forward (generally other large energy consumers). There are additional research and development funding needs, including for standardized microgrid controllers. Perhaps more importantly, outreach and education should be directed at decision-makers and key stakeholders who are not yet familiar with microgrid technology, such as many construction companies, C-suite executives, and facility and building managers. Kaiser Permanente is also continuing to pursue microgrid projects (and solar plus storage) at its facilities, with great interest from medical office buildings.

Las Positas College Microgrid Automation Project

The Las Positas College campus (Figure 19) microgrid project integrated an existing 1.35-MW ground-mounted solar PV array and a 1.0-MW parking lot solar PV canopy array with the grant-funded 1-MWh vanadium flow battery by UET Technologies. These distributed energy resources, along with an existing 3,200-ton/hour ice storage system (Figure 20), are managed in the campus microgrid using Geli software and a master controller from Schweitzer Engineering Laboratories. The inclusion of several types of large-scale energy storage systems, including thermal energy storage and a flow battery, was a unique feature among the grant awardees.

Microgrid Design

- Solar: 2.35 MW in total, consisting of an existing 1.35-MW ground-mounted solar PV array and 1-MW parking lot canopy array
- Energy Storage: 1-MWh vanadium flow battery energy storage (Figure 21)
- Software and Controls: Schweitzer Engineering Laboratories master controller/islanding controls and Geli energy operating system for demand response
- Other Infrastructure: Legacy 3,200-ton/hour ice storage system
- Technology Integration: WSP

Unique Project Aspects

- Large-scale energy storage systems, including thermal energy storage and flow batteries, makes the technology mix distinct from other projects.
- The existing high penetration of solar resulted in a campus "duck curve," which is mitigated by the ice storage system and now the flow battery.
- The goal is to participate in demand response, but the college is currently re-evaluating the value of demand response versus mitigating increasing demand charges on a new time-of-use rate.
- The college plans to continue developing an Internet of Things approach for campus microgrids.

Figure 19: Las Positas Community College

Aerial view of Las Positas Community College

Source: Las Positas College

Figure 20: Ice Storage Tank

One of a dozen legacy 3,200-ton/hour ice storage tanks

Source: Navigant

Figure 21: Vanadium Flow Battery Storage System and Inverter

Housing for the 1-MWh vanadium flow battery energy storage system (left) and one inverter (right)

Source: WSP

Interview Summary

Navigant conducted interviews with Las Positas facilities management and the lead WSP project developer together at the site.

Las Positas Community College is the only college campus-based microgrid in the group and set forth objectives to prioritize onsite solar energy, participate in demand response, demonstrate the effectiveness of microgrid energy management algorithms, collect and analyze performance and operational data, and provide a model for other California public education school sites. California community colleges have a policy goal to achieve zero net energy campuses and Las Positas had a demonstrated interest in renewable energy and sustainability from its numerous previous initiatives.

As the primary microgrid implementer, WSP encountered several challenges with various products and control systems from different suppliers. Despite this, the final microgrid system, with a combination of control software for the various components, has successfully demonstrated significant energy savings for the campus by reducing peak demand using energy storage. Looking forward, the college is commissioning a study to re-evaluate demand response program participation, which was not previously allowed. The college is also monitoring developments in time-of-use rate design from the utility, which may affect future revenues from energy arbitrage activities.

Supplier challenges were also related to flow battery vendors (going out of business) and inverter vendors (requiring Underwriters Laboratories [UL] certification and compatibility with the flow batteries). The flow battery system is not yet fully operational, but several component replacements are planned. The project is collaborating with Sandia National Laboratory to perform additional testing. As with several other projects, the interconnection process posed more challenges to the timeline than the project team originally anticipated.

Las Positas is still optimistic about an Internet of Things approach to campus microgrids, but there are research and development needs related especially to communication protocols between different microgrid components, as demonstrated by some of the challenges encountered in this project. Despite this, the EPIC program proved extremely valuable for the project partners, all of whom developed new and improved products from their experience.

Solar Emergency Microgrids for Fremont Fire Stations

Three City of Fremont Fire Stations were converted into independent microgrids, pairing solar PV carports with battery storage systems. This project is one of several critical facilities with backup power requirements in the group of grant awardees and is the only first responder.

Microgrid Design

- Solar: 115-kW total carport solar PV (38 kW at Fire Station 11, 43 kW each at Fire Stations 6 and 7) (Figure 22)
- Energy Storage: 30-kW/110-kWh Li-ion battery storage at each fire station (totaling 333 kWh) (Figure 23)
- Software and Controls: Gridscape Solutions' cloud-based predictive distributed energy resource management software (DERMS) and energy management system — EnergyScope
- Other Infrastructure: None
- Technology Integration: Gridscape Solutions

Unique Project Aspects

- The solar plus storage microgrid displaces diesel generation and extends fuel reserves in the event of a catastrophic emergency, keeping the fire station online longer as a viable first responder.
- The first fire station deployment was characterized by extensive prototype development and testing, refined over the next two deployments. Grant recipient Gridscape Solutions developed the EnergyScope product through this project.
- The systems have successfully executed 3-hour and 6-hour islanding tests, with plans for a 12-hour test.

Figure 22: Solar Array at Fire Station

43-kW carport solar array at one of the Fremont Fire Stations.

Source: Ecology Way

Figure 23: Battery and Power Conditioning System

Delta's battery system (right) and power conditioning system (left) in the fire station yard

Source: Navigant

Interview Summary

Navigant conducted joint interviews with the grant recipient and developer Gridscape Solutions and representatives from the City of Fremont and the Fire Department, as the microgrid customer, at one of the fire stations.

As a local company looking to deploy cleantech projects, Gridscape Solutions was already in contact with the City of Fremont when the EPIC grant solicitation was issued, and Fremont was the first city to seize the opportunity to partner. The City of Fremont is the fourth largest city in the Bay Area and has goals for climate and sustainability, resiliency, cost savings, and economic development. During the interview, city representatives described how they selected fire stations to be part of the microgrid demonstration project. The city first looked at its critical facilities broadly, including Police Department buildings and the maintenance center; however, these sites were already pursuing solar PV installations under an Alameda County solar purchasing initiative. The fire stations were key critical infrastructure without renewable energy projects already underway, and the Fire Department turned out to be an extremely cooperative partner. From the city's perspective, the project would not have happened without strong support from the Fire Department, including a willingness to do microgrid testing during standard operations and emergency response events.

From the Fire Department's perspective, the microgrid project was attractive due to improved disaster preparedness while meeting specific technical and operational requirements. For example, the fire stations needed to avoid downtime in microgrid installation, with no impact on dispatch and alert systems. The fire stations already have diesel generators for backup power, and one of the biggest benefits of the solar plus storage microgrid is extending the fuel supply for the diesel generator over a longer period of time during a major disaster event. This increases the viability of the fire stations to serve as first responders and alleviates concerns about running out of fuel. Gridscape Solutions provided training and written procedures for operating the microgrids for staff on site. During installation and early operations so far, the Fire Department has "never had one complaint or concern" about the project.

As a startup, Gridscape Solutions was able to significantly accelerate its product development timeline through the grant-funded demonstration project. Importantly, the company was able to do lab testing and prototype development, including comparing AC- and DC-coupled systems, before designing the fire station sites. During the grant program, Gridscape Solutions turned its existing software capabilities into a commercial product through the prototype development process, resulting in EnergyScope — a cloud-based predictive DERMS.

From the city's economic development perspective, Fremont has many cleantech companies and wants to do everything it can to support them. Gridscape Solutions is based in Fremont and had six team members when it started with the demonstration project; it now has a team of over 40 people. The project also used equipment from another Fremont-based company (Delta) and nearby in Berkeley (Sun Light & Power), which has the added benefit of showcasing and scaling innovation in Fremont's own backyard.

The City of Fremont is considering microgrids at other fire stations and critical facilities, with a focus on resilience and supplying critical loads with battery backup rather than traditional diesel generators. In the event of a significant regional natural disaster, the city expects to be on its own for an extended period of time, especially with resources going to the three larger urban centers (San Francisco, San Jose, and Oakland). If critical facilities like the fire stations can stay online with microgrid solutions, they can quickly report their status and needs and get access to aid. There are opportunities for additional research and demonstration projects in line with these disaster preparedness considerations, including mobile battery backup power that can be deployed to disaster sites and electric vehicle charging for transportation when the grid goes down.

All three systems so far are performing better than expected, with higher-than-anticipated building load offsets from the grid. They have completed 3-hour and 6-hour islanding tests on the systems, with plans for a 12-hour test. After developing and refining the products and working through utility interconnection and other challenges, Gridscape Solutions is broadening its scope to additional customer segments, including other critical facilities with backup power requirements (life and safety systems) and commercial and industrial customers with operations 24 hours per day, 7 days per week (24/7). The goal is to standardize and streamline future projects.

> *"The Fremont Fire Station Microgrid project has provided a solid foundation to refine and prove our microgrid solution in a real-life critical facility operation. This project has provided immense value in terms of performance and operational data collection as Gridscape commercializes this solution across the state, country and rest the world."*
>
> *- Vipul Gore, Gridscape Solutions*

Bosch Direct Current Building-Scale Microgrid Platform

The Bosch DCBMP project integrated advanced technologies on a direct current (DC) architecture to provide reliable power to connected commercial loads, resilience during grid outages, and increased energy efficiency and solar energy utilization. The DC building grid architecture also eliminated equipment required to convert electricity from the on-site generation, making the overall system more efficient compared to an AC microgrid. The DCBMP was installed at an American Honda Motor Co. warehouse facility in Chino, California, primarily to serve DC lighting and ventilation loads and reduce demand charges. The Bosch DCBMP was the only fully DC architecture-based microgrid (also considered a DC building grid) in the group of awardees.

