ENERGY RESEARCH AND DEVELOPMENT DIVISION

FINAL PROJECT REPORT

Santa Rosa Junior College Microgrid Demonstration Project

Demonstrating the Business Case for Advanced Microgrids in Support of California's Energy and Climate Policies

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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; transportation; and energy transmission and distribution.

In 2011, 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 electric 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 to promote greater reliability, affordability, and safety for California electric ratepayers. EPIC investments advance these values by:

- 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 projects), and finally with a clean electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Santa Rosa Junior College Microgrid Demonstration Project is the final report for the project of the same name (EPC-17-053) conducted by Santa Rosa Junior College. The information from this project contributes to the CEC Energy Research and Development Division's EPIC Program.

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

In California and nationwide, electricity distribution infrastructure is increasingly vulnerable to extreme weather and natural disasters, including wildfires that are being made more frequent and severe because of climate change. The Sonoma County Junior College District, in partnership with the Center for Sustainable Energy, Worley, and PXiSE Energy Solutions LLC, and with funding from the California Energy Commission, conducted a microgrid demonstration project at the Santa Rosa Junior College campus. The project began in 2019 with modelling, engineering design, and baseline measurement and ran through 2026 with procurement, installation, commissioning, operational measurement and evaluation, and project reporting. The microgrid integrated three types of distributed energy resources — photovoltaic generation, electrical energy storage, and flexible load control systems, all managed by a single microgrid controller.

The goals of this project were to (1) supply up to 40 percent of the campus electricity use with local renewable energy, (2) optimize energy use and reduce the monthly peak electricity demand and associated charges for the campus, and (3) increase campus and local community resilience by supporting local facilities during outages while providing broader grid benefits through flexible operations.

The project validated multiple value streams of the Santa Rosa Junior College campus microgrid, including $670,000 in annual cost savings, a monthly reduction of 1,740 kilowatts, and a reduction of 1,591 metric tons of carbon dioxide equivalent in greenhouse gas emissions. The project served as a blueprint for other campuses in the California Community Colleges, California State University, and University of California systems.

Keywords: renewable energy, microgrid, demand management, power quality, energy storage

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Background

In California and nationwide, the electricity distribution infrastructure is increasingly vulnerable to extreme weather and natural disasters, including wildfires that are being made more frequent and severe because of climate change. Within the past 10 years, Sonoma County experienced three major wildfires — the Tubbs Fire in 2017, followed by the Kincaid Fire in 2019 and the Glass Fire in 2020. These fires led to widespread power outages and significantly impacted the health and safety of the Santa Rosa Junior College student and staff community.

Distributed energy resources like rooftop solar, battery energy storage systems, and flexible loads controlled as a microgrid can provide flexibility to the grid when grid connected and can also be isolated and operated when disconnected from the grid, providing power to local facilities during planned and unplanned outages. This project designed, commissioned, and operated a microgrid to validate these local and grid benefits while demonstrating the commercial viability and business case for replicable microgrid deployment at other California community colleges, universities, and public building complexes.

Project Purpose and Approach

The purpose of this project was to validate the flexibility and resiliency benefits of microgrids and demonstrate a replicable blueprint for campus microgrids that integrate renewable distributed energy resources. The microgrid designed and validated in this project featured adaptive load shed strategies that allowed individual buildings to be dynamically disconnected and reconnected to the microgrid, providing improved resiliency during outages and accommodating future capital improvements undertaken by the college.

The Sonoma County Junior College District partnered with the Center for Sustainable Energy, Worley, and PXiSE to design and build a microgrid serving more than 20 buildings and their critical and noncritical loads on the Santa Rosa Junior College campus. Santa Rosa Junior College is a 100-acre campus located in wildfire-prone Sonoma County in the Pacific Gas and Electric service territory.

The campus owns and maintains a 12-kilovolt switchgear and feeder network behind a single point of connection with the Pacific Gas and Electric Company distribution grid, which constitutes the microgrid boundary when operating disconnected from the grid. The college installed high-accuracy metering at each building connected to the microgrid to gain granular insights into building-level load profiles and to incorporate building flexibility into the energy management system. Meters were also installed for each distributed energy resource in the microgrid, which include the following.

1. Approximately 2.4 megawatts (MW) of new solar photovoltaic generation capacity across three carport systems and one rooftop solar array (paid for with match funding).

2. A new 2-MW/3-megawatt-hour (MWh) lithium-ion battery energy storage system composed of two separate systems with two different inverters, one of which can switch between grid-forming and grid-following in approximately 30 milliseconds; this enables a seamless transition between grid and local power (1 MW/2 MWh paid with match funding and 2 MW/2 MWh paid with California Energy Commission grant funding).
3. Two MW of new flexible load from load management devices that can connect and disconnect different buildings to balance supply and demand in real time (paid for with California Energy Commission grant funding).

The microgrid is controlled by a PXiSE high-speed microgrid controller that maintains stable frequency and voltage. The controller is configured to optimize use of locally generated solar, but it can be flexibly configured to optimize campus energy bill savings and greenhouse gas emission reductions, or to maximize provision of backup power for extended outages. All distributed energy resource and metering components previously described work together as a flexible, fully renewable-powered microgrid.

Key Results and Conclusions

The microgrid was commissioned in 2022 and underwent one year of measurement and verification through 2023. During the measurement and verification period, the microgrid reduced greenhouse gas emissions by more than 1,500 metric tons of carbon dioxide equivalents, achieved a peak monthly demand reduction of approximately 730 kilowatts, and resulted in approximately $670,000 average annual utility bill savings for the campus. The resilience benefits from the microgrid's islanding capabilities were demonstrated during annual microgrid testing, when planned outage tests were implemented.

In addition to microgrid demonstration and deployment, this project developed a unique loss of load value based on metrics of building space use and a building value based on a portion of the general fund assigned, which reflects the cost of not being able to provide student services during outages. The loss of load value was complimented by qualitative data collection obtained through discussions with Santa Rosa Junior College staff to better understand the impacts of outages and benefits of the microgrid's ability to power critical services during outages. The project provides an example of how public entities can create their own loss of load value estimates to more effectively value the resilience benefits of microgrids, which can be particularly challenging for public facilities that provide broader societal services.

The estimated total cost of the system was $14.9 million, and the microgrid provided an annual savings of approximately $670,000 per year. At the same time, the college has experienced a 9-percent escalation in utility rates since 2017. When accounting for the life of the solar panels and the battery energy storage system, combined with projected growth in utility rates, the net present value of the system is positive within the life of the assets at approximately $5.7 million.

Knowledge Transfer and Next Steps

The knowledge transfer efforts were aimed at facility and sustainability managers, as they would be the individuals primarily responsible for making facility management decisions and promoting internal organization environmental goals. The remainder of the outreach efforts were divided between engineers and contractors as well as community choice aggregators. Knowledge transfer activities included webinar presentations at Energy Storage North America and the Local Government Coalition of Northern California City and County Officials Microgrid Education meeting and a conference presentation at the American Council for Energy Efficiency Economy 2022 Summer Study Session.

Benefits to California Ratepayers

This project provided benefits to ratepayers for California's three large investor-owned utilities in alignment with EPIC goals promoting affordability, increasing reliability and resilience, and promoting environmental sustainability. Specifically, the microgrid deployed and demonstrated in this project reduced utility bills for the campus by optimizing distributed energy resources, including flexible loads. The microgrid reduced peak demand on the utility distribution grid, which lowered stress and can extend the lifetime of grid components, and it provided flexibility to the grid, resulting in lower demand charges and compensation for participation in demand response programs. The microgrid also increased the resilience of the campus and surrounding community by enabling critical facilities to remain operational during grid outage events.

CHAPTER 1: Introduction

In California and nationwide, electricity distribution infrastructure is increasingly vulnerable to extreme weather and natural disasters, including wildfires that are being made more frequent and severe because of climate change. Within the past 10 years, Sonoma County experienced three major wildfires — the Tubbs Fire in 2017, followed by the Kincaid Fire in 2019 and the Glass Fire in 2020. These fires led to widespread power outages and significantly impacted the health and safety of the Santa Rosa Junior College (SRJC) student and staff community.

Distributed energy resources (DERs) like rooftop solar, battery energy storage systems (BESS), and flexible loads controlled as a microgrid can provide flexibility to the grid when grid connected and can also be isolated and operated when disconnected from the grid, providing power to local facilities during planned and unplanned outages. This project designed, commissioned, and operated a microgrid to validate these local and grid benefits while demonstrating the commercial viability and business case for replicable microgrid deployment at other California community colleges, universities, and public building complexes.