Microgrid Design

- Solar: 286-kW DC solar PV rooftop array
- Energy Storage: 180-kW Li-ion battery storage (Figure 24)
- Software and Controls: Bosch's DC microgrid energy management system
- Other Infrastructure: 380-volt DC bus, DC LED high-bay lighting (Figure 25) and industrial fan variable frequency drives
- Technology Integration: Bosch

Unique Project Aspects

- The only fully DC architecture-based microgrid/building grid, primarily serving DC lighting and ventilation loads on a 380-V DC bus supporting 24/7 operations at a Honda distribution center (Figure 26).
- Encountered hurdles related to DC equipment (UL certifications for equipment and specifications for interconnection) but also increased system efficiency (2 percent to 6 percent in DC loads, 7 percent to 10 percent solar use) and reduced building maintenance needs.

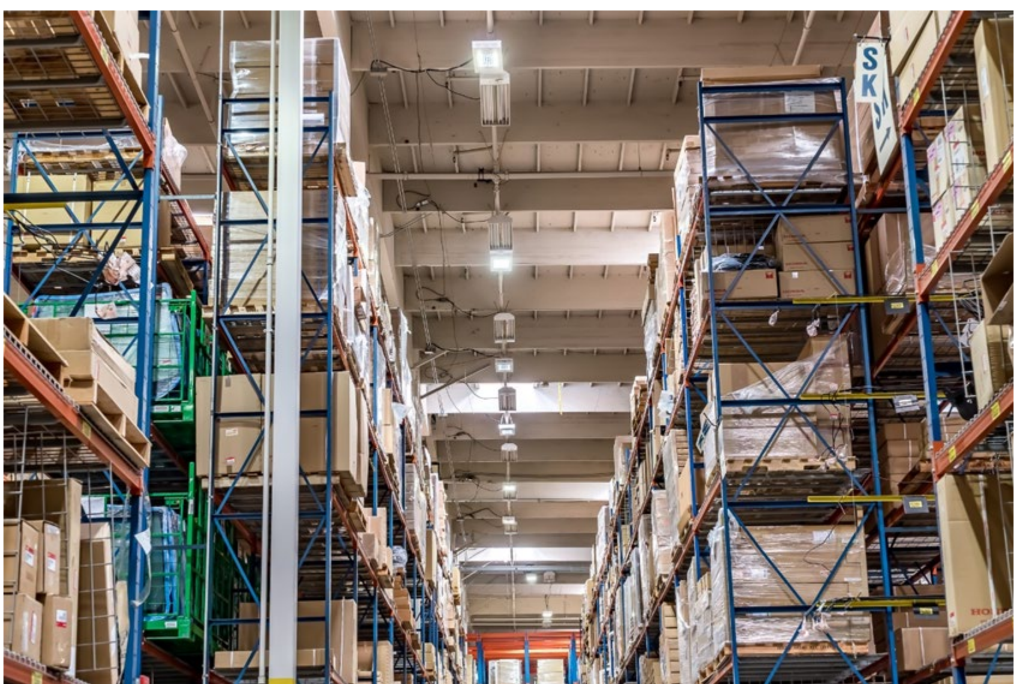
- Estimated approximately30 percent lower total cost of ownership compared to AC microgrids — at commercial scale.
- Bosch and the California Lighting Technology Center developed a DC building grid training program for electrical installers and inspectors.

Figure 24: Energy Storage System Container

Johnson Controls energy storage system container

Source: Bosch

Figure 25: Direct Current LED Lighting



Direct current LED lighting (on) next to legacy lighting fixtures (off)

Source: Bosch

Figure 26: Honda Distribution Center

Honda distribution center rooftop solar PV arrays in Chino, California

Source: Bosch

Interview Summary

Navigant conducted joint interviews with the Honda facility manager and the lead Bosch team members at the site. The group first discussed how Bosch and Honda originally partnered to develop the project. The Bosch team initially connected with the Honda corporate sustainability and energy management group, who gave support and approval for the project and then introduced the project to the facility manager. The DCBMP ended up being a "perfect fit" from the corporate perspective, with Honda's carbon reduction goals and familiarity with DC power, and for the warehouse, with its 24/7 operations, potential for demand charge savings, and interest in reduced operations and maintenance (O&M) with a DC system. Additionally, Bosch's name brand recognition made it a trusted company and there was a strong corporate relationship between the two firms. From the Bosch team's perspective, the 24/7 operations, suitable loads for DC (high-bay lighting and fans), available roof space for solar PV, and summer peak demand charges made the Chino facility the best Honda site for the DCBMP.

Challenges with some equipment suppliers (e.g., flow battery vendor going out of business), the utility interconnection process, and changes at the warehouse facility (a separate rooftop solar array and changing electric rate schedules) caused delays in the project timeline and limited the demonstration project's ability to collect both baseline and operational data. The team discussed these issues in depth during the interview to extract lessons learned and guidance for future projects. However, the facility manager was confident that the DCBMP would result in significant benefits for his operations, estimating up to a 45 percent to 50 percent reduction in maintenance costs due to the DC LED lighting and DC-based equipment. The benefits from DC equipment would ideally have been proven over a longer-term data collection timeframe of three to five years. The longer the equipment lasts, the better it is for the facility manager, although this is difficult to quantify over a demonstration period. Fortunately, the benefits of the DC LED lighting were immediate — the warehouse lighting became much better, cleaner, and crisper. The DC LED lighting and other components also helped the facility achieve Title 24 compliance.

The DCBMP was uninstalled at the end of the grant period due to outside factors (at a corporate level, Bosch decided to discontinue the DCBMP technology solution offering), but the facility manager came out of the experience a firm believer in DC microgrids (DC building grids), with several key recommendations to support this technology. Recommendations included additional outreach to and education of facility managers through the Building Owners and Managers Association, demonstrations with longer data collection periods, and incorporation of DC building grids into Title 24 building efficiency standards.

After working through a variety of technical challenges in the grant-funded demonstration, the Bosch DCBMP was ultimately unable to pursue a broader market launch because of discontinuation of the solution offering. However, there are still opportunities for the CEC and other entities to fund additional DC-specific research and development projects that leverage lessons from the Bosch DCBMP. Future work could develop additional DC equipment, such as lighting, electric vehicle chargers, and HVAC systems that would be components of a DC building grid. The Bosch team, as the grant recipient and microgrid developer, and Honda, as the microgrid customer, both saw significant value in DC systems going forward.

Borrego Springs: Renewable Energy Based Community Microgrid

The Borrego Springs microgrid is unique among the seven EPIC awardees in that it is a utility-owned and operated project. The microgrid is a phased project, partially established and operational as early as 2008 due to a prior grant from the US Department of Energy.

Microgrid Design

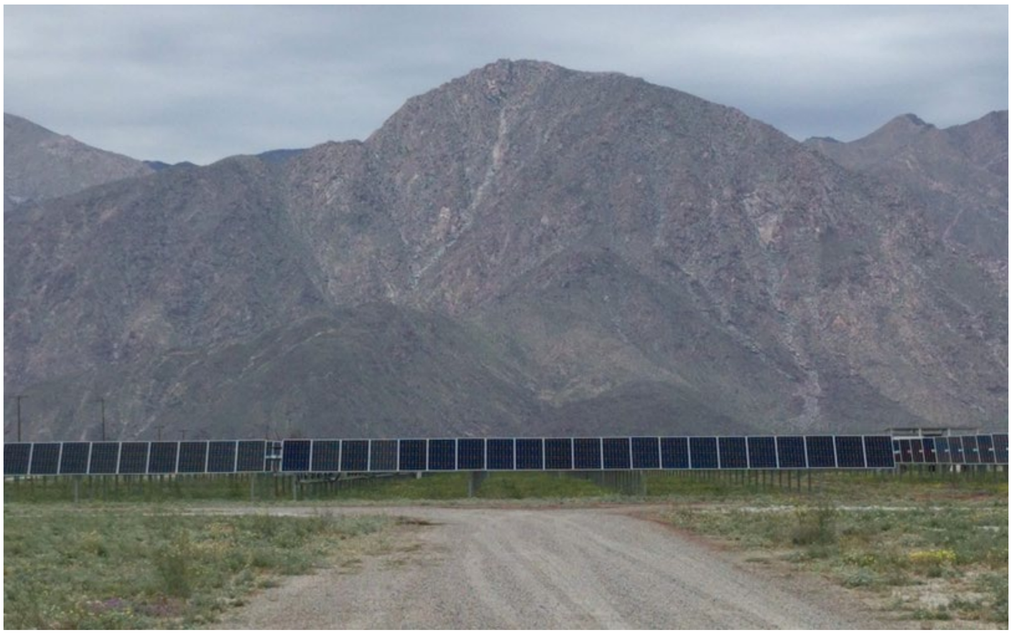
- Solar: Integrated existing 26-MW ground-mounted solar PV array (Figure 27) and 3-MW distributed customer rooftop solar PV
- Energy Storage: 1.0-MW/3-MWh Li-ion battery storage (Figure 28), adding to a 500-kW/1,500-kWh Li-ion battery and 3x 25-kW Li-ion batteries (previous project phase)
- Software and Controls: SDG&E and Spirae DERMS/Advanced Microgrid Controller
- Other Infrastructure: Incorporates all three 12-kV circuits in Borrego Springs (Figure 29), and currently integrating a 250-kW ultracapacitor
- Technology Integration: SDG&E

Unique Project Aspects

- Multiphase project, with most recent EPIC-funded phase focused on increasing solar plus storage and microgrid automation and controls. The utility-operated DERMS/microgrid controller now connects to the 26-MW Borrego Solar Project owned by Clearway (previously NRG).

- All of Borrego Springs (2,800 customers) can island for several hours during the day (4.5 hours in May 2018), and designated critical loads can island at night.
- SDG&E is working to resolve challenges with such a high penetration of solar PV, which can cause frequency issues while islanding. This will be important experience for the state as it moves to 100 percent carbon-free energy.

Figure 27: Clearway Solar Photovoltaic Array



Clearway-owned 26-MW ground-mounted solar PV array in Borrego Springs

Source: SDG&E

Figure 28: Battery Storage Containers

Battery storage containers and SDG&E engineer

Source: The Los Angeles Times, March 19, 2019

Figure 29: View of Borrego Springs

Mountain-side view of Borrego Springs

Source: Navigant

Interview Summary

Navigant conducted interviews with key members of the SDG&E team at the site.