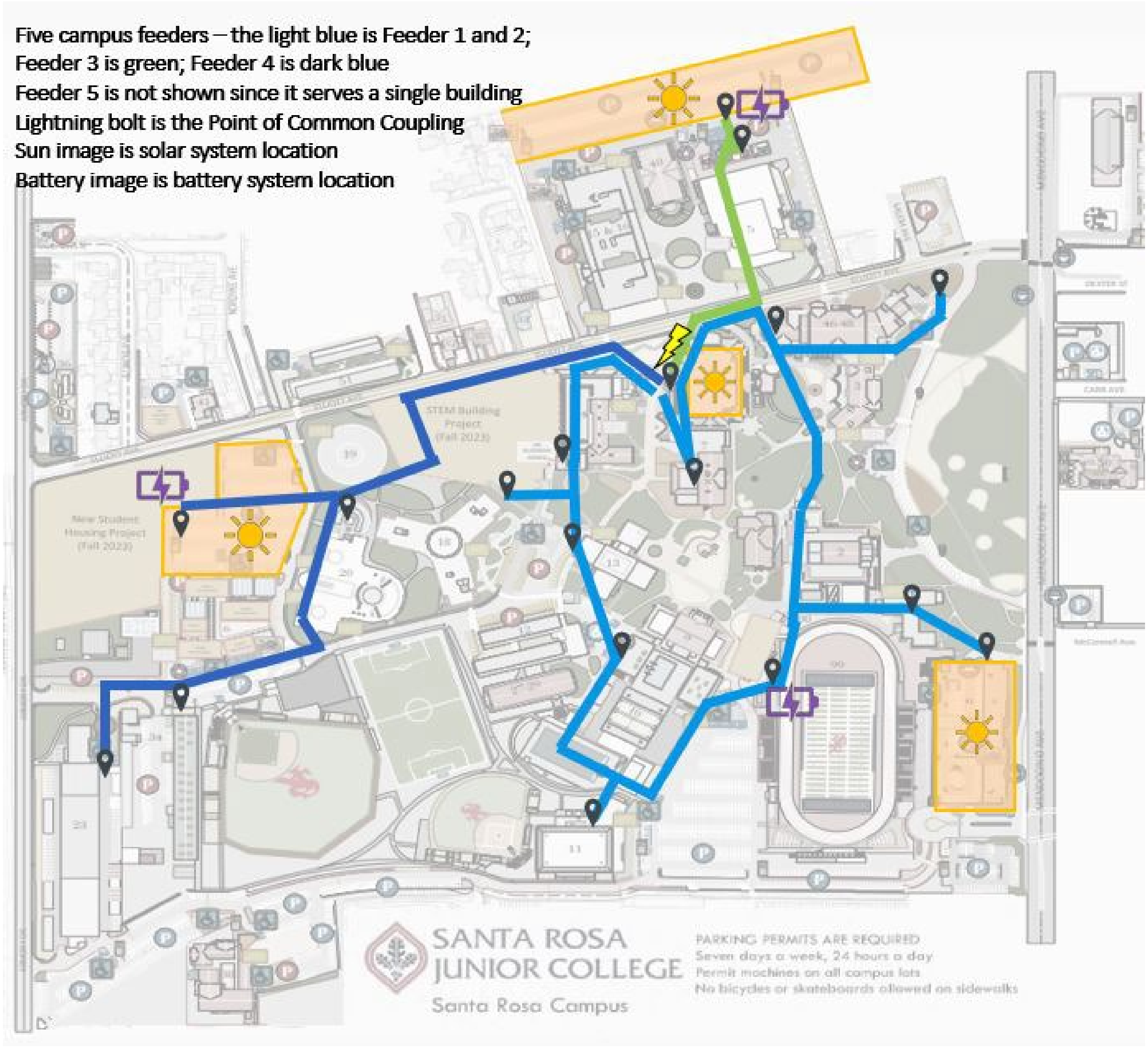
SRJC Site Overview

The SRJC campus occupies more than 100 acres in wildfire-prone Sonoma County. The campus is located in California's Climate Zone 2, with an average annual temperature of 59°F (15°C) and typical seasonal temperature trends. Most classes are held between Monday and Thursday during each term, with a smaller number of classes meeting on Friday and limited activity throughout the campus during nights and weekends.