The goals for the initial microgrid development phase (Borrego 1.0) centered around achieving at least a 15 percent feeder peak load reduction, integration of an outage and distribution management system, and the capability to intentionally island customers in response to system problems. Borrego Springs was chosen from a list of 20 substations for satisfying the most qualifying criteria, including: having a substation property with room for expansion, two or three 12-kV interconnected circuits, a progressive customer base, a mix of residential and commercial loads, and a history of reliability concerns.

In 2009, the Borrego Springs microgrid received a PIER (Planning, Infrastructure, and Economic Revitalization) grant from the CEC that focused on customer advanced metering infrastructure and demand response. Home-area-network devices (thermostat, water heater, pool pump) were installed and connected to the system so that pricing signals could be sent to customers. This information would encourage customers to curtail their local energy usage, thereby reducing load on the system. However, customers were brought into the program in November and December, when they did not have large loads in their homes.

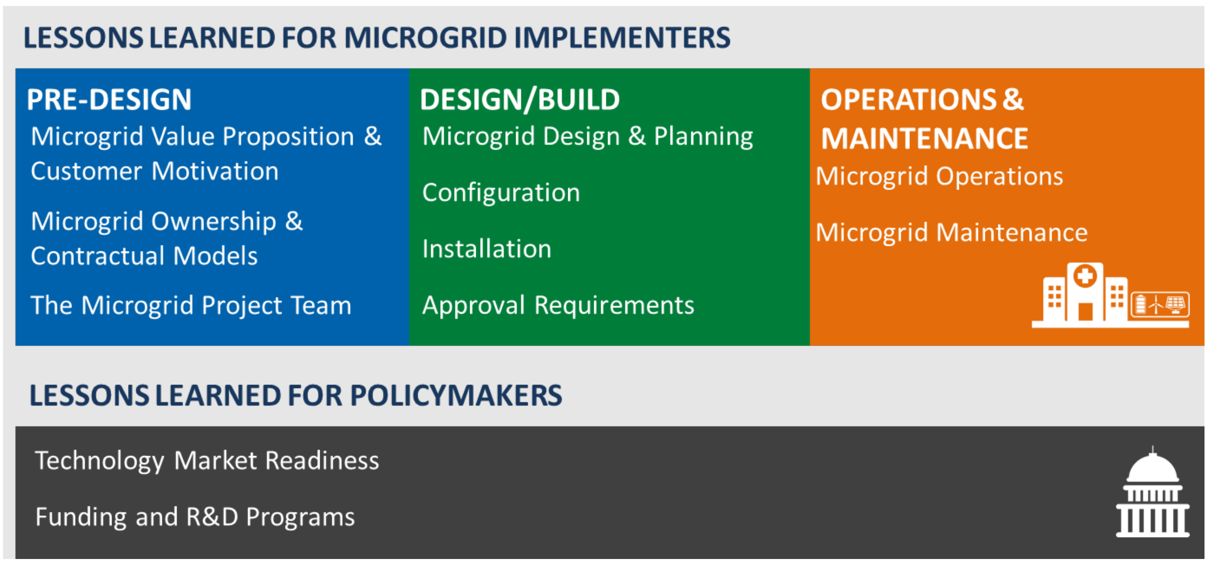
Under the EPIC program in 2015, SDG&E expanded the microgrid to cover all three local circuits, installed Spirae's Wave™ product an advanced microgrid controller — and connected the microgrid to NRG's 26-MW Borrego Solar Facility. The goal of this phase of the demonstration project (Borrego 2.0) was to provide power to the entire town of Borrego Springs during the day and to drop non-critical loads at night, using 100 percent renewable energy sources and focusing on automation. Critical loads include the fire station, library, grocery store, gas stations, and the cool zone in the town's center. Critical facilities are more than emergency services because of the remote nature of the community and the historical length of outages. The Borrego Springs microgrid currently serves approximately 2,800 utility customers, with an average peak load of 14 MW. Residential solar installations have tripled from 1 MW to 3 MW over the last few years, which has greatly reduced peak load on the grid. The system uses the large 26-MW third-party solar PV system in addition to residential rooftop PV systems, two 1.8-MW diesel generators, large-scale substation batteries, and three small-scale distributed community batteries.

SDG&E has approached the project as a continuously improving commitment to the community. It has run several successful planned maintenance outages in which the microgrid powered all of Borrego Springs. However, complications with communication between the microgrid controller and frequency stabilization in the renewable-powered islanded system have resulted in several unsuccessful islanding demonstrations. There is a need for future research and development to address challenges with frequency and voltage ranges in a solar plus storage island, which may become a significant issue as California moves to a higher penetration of renewables.

CHAPTER 3: Lessons Learned

The EPIC-funded demonstration projects provided valuable lessons learned across the micro-grid project lifecycle and stakeholder ecosystem, aggregated from the in-depth interviews conducted for this study. The following figure shows the categories of lessons learned presented in this chapter. There are two primary audiences for the lessons learned, in addition to increasing public knowledge generally: microgrid “implementers” (developers, vendors, and customers/site hosts) and microgrid policymakers (the CEC, state decision-makers, and the CPUC). These categories grew out of the themes heard during interviews.

Figure 30: Lessons Learned Categories



Source: Navigant

The lessons described in the following sections are based on the experiences of the inter-viewees over the past several years. All the lessons identified here were echoed by more than one interviewee, and, in many cases, by all of them. Some of the challenges described are more relevant to early demonstration projects, and in some areas the microgrid market has matured since these experiences. Regardless, these lessons and best practices should be considered for microgrid projects being developed today and into the future.

The final section of this chapter takes a slightly deeper dive into several “focus areas” for specific microgrid development topics:

- Microgrid Standards and Certifications.
- Direct Current Microgrids.
- Healthcare/Hospital Microgrid Implementation.
- Electric Rule 21 Interconnection.
- IOU-Owned Microgrids.

Lessons Learned for Microgrid Implementers

The microgrid implementer lessons are divided into three categories to generally describe the timeline or phases of a project: pre-design, design/build, and O&M. Some of the best practices, especially in the design/build phase, apply to many different types of construction projects and not microgrids alone. However, these apparently more basic lessons are instrumental for microgrid success, primarily because these projects bring together diverse stakeholders, technologies, value streams, and end use applications in what is still a developing market.

Pre-Design

Microgrid Value Proposition and Customer Motivation

Navigant first discussed the origins of the microgrids with interviewees, including the reasons these particular projects were pursued by the grant recipients, and why end users were motivated to sign up as microgrid demonstration project customers.

Although they were demonstration projects, achieving cost savings was one of the most important requirements for the microgrids. Key financial drivers included:

- Cost savings: Demonstration projects reported utility bill savings of 20—30 percent.
- Optimized investments: Sites with existing renewable energy are often interested in better integration or use of their renewable resources with a microgrid, optimizing past investments.
- Economic development: Government and community based microgrids also value local economic development, both for microgrid customers and for microgrid-related technology startups in their community.

Payback was not a financial driver for these early microgrid demonstration, but, as the costs of key enabling microgrid technologies come down, microgrid projects should have more attractive payback periods (including the current round of EPIC-funded microgrids). Underlying customer drivers also relate to sustainability goals, emissions reductions, and climate action planning, with an emphasis on deploying renewable energy.

As with most microgrid projects being deployed, critical facility backup power is another key driving factor for the customer. Key resilience drivers included:

- Disaster preparedness: Microgrids supplement existing diesel generators to extend operations in a major disaster event. Facility resilience also supports broader regional emergency preparedness, especially when first responders and critical care facilities are operational for surrounding communities.
- Business continuity: Microgrids provide continuity for business and government operations during power outages.

Interviewees recommended that, in the absence of a quantified and accepted dollar value for resiliency, stakeholders must tell a compelling story to demonstrate its value.

> **INSIGHT** Microgrids are increasingly shown to provide value to the State of California broadly and not just individual facilities and customers, especially considering recent wildfires and floods and resulting power outages and damage to communities. First responders focused on emergency preparedness are embracing microgrid deployments.

Microgrid Ownership and Contractual Models

As shown previously, the seven projects included the three common ownership structures: customer-owned, third party-owned, and utility-owned. Customer-owned microgrids were most common among the demonstrations (four projects), followed by third party-owned microgrids (two projects), and utility-owned microgrids (one project). Key ownership lessons included the following.

- Customer owners usually cannot take on the administrative burden of a grant application and often need a prime contractor as a partner ahead of time, to apply together for funding.
- Customer owners typically prefer a long-term service agreement where a third party provides the time and expertise needed for microgrid O&M, both for maintenance and market participation.
- Third party-owned microgrids still require significant customer involvement up-front but less responsibility for the system O&M over time.
- Utilities have justified microgrid investments as a non-wire alternative, and they are increasingly looking at more microgrid solutions as a resilience measure for wildfires in California.

The best practices described in the other sections of this chapter are generally relevant across all three models. Similarly, regardless of the ownership model, interviewees identified the need for project partners to cost-share and risk-share, at least for demonstration projects and while microgrid solutions continue to mature.

> **INSIGHT** Stakeholders could consider energy-as-a-service / microgrid-as-a-service business models that include long-term service agreements and may be less of a burden on the customer/site host.

In terms of contracting approaches, interviewees recommended reducing the number of contracts involved in the project and, ideally, holding one vendor responsible for meeting project milestones and project performance. Additionally, "turnkey" agreements generally lower the system integration burden and help manage risk.[7]

[7] Under a turnkey agreement, the contractor/installer assumes total responsibility, from design through completion of the project, handing over a fully operational product at the end of the contract.

The Microgrid Project Team

The microgrid integrator role (making sure all stakeholders and technologies work together) is critical. Successful microgrid demonstrations are founded on strong partnerships among vendors, orchestrated by the integrator. In addition to a strong organizational approach, it is important to find partners with the appropriate technology mix for the microgrid application.

> **INSIGHT** Finding the correct technology mix applies to the distributed energy resources (DER) portfolio of the microgrid, but even more importantly, the controls approach. Be careful to choose an integrator with experience leveraging the different DER and controls technology incorporated into the microgrid.

More broadly, microgrid projects depend on good communication among all stakeholders, and they generally need highly engaged people for success. This includes the customer; customer buy-in is crucial to project success and meeting project and budget milestones.

Customers/site hosts enable successful projects when they have a core team that has worked on the project from start to finish, alongside the developer. Ideally, microgrid projects have a customer champion at various organizational levels (or city departments). Especially important are facility managers and local administrators who understand the benefits of microgrids and are motivated to see the project be successful.

In terms of other partners, bringing in local firms who have direct experience with the customer facility can be extremely beneficial for installation and troubleshooting (e.g., a long-time electrical contractor). The microgrid team should also try to engage the utility as a partner early in the process, especially for more complex projects (more on this topic later).

Design/Build

Microgrid Design and Planning

For these demonstrations, it was critical to conduct laboratory testing and spend time on prototype development for microgrid controllers. This will be less critical going forward as products become more standardized, but it is still typically needed for control systems in specific microgrid applications. Even for more mature products, the developer must ensure that the many different components work together as expected.

Emerging energy storage technologies may require testing to ensure that the product is achieving the expected performance. UL-certified devices are typically required in a microgrid design, but the UL certification process can be time-consuming for new products. UL Mark evaluation involves:

- Service quotes and agreements from UL.
- Stringent testing by UL for compliance and fulfillment of Occupational Safety and Health Administration and American National Standards Institute criteria.
- Production inspections.
- Periodic follow-up services.

For example, one relevant certification is UL 1741 SA: As of September 2017, new inverters must be certified as providing "Grid Support" or "Smart Inverter" functions. For one of the seven EPIC-funded project's new flow battery inverter system, UL certification took one year to accomplish this.

In project planning stages, it is critical to perform financial due diligence on all technology suppliers, including controls vendors and especially energy storage vendors. For technology components, interviewees recommended having a "backup supplier for the backup supplier." Flow battery and even lithium-ion battery suppliers went out of business over the course of the demonstration period, adversely affecting several projects.

Customers and end users should also provide design input up-front. It is important for the developer to have a good understanding of existing physical site constraints, land ownership, and other characteristics (and form a checklist for these items) to determine whether a site is a good microgrid host candidate and what site challenges will have to be resolved during engineering, construction, and operations. For example:

- The site may need adequate space for a solar array, at a distance that is not too far to tie into the microgrid controls.
- Microgrids need a good internet connection, which can be a challenge with secure customer networks.

For new construction buildings, interviewees advised considered the technical design for a microgrid as early as possible. While most microgrids are retrofits and incorporate existing infrastructure, best practice guidelines should include ways to make new buildings microgrid-friendly in the future. In retrofits, the developer and the end user must identify where the critical loads to island are located in the facility or campus. For new construction, these loads can be proactively grouped together.

Configuration and Controls

For the seven projects, microgrid configuration was often highly customized to the specific customer application. Broadly, developers should consider available controls solutions and the best fit for their use case. For example, some microgrid management systems or DERMS may be too complex for more straightforward microgrid applications. In these cases, simpler controls solutions can lower costs and improve operations. As the number of microgrid management solutions increases, it will be important to select an appropriate level of control complexity.

In some applications, the microgrid must still be configured for legacy backup generators to serve as the "island master." This is the first generating device to come online when in islanded mode. After synchronization with the grid has occurred, additional renewable generating devices are then allowed to come online. In some cases, diesel generators and onsite diesel fuel storage are required by regulation for backup power supply (e.g., acute health facilities and fire stations or other emergency response facilities). Other microgrids still rely on generators to maintain frequency and voltage. They are actively working through technical challenges related to an inverter-only low-carbon/renewable microgrid.

Interviewees also found success in configuring the microgrid controller with a building energy management system, which can enable additional resiliency and value to the customer by implementing a load shedding order (defined by the customer) to prolong critical operations in outage scenarios.

Installation

Almost all of the seven microgrid demonstrations shared installation success stories, identifying only a few key lessons learned outside of general construction project best practices.

Most importantly, local customer representatives should be involved ahead of installation. If the project is driven by a corporate-level customer, developers should notify local facilities teams and administration about the project well in advance of installation and should collaborate to resolve concerns about impacts to operations during construction and testing. This may include preparing a disruption mitigation plan for the facility. The EPIC-funded microgrid demonstrations had well-developed mitigation plans and experienced minimal customer disruption across the board.

Several interviewees shared their experiences around setbacks that came up during installation. Once the microgrid design is finalized and/or installation has already begun, having to switch major technology components of the microgrid (such as flow batteries to Li-ion batteries) can have significant repercussions for the project cost and timeline. For the relevant battery component example, repercussions included:

- Changing already purchased or installed inverters.
- Redesigning custom equipment connections.
- Restarting the interconnection process.

Approval Requirements

Across all seven projects, interviewees emphasized the importance of understanding all required permitting, regulatory, and utility approval processes ahead of time and the associated risks of schedule delays. Permitting and utility interconnection processes are highly structured and sequential, so one missed step or error will delay the entire timeline (as several projects experienced firsthand).

Microgrid implementers should note that different types of customer facilities need approval from different authorities; for example, OSHPD for hospitals and the California Division of the State Architect for public schools and colleges.

Energy storage systems have historically posed an extra challenge for local permitting; it may take longer than expected for a less experienced authority having jurisdiction to approve the system. Processes and fees for energy storage system permits are also inconsistent across different jurisdictions in California. For energy storage and other microgrid components and designs, interviewees advise sitting down with the inspector, going over the drawings with them in detail, and negotiating what they require for the project.

As the site and the utility account owner, the customer should expect to be directly involved in these processes, even under a third-party ownership model. This can be a significant effort.

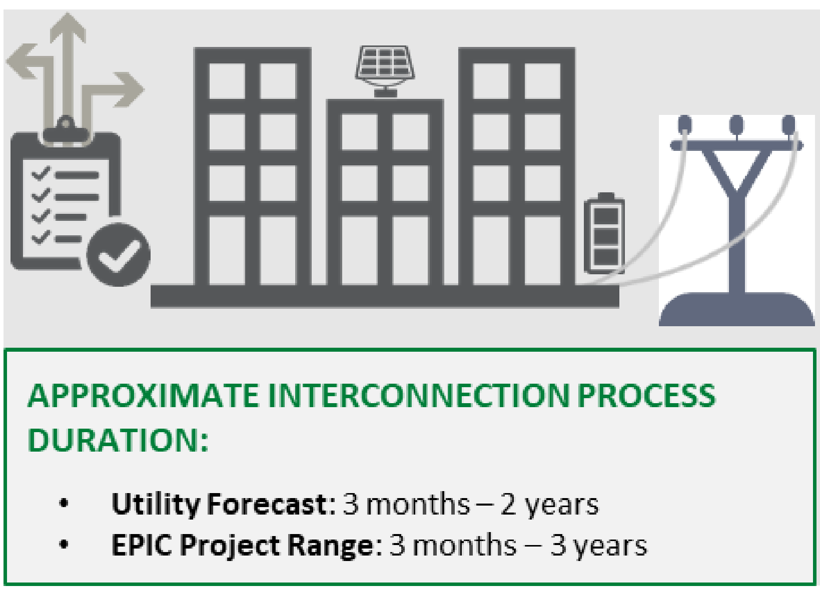
Similarly, a city government customer must go through the standard local permitting process and "check all the boxes"; however, there is a benefit to having a government site host that is invested in the project and will help identify and talk though local regulatory barriers.

The utility interconnection process is one the biggest hurdles for microgrid projects to overcome. Early communication and coordination with the utility is critical. Interviewees (both developers and utility representatives) recommend starting the discussion with the utility as soon as possible.

Project developers should reach out to the utility with any interconnection process questions and should provide early information about the project — the more information the better. The utility cannot consult on the project itself but can answer basic application questions. It is important to submit the interconnection application significantly in advance, as soon as the system design is finalized (although this is a challenge for early demonstration projects that often require design changes later).

Microgrids within IOU territory typically apply for interconnection under the Electric Rule 21 tariff. Microgrids often fail the Rule 21 Fast Track Initial Review and go to Supplemental Review. There is a wide range of timelines for projects under Electric Rule 21, anywhere from three months to several years (depending on the size and needs of the local distribution or transmission grid). Additionally, any material modifications to the application cause it to be sent back to the beginning of the process. Many microgrids do not export electricity to the utility grid (non-export), but there are still challenges that can take extra time to resolve.