The campus comprises 27 buildings, including classrooms, libraries, sports facilities, and student support services, as well as administrative, maintenance, and other various buildings, with a total square footage of nearly 1.2 million square feet. Buildings are served by a number of isolated heating and cooling systems, including individual chillers, cooling towers, and boilers. A smaller thermal energy storage system and geothermal loop also exist on site as well as a decommissioned cogeneration plant that ceased operations in 2015.

Electricity is provided to the campus by Pacific Gas and Electric Company (PG&E) via a single point of interconnection at the north end of campus. The main switchgear at the point of common coupling (PCC) serves five 12-kilovolt (kV) feeders in a star-connected network that deliver electricity to different parts of the campus, as shown in Figure 1. There are additional buildings located at the campus that are not part of the main campus electrical distribution system and were not included in campus microgrid modeling.

Figure 1: Santa Rosa Junior College Campus Feeder Map



Source: SRJC

SRJC is a direct access customer, meaning it purchases electricity from Direct Energy as the third-party electric service provider that is delivered by PG&E's infrastructure via the E-20 Option R Tariff. SRJC qualifies for grandfathered time of use periods and will continue to follow this time of use schedule through 2027. The campus installed 2.4 megawatts (MW) of solar photovoltaic (PV) systems (match funded), interconnected through the NEM 2 Tariff, and has an existing 60-kilowatt (kW) rooftop solar system (pre-existing system) on Doyle Library, interconnected in 2008. While SRJC is not subject to generation charges from PG&E, all other charges, including fixed charges, demand charges, distribution charges, and surcharges, still apply.

Project Team

SRJC was the prime recipient, site host, and overall project lead. SRJC was responsible for project design, procurement, construction management, and oversight of microgrid testing and operations. SRJC partnered with the Center for Sustainable Energy, which was responsible for project management and measurement and verification of microgrid grid performance. PXiSE was selected as the microgrid controller and led the design, installation, and testing of the microgrid controller as well as overall microgrid functionality. Worley served as the engineer of record for the project and was responsible for microgrid design and provided technical support during the installation and testing of relays and building disconnect devices.

Goals and Objectives

The goals of the project were to design, construct, and operate a microgrid that (1) provides 40 percent of the campus electricity consumption with zero emission solar power, (2) reduces the campus peak demand drawn from the utility distribution system and associated demand charges, and (3) increases the resilience of the campus and surrounding community by maintaining service to critical facilities during power outages.

To achieve these goals, the project identified and achieved a number of specific objectives, including the following.

- Assess individual and building level load to inform microgrid design and adaptive load shedding controls and hardware.
- Integrate multiple distributed PV generation sources installed on different feeders, two varieties of energy storage optimized for power and energy storage capacity, and adaptive load shedding devices within the microgrid controls.
- Demonstrate economic, environmental, and resilience benefits of the microgrid for the campus community and broader grid benefits from local frequency support and participation in demand response programs.
- Disseminate the technology advancements and experience gained through this project to other community college and public facility managers to inform future campus microgrid deployments.

CHAPTER 2: Project Approach

The SRJC microgrid project progressed through a sequence of activities with associated tasks and deliverables, including:

1. Baseline measurement of campus energy consumption at the building level through installation of advanced smart meters, data from which was used in subsequent design tasks.
2. Microgrid design and engineering, including both communications and physical assets, with the goal of optimizing economic and environmental benefits, increasing campus resilience to outages, and maintaining cyber and physical security.
3. Procurement, installation, and commissioning of the BESS, controls, and other microgrid components, including verification of adaptive load management and islanding capabilities.
4. Measurement and verification of microgrid performance and benefits over a period of one year.

These activities, including key lessons that can inform future projects, are described in greater detail in this chapter.

Baseline Measurement and Submetering Strategy

Adaptive load management within the microgrid was implemented at the building and DER level, so metering was installed in these locations and there was no need for more granular metering of individual end-use devices such as heating, ventilation, and air conditioning (HVAC) and lighting systems. The major submetering points on the campus microgrid included:

- Building level electrical consumption (kW and kilowatt-hour [kWh]) for 22 buildings on campus.
- Doyle Library Ice Bear Thermal Storage (kW and kWh) (pre-existing system).
- Solar PV production (kW and kWh) of all existing systems (pre-existing and match funded).
- Charge and discharge (kW and kWh) for the on-site BESS (match funded and grant funded).
- Energy and power (kw and kWh) at the PCC with the PG&E grid.