Figure 31: Approximate Interconnection Process Duration



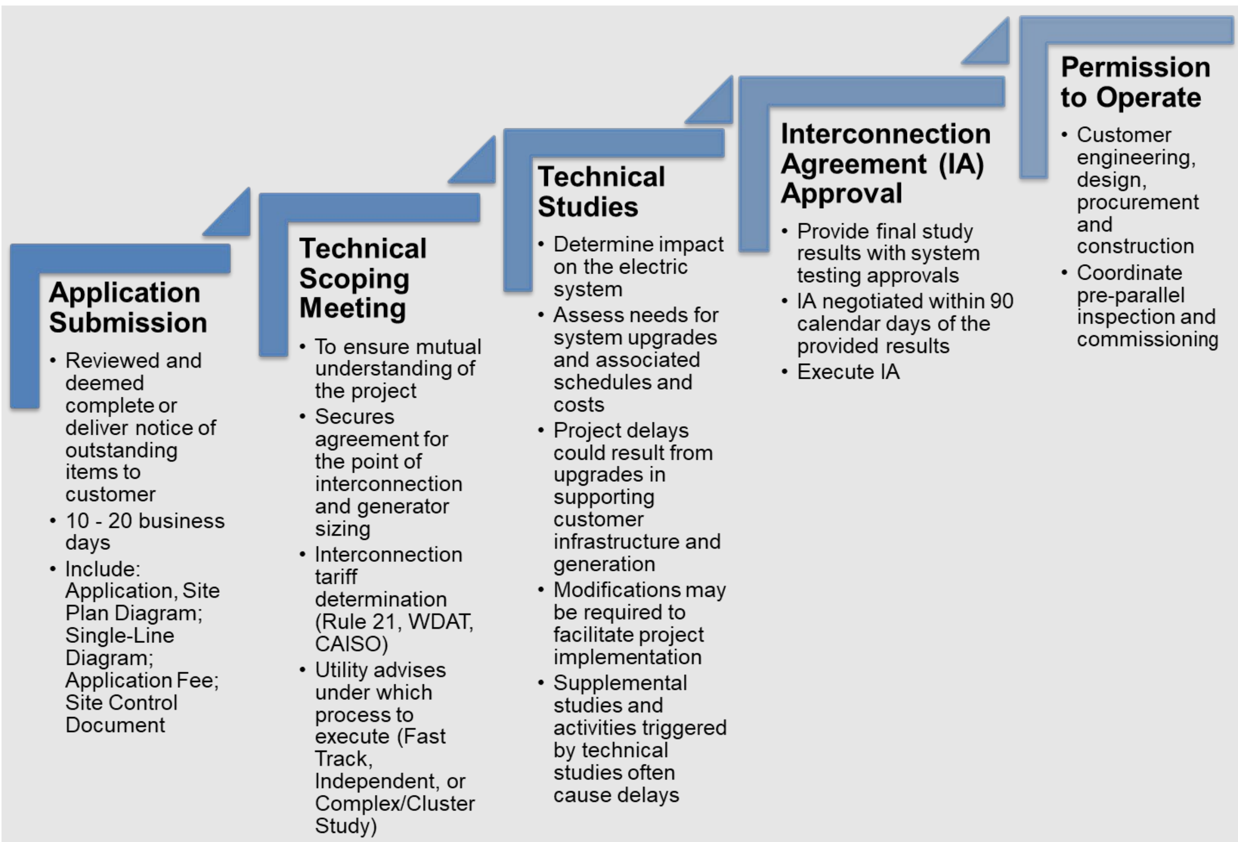
Source: Navigant

Utilities prefer to work with interconnection applicants who have prior experience applying for interconnection and demonstrate familiarity with the process. Interconnection applicants should review and refer to existing interconnection guides (see Appendix C):

- Electric Rule 21 Interconnection Tariff.
- Net Energy Metering Interconnection Handbook (for projects that plan to export electricity to the grid).
- Utility-specific interconnection handbooks.

A high-level overview of the interconnection process is shown in Figure 32.

Figure 32: Steps Required for Interconnection



Source: Navigant, from PG&E documents, including the Generation Interconnection Process & Timeline: https://web.archive.org/web/20200929183043/https://www.pge.com/includes/docs/pdfs/b2b/newgenerator/GenerationInterconnectionProcessTimeline.pdf

INSIGHT

Utility engineers may not be aware of all new technologies being integrated into microgrids. Be prepared to educate on any non-standard components such as software optimizations and controls.

The utility may need to evaluate the prototype of a non-exporting system for a period of testing. Early on in several of the demonstration projects, the utilities had little basis to judge software-based non-export functionality. From working through these types of technical challenges, microgrid implementers expressed an interest in more direct communication with utility engineers to resolve technical application issues more quickly. DC microgrids can face even more technical issues, based on the relative inexperience with DC equipment.

In the past several years, utility engineers have reviewed control systems and are much more familiar with them, in part because of these microgrid demonstrations. More recent testing processes for software controlled non-export functionality have reportedly gone more smoothly. If the developer follows the utility process, the control system may also be able to be pre-approved.

Operations and Maintenance

Microgrid Operations

Lessons learned are somewhat limited in the O&M category because many of the demonstrations have not been operating for very long (or at all yet). Ongoing performance should be tracked going forward, as these and other microgrid projects accumulate years of operational data.

So far, the operational microgrid demonstrations are achieving significant financial benefits through utility bill savings, particularly demand charge reductions. From this perspective, customers are largely achieving the value that motivated them to participate in the project.

Several demonstrations identified demand response and CAISO market opportunities for revenue generation, but these remain less proven than utility bill savings. Microgrid services to the grid have not fully materialized yet, but some of the microgrids will continue to pursue these opportunities and collect data on market participation models. Microgrid contracts should be structured to anticipate multiple value streams, including revenue generation opportunities, and should designate shared savings arrangements among project stakeholders.

As mentioned previously, having an overall technology integrator is crucial – not just to the development of the microgrid but to achieve a high-performing microgrid over time. Someone must be responsible for making sure individual technology solutions and products work well together beyond the commissioning date. An integrator will continue to optimize the microgrid on an ongoing basis, including normal grid-connected operations (e.g., to maximize demand charge reductions) and islanded operations (e.g., acceptable levels of load shedding in outages).

> **INSIGHT**
> CAISO's Demand Response Programs are potential avenues for microgrid revenue generation, including the current Proxy Demand Resource model and future programs under the Energy Storage and Distributed Energy Resources initiative.

Microgrid Maintenance

Stakeholders may underestimate how much continued maintenance there is for a microgrid; there are controls and software maintenance requirements beyond typical maintenance on equipment. Troubleshooting between microgrid components and managing software version control and updates are important maintenance activities.

Customer-owned microgrids typically require long-term service agreements to support O&M, from either the technology provider or another third party. This structure is similar to maintenance agreements for traditional diesel generators. For the customer/site host, limited facility staff and engineers would face significant challenges trying to operate and maintain complex technology that is not a part of their core business.

> INSIGHT
>
> Significant O&M costs can be associated with automation and controls, including upgrades / updates and potentially product replacements. O&M costs are also associated with fuel costs for diesel and natural gas generators.

Many batteries require significant HVAC in hot environments in California to maintain expected battery lifetime. DC microgrids associated with DC building equipment (lighting, fans, etc.) are expected to lower facility maintenance costs overall.

Lessons Learned for Policymakers

Interviews with representatives from each of the seven EPIC-funded microgrid projects identified challenges and needs related to microgrid research, development, and commercialization. These lessons are shared for the benefit of microgrid policymakers (the CEC, state decision-makers, and the CPUC), considering funding and other market support going forward. Navigant also solicited feedback on the EPIC program specifically, to identify potential areas for improvement.

Technology Market Readiness

For the microgrid market to continue to mature, component standardization is key. Based on progress made through the demonstration projects, microgrids are already becoming increasingly modular and component based, but there are still some areas that require further advancement. For example, microgrids need seamless communication between the various system components and interfaces with other devices. Communication protocols are still not quite aligned between different components and manufacturers.

Microgrid controllers would also benefit from further standardization and commercialization. Many current products still require additional software development for more complex algorithms in specific microgrid applications. Demonstration participants often felt that there still was not a complete microgrid controller product available, including forecasting and optimization capabilities. Interviewees also noted that IEEE microgrid standards are helpful but not always available to small businesses because of the cost.

In an ideal project, microgrid controls and protection schemes would be integrated into one platform. Several interviewees shared the vision for an all-in-one UL-listed microgrid solution that could be installed without significant engineering design and customization work (at least, for small to medium commercial businesses) and are working toward this solution. This concept, however, remains more challenging for larger and more complex microgrids.

For utility-owned microgrids, there are only a few distribution management system solutions available in the market, which limits large-scale microgrid applications integrated with and operating in the larger distribution grid. However, there are still some technical issues with inverters in microgrids. Inverters must be able to provide enough fault current during islanded operations. Frequency issues (tripping solar PV systems offline) are a challenge for high renewable environments/islanded operations.

> **INSIGHT** Most control products have not been designed with utility needs in mind, though new Distributed Energy Resource Management Systems (DERMS) appear to be gaining ground and do address these issues.

There are still battery product issues in the emerging storage markets that affect microgrid projects, for example, flow battery efficiency and quality.

Several demonstrations found improved efficiency with DC-coupled systems and would recommend DC microgrids (especially in new buildings). Through demonstrations, UL-certified DC equipment is becoming more available for DC building grid applications but is still comparatively very limited.

Finally, cost reductions remain critical to moving the market forward, particularly for controller costs and soft costs. This is necessary to achieve the return on investment required by many customers (often two to seven years for capital equipment).

Funding and Research and Development Programs

One key finding was that the complexity and functionality of the seven microgrid demonstrations would not have been achievable if they had not received CEC EPIC funding. Interviewees shared that the initial EPIC grant was critical to project success. The grant was valuable not only in implementing the project but also in terms of publicity. It supported the idea of microgrids being taken more seriously by utilities and by skeptics of the microgrid value proposition.

Microgrid developers and customers are actively seeking additional grants for these types of projects today. From 2015 to 2019, the California microgrid market has significantly matured and projects have largely moved from research and development to commercialization. The continuation of funding opportunities has enabled developers to expand and has increased market adoption.

As with many government grant programs, several aspects of the EPIC framework and the PON-14-301 solicitation posed challenges for the grant recipients and other partners. Interviewees suggested that the CEC consider addressing the following demonstration project challenges:

- The CEC proposal guidelines are very work-intensive and time-consuming.
- Costs associated with staff support in development pose a barrier to the applicant, especially for nonprofits with limited resources.

- It is difficult to implement a newly conceived idea under a rigid budget.
- In demonstrations there are always modifications to the original plan, but there is little flexibility in design and vendor selection and timing.

Grant recipients and other project stakeholders identified specific research areas to enable continued microgrid growth as supported by the CEC:

- Microgrid controls: Additional R&D funding for controller technology and communication protocols.
- Direct current: DC technology-specific funding.
- Data analysis: Monitoring and analyzing the data collected from microgrids will help identify the appropriate technology, designs, and operational schemes (including revenue opportunities) going forward.
- Long-term O&M: Funding for extended duration demonstrations (enabling more testing and data collection).

Best Practice Focus Areas

This section describes several areas of interest identified by one or more of the evaluated projects that may assist in guiding future, similar microgrid deployments.

Microgrid Standards and Certifications

To enable smart-grid technologies, several certifications are required for components related to inverters, controllers, and other necessary equipment.