For metering at buildings, the team selected and procured revenue grade meters with the ability to communicate using standard protocols such as Modbus TCP/IP to BacNET that were relatively easy to install. Metering at existing DER locations was done using data from the inverter communicated through Modbus TCP/IP, while metering at the PCC was done with a highly granular cycle-by-cycle sampling for synchorphasor data and implementation of protections.

Metering at the PCC relies on a “Mirrored Bits” communication protocol, which is proprietary and allows for high-speed communication.

The baseline data collected by these meters was used to develop typical energy profiles of building and campus energy consumption as well as in microgrid controls using near-real-time data. The data was combined with qualitative factors decided upon by facility, staff, and control operators — for example, regarding the prioritization of which buildings to disconnect from the campus microgrid during load shed events. These qualitative factors and underlying baseline data shaped the microgrid control logic.

Microgrid Design and Engineering

A range of microgrid planning and design tools are available for commercial use, including XENDEE (Xendee Corporation n.d.), *REopt* (Anderson et al. 2017), HOMER (HOMER Energy LLC n.d.), and the *Microgrid Design Toolkit* (Sandia National Laboratories 2024). Most design tools are either simulation-based and produce a matrix of results for a selection of DER portfolios or combine simulation and optimization techniques to optimize design around user-defined dispatch schedules.

The microgrid design software XENDEE was chosen for this project because it allowed the team to simultaneously optimize the front-end design and lifetime hourly operation schedule of the microgrid to minimize total annualized energy cost for the campus. The model combines both resource sizing and dispatch logic to identify an optimal solution for the modeled site and use case, directly informing the microgrid controls strategy.

Conceptual Methodology

The general process used to select the optimal microgrid portfolio includes the following steps.

1. Input site and product specific data covering environmental, economic, operational, and storage into XENDEE.
2. Run multiple scenarios covering:
    a. Current operations — modeling the campus as-is without the microgrid and additional DERs installed in this project.
    b. Sizing scenarios — determining optimal microgrid design and operations to meet resilience and other needs while minimizing energy costs across a range of outage and demand assumptions, including “blue sky” conditions with no outages.
3. Compare the economic and environmental attributes of each microgrid design scenario relative to current operations.
4. Conduct sensitivity analyses to explore specific influential operational factors within the sizing scenarios.

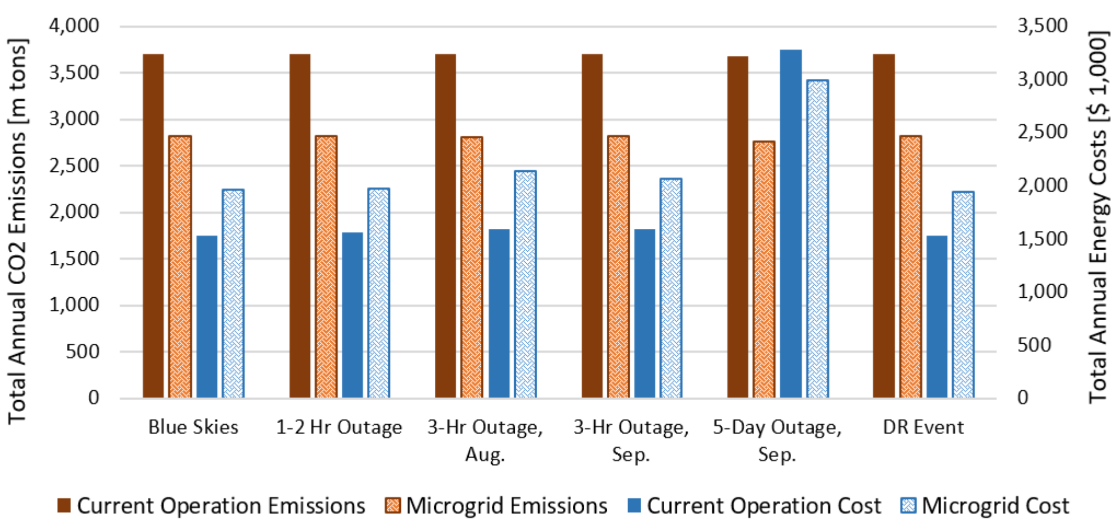
For all scenarios, the campus was modeled as representative normal campus operation days and, when applicable, outage or demand response event days, constructed from the provided 15-minute-interval campus meter data. The utility costs were modeled by specifying the volumetric electricity and demand charge tariffs for each month, as well as the time of use periods.

Microgrid Design Findings and Cost-Benefit Analyses

The optimal storage sizing is the required minimum capacity of 4 megawatt-hours (MWh), with additional storage selected only for outages longer than two hours without load shedding or three hours with load shedding considered. For a three-hour midday outage on a representative high-demand day in September, 4.8 MWh of storage was needed to meet all critical and noncritical loads on campus, assuming seasonally typical solar production. If the outage occurred in August, the required capacity increased to 5.5 MWh.

The estimated annual greenhouse gas (GHG) emissions (red bars, left axis) and annual campus energy costs (blue bars, right axis) are shown in Figure 2 for the current operation scenario and the sizing scenarios; these model the campus microgrid with PV, storage, and flexible loads across a range of outage and demand scenarios. The one- to two-hour outage and demand response event scenarios exhibited negligible variation in emissions and costs across the different events and are therefore presented as average results. The demand response results reflected modeled participation in the capacity bidding program, which was estimated to generate the highest revenue compared to other demand response programs.

Figure 2: Total Annual Emissions and Energy Costs for Select Design Scenarios

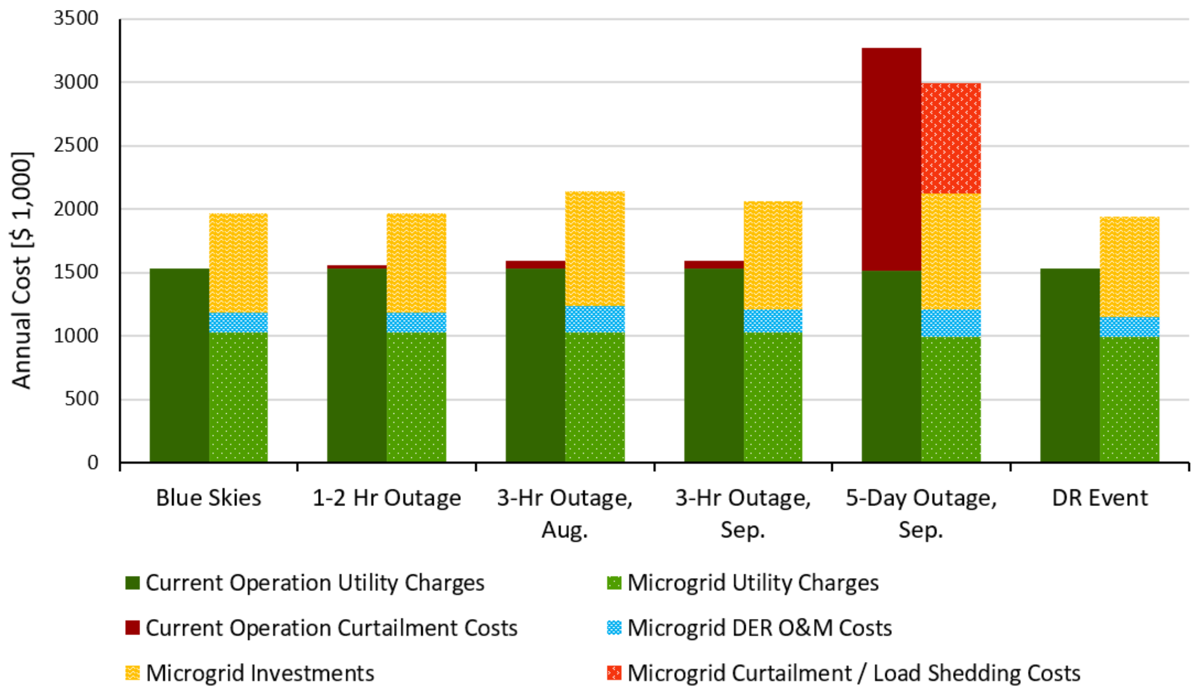


Source: SRJC

Across all scenarios, the microgrid reduced campus annual emissions by an average of 24 percent, which was driven by the addition of 2.2 megawatt alternating current (MW-AC) of PV installed. For all sizing scenarios except the five-day outage, the microgrid had increased annual costs ranging between $393,000 (blue skies) and $548,000 (August 3 day outage) due to the additional costs for the incremental storage capacity required to meet load over longer outage durations.