The IEEE exists as one of the leading technical organizations for the advancement of technology. Its work includes thought leadership (e.g., publications and conferences) as well as the development of standards for functionality, capabilities, and interoperability of a varied rage of product and services. The standards corresponding with microgrids and DER include:

- IEEE 1547 Suite defines Interconnection System and Test Requirements.
- IEEE 2030 Suite:
    - IEEE 2030.7: Standard for the Specification of Microgrid Controllers (2017). Establishes an industry standard that lays out the technical and functional requirements of advanced microgrid controllers.
    - IEEE 2030.8: Approved Draft Standard for the Testing of Microgrid Controllers (2018). Complementary to IEEE 2030.7, it establishes test specifications and procedures for a microgrid controller.
    - IEEE P2030.9: Recommended Practice for the Planning and Design of the Microgrid

- IEEE P2030.10: Standard for DC Microgrids for Rural and Remote Electricity Access Applications. Targets sustainable DC off-grid and remote power, in both the developed and the developing world.
- IEEE P2030.11: DERMS Functional Specification.

UL is a nationally recognized testing laboratory that provides product safety testing and certification related to many types of devices, including technology components in microgrids. The device receives a "UL Mark" or label after passing technical and operability requirements. One relevant example for microgrids is UL 1741, which applies to inverters interconnecting with the grid that meet requirements for grid voltage and frequency.

The National Electrical Code (NEC), published by the National Fire Protection Association (NFPA), is a nationally accepted benchmark for electrical design, installation, and inspection to ensure safety in operations. The standard has been approved by the American National Standards Institute and is updated every three years. NFPA 70 NEC sets the scope, technical engineering requirements, and enforcement surrounding electrical component installation.

Direct Current Microgrids

DC microgrids have the advantage of greater efficiencies (e.g., eliminating conversions between AC and DC for generation and loads) and a reduced facility maintenance burden compared to AC microgrids. In DC systems, fewer solar panels are required to produce the same amount of electricity by avoiding the conversion losses. In 24/7 facility operations, the solar energy is used directly by building loads as soon as it is generated.

Installing DC LED lighting and other DC loads integrated into a DC microgrid could save a warehouse-type facility up to an estimated 50 percent in ongoing maintenance costs all together.[8] DC equipment is expected to have longer lifetimes, with less equipment stress and fewer points of failure. DC lighting manufacturers have commercial-ready, certified products today. Other DC equipment has recently been or is in the process of being UL-certified.

DC microgrids also offer several advantages to utilities compared to AC microgrids, for example, the lack of need for resynchronizing the microgrid when power is restored on the larger grid.

Implementers should especially consider DC microgrids for new customer facilities, which would be less expensive and more efficient overall (not including current high costs for the limited supply of DC equipment loads). Retrofitting an existing AC facility to a DC building grid is feasible but likely more expensive.

The EMerge Alliance is an open industry association leading the rapid adoption of safe, low-voltage DC power distribution and use in commercial interiors. The not-for-profit organization is working with several groups to develop a worldwide low-voltage DC standard and standards for lighting, appliances, and DC meters.

[8] Including the impact of the conversion from non-LED lighting to Title 24-compliant DC LED lighting.

Healthcare/Hospital Microgrid Implementation Lessons

Microgrids serving hospitals are regulated by California's OSHPD, which requires, for example, two sources of power to the hospital facility at all times and at least 72 hours of on-site fuel storage.

Interviewees for the Charge Bliss microgrid project at Kaiser Permanente identified several key recommendations to support the deployment of microgrids at healthcare facilities:

- The microgrid development team (installers and customers) should engage OSHPD early in the process and take a collaborative approach to make sure all potential or perceived threats to patient care are resolved. For example, the developer should set up a design review of the project with OSHPD staff.
- Buy-in from multiple levels at OSHPD is important, from the local inspector of record up to director levels.
- Microgrid equipment can be certified through an OSHPD preapproval process, for example, the Special Seismic Certification Preapproval.

Through this and other projects, OSHPD is becoming much more familiar with microgrid technology and is generally willing to negotiate new ways of complying with requirements for advanced energy projects.

For healthcare end users outside of OSHPD's regulatory control, medical office buildings have a 4-hour backup power requirement and are often good candidates for microgrids.

Investor-Owned Utility-Owned Microgrids

The three largest IOUs in the state have been investigating applications for distributed energy resources (DER) — including microgrids — for several years through the CPUC's Distribution Resources Plan proceeding (R.14-08-013), but few microgrids have resulted to-date.

In 2015, the three IOUs were required to propose demonstration projects in which the utility would serve as a distribution system operator of a microgrid where DER served a significant portion of the customer load and reliability services. SDG&E proposed deploying a DERMS on the existing Borrego Springs microgrid to optimize the microgrid over various outage scenarios.

IOUs are often limited by their ability to rate-base microgrid costs (as approved by regulators). However, California's recent wildfires have increased pressure on utility companies to boost resiliency. An IOU may be able to rate-base a microgrid investment if the utility can prove it provides benefits beyond those to the behind-the-meter microgrid customers. However, in a recent proposed decision on the AB 2868 Energy Storage Program and Investment Framework, the CPUC did not grant rate recovery for SDG&E's seven requested utility-owned microgrid projects, agreeing with intervenors that SDG&E' "failed to demonstrate that its proposed projects will result in ratepayer benefits because its proposed project benefits are uncertain and may not sufficiently offset its proposed microgrid projects' net present value" (CPUC, 2019). The extent to which the three IOUs will deploy utility-owned microgrids is uncertain.

Electric Rule 21 Interconnection

Electric Rule 21 governs CPUC jurisdictional interconnections and outlines the requirements of DER to interconnect, operate, and meter generation facilities on a utility's electric grid.

Rule 21 applies to generators under:

- Net Energy Metering — Customers generating power for onsite use and exporting excess energy back to the grid to receive utility bill credits.
- Renewable Energy Self-Generation Bill Credit Transfer (RES-BCT) — Local government and college campus customers generating power for onsite use and exporting excess energy back to the grid for generation credits.
- Rule 21 Export — Public Utility Regulatory Policies Act PPAs for Qualifying Facilities less than 20 MW.
- Rule 21 Non-Export (most common for these demonstration projects) applies to customers generating power in parallel to the grid for sole onsite use; no export from or back-feeding to the utility's distribution lines is permitted.

Rule 21 does not apply to the interconnection of generating or storage facilities intending to participate in wholesale markets. The Wholesale Distribution Access Tariff (WDAT) applies to customers interconnecting generation facilities to utility distribution systems to deliver energy and capacity services to the CAISO-controlled grid. Each of California's large investor-owned utilities has its own WDAT.

On July 13, 2017, the CPUC issued an Order Instituting Rulemaking to Consider Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21.

CHAPTER 4: Conclusions

Together, the lessons and best practices aggregated across the seven EPIC-funded microgrid demonstration projects awarded under PON-14-301 represent an enormous amount of knowledge and experience gained by project participants over 3+ years. These microgrids provide compelling value for their customers and communities, even as early demonstration projects. Project developers have gone on to pursue numerous new microgrid opportunities, armed with the expertise gained from these experiences, and multiple participating customers are expanding or building new microgrids for their facilities.

Many of the lessons and best practices identified by interviewees are fundamental to successful microgrid projects and should be considered for projects developed today and in the future. Even the most basic best practices — related to communication, coordination, and technology integration, for example — carry greater weight for complex, multistakeholder, and multivalue stream projects in a developing market. Key lessons learned for microgrid implementers included:

- Customers are motivated by three main benefits: (1) financial (utility bill savings), (2) environmental (low carbon footprint and renewable energy), and (3) resiliency (emergency preparedness and business continuity through outages).
- The microgrid integrator role is especially critical, along with good partnerships between vendors and communication between all stakeholders.
- Testing and thoroughly vetting emerging technology — typically microgrid controllers and energy storage solutions — remain important.
- Customer needs and site characteristics must be well understood in the design and planning phases and must be accommodated during construction and operations.
- Permitting and especially interconnection processes can pose a major challenge to project timelines without significant upfront preparation and coordination with the permitting agency and the utility.
- Operational microgrids are successfully achieving utility energy and demand charge savings.
- Microgrids are successfully running islanding test, and, in some cases, have already islanded through unplanned power outages. However, there are still some challenges around eliminating legacy fossil fuel generators from the islanding equation.
- Microgrids typically need long-term, third-party service agreements to support ongoing O&M needs that are outside the core business of the customer site.

One key finding was that the complexity and functionality of the seven microgrid demonstrations would not have been achievable if they had not received CEC EPIC funding. Interviewees shared that the initial EPIC grant was critical to project success. The CEC has a variety of paths forward to continue to advance microgrids in California. Public funding could: contribute to the further standardization of microgrid technology, including controllers, communication protocols, and configurations; support advanced and long-duration energy storage solutions; and support direct current microgrids. Finally, analyzing data from operating microgrids, including these seven projects, is critical for providing valuable post-implementation lessons.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
24/7	24 hours per day, 7 days per week
AB	Assembly bill
AC	alternating current
BESS (battery energy storage system)	A BESS stores energy via the use of battery technology. Types included in this report: vanadium flow and lithium-ion.
BLR (Blue Lake Rancheria)	The Blue Lake Rancheria is a federally recognized Native American tribe in northwestern California, near the cities of Eureka and Arcata, five miles inland from the Pacific Coast, along California Highway 299
CAISO (California Independent System Operator)	The Independent System Operator manages 80 percent of the California transmission grid by providing five-minute to day-ahead forecasts of electricity demand and generation and authorizes the scheduling of energy dispatch to meet exact demand.
CEC (California Energy Commission)	The state's primary energy policy and planning agency, established by the governor in 1974.
CHP (combined heat and power)	A type of distributed generation, which, unlike central station generation, is located at or near the point of consumption and is the concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy.
CPUC (California Public Utilities Commission)	The state regulatory body with jurisdiction over investor-owned utilities and their territories.
DC (direct current)	The one-directional flow of electric charge.
DCBMP (Direct Current Building-Scale Microgrid Platform)	The Bosch DCBMP project is an integrated advanced technologies project using DC architecture to provide reliable power to connected commercial loads, resilience during grid outages, and increased energy efficiency and solar energy utilization.
DER (distributed energy resources)	Smaller generating facilities that interconnect into the grid, providing energy to meet local demand.
DERMS (distributed energy resource management software)	A software-based integration platform that provides control and monitoring functions to coordinate and optimize multiple distributed energy resources within a microgrid/electric grid.
EV	electric vehicle
EPIC (Electric Program Investment Charge)	A program created by the California Public Utilities Commission in December 2011 that supports investments in clean energy technologies that benefit electricity ratepayers of Pacific Gas and

Term	Definition
	Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company.
Export	The ability to send unused, self-generated power back to the electrical grid, typically under a strict utility tariff agreement.
IEEE (Institute of Electrical and Electronics Engineers)	An American 501(c)(3) professional association for electronics engineering, electrical engineering, and other related disciplines.
IOU (investor-owned utility)	A public electric utility authorized to serve load within its service territory, with ownership distribution and transmission infrastructure into which the studied microgrids interconnected. Microgrids in this project interconnected in the distribution grids of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company.
GHG (greenhouse gas)	The gases in the atmosphere that raise the surface temperature of planets such as the Earth and include water vapor, carbon dioxide, methane, nitrous oxide, ozone.
kW	kilowatt
kWh	kilowatt-hour
Li-ion	lithium-ion
MGMS (microgrid management system)	MGMSs are essential controls that allow optimal use of distributed energy resources through instantaneous communication and control capabilities.
MW (megawatt)	A unit of power equal to one million watts, especially as a measure of the output of a power station
NFPA (National Fire Protection Association)	A U.S.-based international nonprofit organization devoted to eliminating death, injury, property, and economic loss due to fire, electrical, and related hazards
Non-export	Referencing the requirement of IOUs in preventing behind-the-meter backflow of excess generated power onto the distribution grid infrastructure.
NOPA	Notice of Proposed Award
O&M	operations and maintenance
OSHPD (Office of Statewide Health Planning and Development)	The agency that oversees the planning of health care facilities in California. Working with representatives early on will help accelerate implementation of microgrid projects at regulated facilities.
PG&E (Pacific Gas and Electric)	An IOU who provides natural gas and electricity to millions of households in the northern two-thirds of California.

Term	Definition
PPC (point of common coupling)	The point at which the microgrid is interconnected to the local electric grid.
PDR (Proxy Demand Resource Program)	This participation model for load curtailment is a demand response market program facilitated by the California Independent System Operator.
PON	Program Opportunity Notice
PV (photovoltaic)	Relating to the production of electric current at the junction of two substances exposed to light.
RAM	Renewable Auction Mechanism
Rule 21 (Electric Rule 21 Tariff)	Rule 21 describes the interconnection, operating, and metering requirements of generating facilities connecting to the utility's adjacent distribution system.
SB	Senate bill
SCADA	supervisory control and data acquisition
SCE (Southern California Edison)	The primary IOU company for much of Southern California that provides natural gas, electricity, and water services.
SDG&E (San Diego Gas and Electric)	A utility company that provides natural gas and electricity services to San Diego County and parts of Orange County.
SERC	Schatz Energy Research Center
SGIP (Self-Generation Incentive Program)	A California Public Utilities Commission program that allows incentives to support existing and emerging distributed energy resources.
UL	UL Solutions, formerly known as Underwriters Laboratories
WDAT (Wholesale Distribution Access Tariff)	WDAT describes the interconnection, operating, and metering requirements for wholesale load customers and generation facilities that are connecting to the distribution grid.
WWTP	Wastewater Treatment Plant

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CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix A: Interview Questionnaires

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APPENDIX A: Interview Questionnaires

Microgrid Grant Recipient / Project Developer

Project Motivation & Design

1. How did you first connect with the site host regarding a microgrid deployment?
    a. What was the site host's primary motivation for deploying a microgrid?
    b. What made it a suitable site for your solution?
2. What decisions led to the final microgrid design and why?
    a. Technology (solar, storage, CHP, etc.)
    b. Functionality (islanding duration, demand response, etc.)
    c. Repeatability (commercial investment potential, demonstration, etc.)
    d. Vendor priorities (technology or business model validation, etc.)
    e. Other
3. If applicable, what other technologies or reliability-related equipment were considered (or in use) on-site prior to the microgrid design?
    a. Smart meters
    b. Smart inverters
    c. SCADA
    d. Advanced software
    e. Energy storage
    f. Other
4. What microgrid value streams were pursued?
    a. Backup power / resiliency
    b. Demand response participation
    c. Solar PV utilization / DER optimization
    d. Demand charge reduction
    e. Premium power / reliability
    f. Other
5. How were value streams prioritized?

6. How important was the role of renewable integration as a proposed value?
    a. Does the microgrid allow the site to reduce carbon emissions by displacing fossil generation with renewable energy?
    b. Does the microgrid allow for maximizing renewable energy generation from multiple renewable energy resources?

Project Implementation

7. What issues, if any, came up when requesting interconnection with the utility?
    c. What documentation was requested to support interconnection and how difficult was it to produce the required materials in a manner that was acceptable by the utility?
    d. Did the interconnection process delay the project timeline? If so, please describe.
    e. What recommendations would make the interconnection process more efficient?
8. What were the major challenges working with the utility overall and how were they overcome?
9. Did you have any engagement with the California Public Utilities Commission regarding interconnection?
    a. What triggered the engagement?
    b. How was the experience with the CPUC?
10. What local permits were required for your project, if any?
    a. City permits
    b. Land use
    c. Triggered environmental/engineering studies
    d. Other (describe)
11. Did you have any concerns with permitting requirements from the local governing authorities? If so, please describe.
12. Were there any issues encountered in acquiring certifications for facility devices?

Microgrid Operations & Performance Assessment

13. How did the facility perform relative to plan? If applicable, what were the major reasons for the departures from the original project plan and why?
    a. If applicable, describe any facility components or interconnections that did not operate at the capacities and efficiencies listed in their product specifications or according to the technical design. What caused these operational challenges?
    b. Did any pre-existing generation or other equipment (e.g., legacy solar PV arrays) cause any issues for the microgrid?

   c. If applicable, after commissioning the facility, what, if anything, caused significant downtime and for how long did this occur?
   d. If applicable, describe any grid outages during the demonstration.
14. How did the final project cost compare to the plan? What equipment or other costs varied significantly?
15. How did the value proposition compare to actual performance after commissioning?
    a. Which value propositions failed to materialize, if any?
    b. Were there any surprise/unanticipated system benefits?
16. What conditions challenged microgrid feasibility, reliability, or cost?
17. Were there any issues related to implementing a multiple-use case value stack and, if so, how were these issues resolved?
18. What unanticipated real-world issues were encountered or became larger issues than expected?
19. In hindsight, was there anything that could have been done differently to better achieve project goals?

Stakeholder Engagement

20. What were the major challenges working with contractors/installers and how were they overcome?
21. What were the major challenges working with equipment/technology suppliers and how were they overcome?
22. How did the business model configuration impact these relationships, if at all?
23. Do you have any recommendations for communication and planning between stakeholders such as:
    a. Site host/Facility manager
    b. Developers/Installers
    c. Local utility
    d. Microgrid controls provider
    e. Other component manufacturers
24. What outreach activities were pursued? (Utility, community, etc.)
25. Who was/is your partner at the utility and what is their contact information? *(If applicable, will you introduce the Navigant / CEC team for an interview?)*

Looking Forward

26. What commercialization actions have been taken to-date?
27. What future plans do you have for microgrid projects and how were they influenced by this deployment?
28. What has changed in the commercial sector that would have added value to this microgrid project over the lifecycle?
29. What utility processes have been modified or streamlined, if any, to assist microgrid design over the length of this project?
30. What recommendations do you have for additional research needs based on the execution of the project?

Funding & Administration

31. How important was the EPIC grant funding to the project?
    a. How did the grant add value to the existing facility?
    b. When was the grant received by the respective microgrid project stakeholders?
    c. How did the grant assist in the installation process?
    d. Would this project have materialized in the absence of the CEC grant?
    e. How do you rate the necessity of the grant for future microgrids moving forward?
32. Do you think a CEC grant would be most valuable for microgrids targeting specific application segments?
33. Do you think technology choices should drive future microgrid grant funding?
34. What critical support did the CAM provide? (Anonymous, follow-up if needed)
35. What were the major challenges working with the CEC, if any, and how were they overcome? (Anonymous, follow-up if needed)

Microgrid Host Facility/Customer

Project Motivation & Design

1. What was your primary motivation for deploying a microgrid?
2. What decisions led to the final microgrid design and why?
    a. Technology (solar, storage, CHP, etc.)
    b. Functionality (islanding duration, demand response, etc.)
    c. Repeatability (commercial investment potential, demonstration, etc.)
    d. Vendor priorities (technology or business model validation, etc.)
    e. Other

3. If applicable, what other technologies or reliability equipment were considered (or in use) at your facility prior to the microgrid design?
    a. Smart meters
    b. Smart inverters
    c. SCADA
    d. Advanced software
    e. Energy storage
    f. Other
4. What microgrid value streams were pursued?
    a. Backup power / resiliency
    b. Demand response participation
    c. Solar PV utilization / DER optimization
    d. Demand charge reduction
    e. Premium power / reliability
    f. Other
5. How were value streams prioritized?
6. How important was the role of renewable integration as a proposed value?
    a. Does the microgrid allow the site to reduce carbon emissions by displacing fossil generation with renewable energy?
    b. Does the microgrid allow for maximizing renewable energy generation from multiple renewable energy resources?

Project Implementation

7. What issues, if any, came up when requesting interconnection with the respective utility?
    a. What documentation was requested to support interconnection and how difficult was it to produce the required materials in a manner that was acceptable by the utility?
    b. Did the interconnection process delay the project timeline? If so, please describe.
    c. What recommendations would make the interconnection process more efficient?
8. What were the major challenges working with the utility overall and how were they overcome?
9. Did you have any engagement with the California Public Utilities Commission regarding interconnection?
    a. What triggered the engagement?

    b. How was the experience with the CPUC?

10. What local permits were required for your project, if any?
    a. City permits
    b. Land use
    c. Triggered environmental/engineering studies
    d. Other (describe)
11. Did you have any concerns with permitting requirements from the local governing authorities? If so, please describe.
12. Were there any issues encountered in acquiring certifications for facility devices?

Microgrid Operations & Performance Assessment

13. How did the facility perform relative to plan? If applicable, what were the major reasons for the departures from the original project plan and why?
    a. If applicable, describe any facility components that did not operate at the capacities and efficiencies listed in their product specifications. What caused these operational challenges?
    b. If applicable, after commissioning the facility, what, if anything, caused significant downtime and for how long did this occur?
    c. If applicable, describe any grid outages during the demonstration.
14. How did the value proposition compare to actual performance after commissioning?
    a. Which value propositions failed to materialize, if any?
    b. Were there any surprise/unanticipated system benefits?
15. What conditions challenged microgrid feasibility, reliability, or cost?
16. Were there any issues related to implementing a multiple-use case value stack and, if so, how were these issues resolved?
17. What unanticipated real-world issues were encountered or became larger issues than expected?
18. In hindsight, was there anything that could have been done differently to better achieve project goals?

Stakeholder Engagement

19. What were the major challenges working with the microgrid project developer and installers?
20. How did the business model configuration impact these relationships, if at all?

21. Do you have any recommendations for communication and planning between stakeholders such as:
    a. Project developer/installer
    b. Component manufacturers
    c. Local utility
22. What outreach activities were pursued? (Utility, community, etc.)

Looking Forward

23. What future plans does your facility have for continued use of the microgrid?
24. What future plans does your organization have for microgrids at other facilities?
25. What recommendations do you have for additional research needs based on the execution of the project?

Utility

Project Motivation & Design

1. How closely was the utility involved in microgrid design, if at all?
    a. When were you notified of the microgrid design and specifications?
    b. Who at the utility was involved?
    c. Did the utility co-fund the projects in any way, or provide incentives?
2. What were the microgrid project value propositions, if any, for the utility?
3. What were you hoping to learn from the microgrid project?

Project Implementation

4. What issues, if any, came up when the microgrid requested interconnection?
    a. What documentation do you require for interconnection?
    b. To your knowledge, did the interconnection process delay the project timeline? If so, please describe.
    c. What recommendations would make the interconnection process more efficient for microgrid projects?
5. Did you have any engagement with the California Public Utilities Commission regarding interconnection?
    a. What triggered the engagement?
    b. How was the experience with the CPUC?

Microgrid Operations & Performance Assessment

6. Does the utility monitor microgrid performance?
    a. If applicable, after commissioning the facility, what, if anything, caused significant downtime and for how long did this occur?
    b. If applicable, describe any grid outages during the demonstration and how the microgrid affected the utility grid.
7. From the utility's perspective, how did the value proposition compare to actual performance after commissioning?
    a. Which value propositions failed to materialize, if any?
    b. Were there any surprise/unanticipated system benefits?
8. What unanticipated real-world issues were encountered or became larger issues than expected related to the microgrid project?
9. In hindsight, was there anything that could have been done differently to better achieve project goals?

Stakeholder Engagement

10. Who was the primary day-to-day point of contact with the microgrid host? (E.g., key account representative)
11. Do you have any recommendations for communication and planning between stakeholders such as:
    a. Site host/Facility manager
    b. Microgrid controls provider
    c. Component manufacturers
    d. Developers/installers
    e. Local utility

Looking Forward

12. What utility processes have been modified or streamlined, if any, to assist microgrid design over the length of this project? (Including the interconnection process)
13. Did you come out with a positive or negative view of the microgrid project and its value overall?
14. Is the utility interested in working with similar microgrid projects in its territory in the future? Why or why not?
15. What recommendations do you have for additional research needs based on the execution of the microgrid project?

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Appendix B: Schedule of Interviews

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APPENDIX B: Schedule of Interviews

The schedule of interviews led by Navigant is reflected below.

Project	Date	Location	Interviewee
Demonstrating a Secure, Reliable, Low-Carbon Community Microgrid at Blue Lake Rancheria	**3/13/2019**	Arcata, CA	• Peter Lehman (Schatz Energy Research Center) • David Carter (Schatz Energy Research Center) • Jim Zoellick (Schatz Energy Research Center)
		Blue Lake, CA	• Jana Ganion (Blue Lake Rancheria) • Jason Ramos (Blue Lake Rancheria)
Laguna Wastewater Treatment Plant Microgrid	**3/19/2019**	Santa Rosa, CA	• Richard Swank (Trane) • Tasha Wright (City of Santa Rosa) • Joseph Schwall (Santa Rosa Water)
A Novel, Renewable Energy Microgrid for a California Healthcare Facility	**2/21/2019**	Conference Call	• David Bliss (Charge Bliss)
	3/5/2019	Richmond, CA	• Jeff Harding (Charge Bliss) • John Griffiths (CONTECH-CA)
	3/18/2019	Conference Call	• Seth Baruch (Kaiser Permanente)
	4/3/2019	Conference Call	• Michael Flynn (Kaiser Permanente)
Las Positas College Microgrid Automation Project	**3/6/2019**	Livermore, CA	• Bruce Rich (WSP) • Owen Letcher (Chabot-Las Positas Community College District) • Walter Blevins (Chabot-Las Positas Community College District)
Solar Emergency Microgrids for Fremont Fire Stations	**2/11/2019**	Fremont, CA	• Vipul Gore (Gridscape Solutions) • Rachel DiFranco (City of Fremont) • Amiel Thurston (City of Fremont Fire Department)

Project	Date	Location	Interviewee
Bosch Direct Current Building-Scale Microgrid Platform	**1/30/2019**	Chino, CA	• Robert (Bob) Meyer (Honda) • Sharmila Ravula / Ian Tilford (Bosch)
Borrego Springs: California's First Renew-able Energy Based Community Microgrid	**3/11/2019**	Borrego Springs, CA	• Laurence Abcede (SDG&E) • Tom Bialek (SDG&E) • Steven Prsha (SDG&E)

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Appendix C: Interconnection Resources

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APPENDIX C: Interconnection Resources

Interconnection requirements are poised to evolve as distributed energy resources (DERs) integration advances. The state, regulatory bodies, and electrical corporations have demonstrated streamlined improvements to support a reliable, safe grid with higher penetration of DERs and microgrids. An example of this is the California Public Utilities Commission (CPUC) adopted Order Instituting Rulemaking to Consider Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21 (CPUC, 2017a).

Several available resources provide background knowledge for interconnecting to the investor-owned utility (IOU) grid. For example, Rule 21 interconnection regulatory requirements can be found on the CPUC's website containing directional links to the IOU Rule 21 websites (CPUC, 2017b). Additionally, the large IOUs have provided a variety of guidance documents with detailed information.

The following links serve as public resources for interconnecting within IOU service territory. Information shared includes the requirements for interconnection, costs associated with the project timeline, guidance handbooks that list additional service and construction needs, and tariff information relating to the interconnection agreement.

PG&E Available Resources

- PG&E Rule 21 Tariff:
  - https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_RULES_21.pdf
- Distribution Interconnection Handbook:
  - https://www.pge.com/en/about/doing-business-with-pge/interconnections/handbooks.html#tabs-7ffb3b43d3-item-908841ce98-tab
- Transmission Interconnection Handbook:
  - https://www.pge.com/en/about/doing-business-with-pge/interconnections/handbooks.html#tabs-7ffb3b43d3-item-828ab71190-tab
- PG&E Pre-Application:
  - https://www.pge.com/en/clean-energy/solar/getting-started-with-solar.html
- PG&E Unit Cost Guide:
  - https://www.pge.com/content/dam/pge/docs/about/doing-business-with-pge/unit-cost-guide.pdf

- PG&E Renewable Auction Mechanism (RAM) Map:
  - https://www.pge.com/en/about/doing-business-with-pge/interconnections/distributed-resource-planning-data-and-maps.html
- PG&E Electric & Gas Service Requirements (Greenbook):
  - https://www.pge.com/en_US/large-business/services/building-and-renovation/greenbook-manual-online/greenbook-manual-online.page

SCE Available Resources

- SCE Rule 21 Tariff:
  - https://www.sce.com/sites/default/files/inline-files/Rule21_FAQ%20%281%29.pdf
- SCE Interconnection Handbook:
  - https://www.sce.com/sites/default/files/custom-files/Web%20files/SCE_InterconnectionHandbook.pdf
- SCE Optional Pre-Application:
  - https://www.sce.com/business/generating-your-own-power/submit-documents
- SCE Unit Cost Guide:
  - https://www.sce.com/sites/default/files/inline-files/Attachment_A-Unit%20Cost%20Guide%202021_Final.pdf
- SCE Community Renewables — RAM:
  - https://www.sce.com/procurement/solicitations/archive/cr-ram5
- SCE Electrical Services Requirements:
  - https://www.sce.com/regulatory/distribution-manuals/electrical-service-requirements

SDG&E Available Resources

- SDG&E Rule 21 Tariff:
  - https://www.sdge.com/more-information/customer-generation/electric-rule-21
- Distribution Interconnection Handbook:
  - https://www.sdge.com/sites/default/files/documents/DistributionInterconnectionHandbook.pdf
- Transmission Interconnection Handbook:
  - https://www.sdge.com/sites/default/files/GI_Handbook_12-18-2017.pdf

- SDG&E Pre-Application:
  - https://www.sdge.com/apply-service
- SDG&E Unit Cost Guide:
  - https://www.sdge.com/sites/default/files/documents/Updated_Rule_21_Unit_Cost_Guide.pdf?nid=8681
- SDG&E RAM:
  - https://www.sdge.com/more-information/customer-generation/renewable-auction-mechanism-ram-map-0
- SDG&E Electric Distribution Engineering Manuals & Guides:
  - https://www.sdge.com/sites/default/files/SDGE%20Builder%20Services%20Guidebook%20March2021.pdf