The principal contributors to annual energy costs for the current operations and sizing scenarios are shown in Figure 3. In all scenarios, the microgrid resulted in lower utility charges for the campus, but this was generally outweighed by the increased capital investment in the microgrid. Curtailment costs were relatively limited in all scenarios except the five-day outage, in which the microgrid resulted in significantly less curtailment cost and resulted in a lower total annual energy cost.

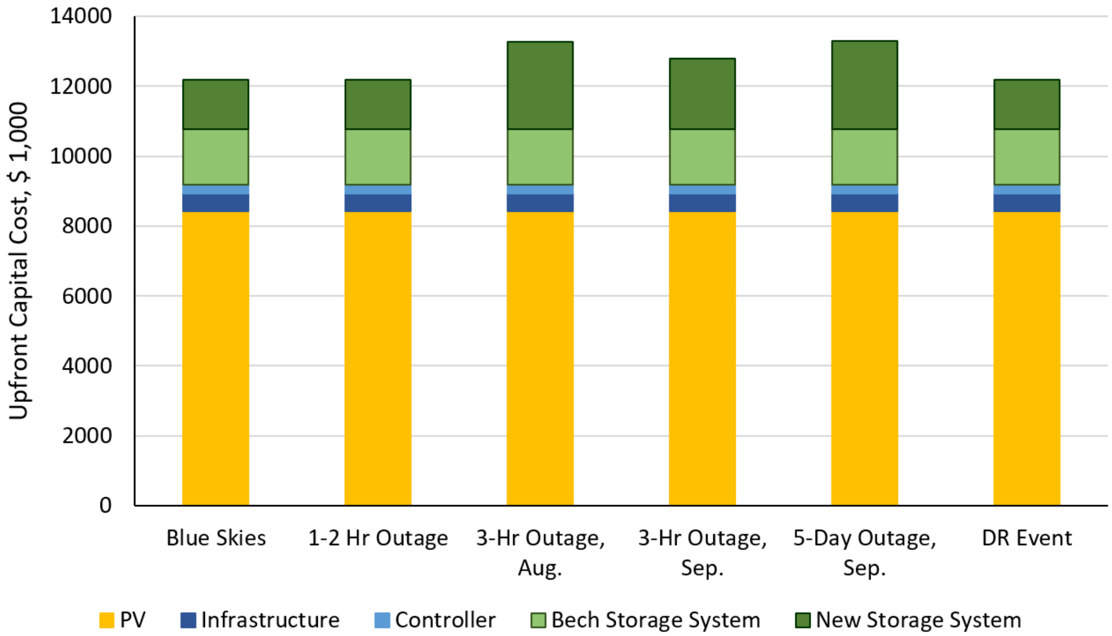
Figure 3: Components of Annual Energy Costs for Select Design Scenarios



Source: SRJC

Figure 4 shows the upfront costs for all investments. Depending on the capacity of battery storage selected, 56 to 64 percent of the annualized costs are attributed to the PV system and 32 to 41 percent are attributed to the storage systems. The PV system and the Bech storage system are funded by SRJC, with half of the upfront cost for the Bech storage system offset by the Self-Generation Incentive Program. The infrastructure, controller, and new storage system were funded through this grant.

Figure 4: Upfront Capital Investment Costs for Select Design Scenarios



Source: SRJC

Electrical and Hardware Design and Engineering

The microgrid electrical engineering and hardware design were driven by the main operating objectives of the microgrid, including the following functions.

- Integrate multiple DERs across multiple feeders.
- Provide real-time, localized frequency support to the utility distribution grid.
- Demonstrate economic value streams for the microgrid, such as demand response participation.
- Optimize energy use and reduce the campus peak load.
- Transition between grid-following and grid-forming modes seamlessly, without any disruption to service to campus buildings.
- Isolate and adaptively shed building loads when islanded, in case local generation cannot meet campus demand.

The goal of the electrical and hardware engineering phase of the project was to develop the electrical, mechanical, and civil engineering designs that meet these objectives and to inform the purchase and installation of the microgrid components. These included, but were not limited to, interconnection devices, BESS, concrete equipment pads, and utility trenches. This phase built on the microgrid design task previously described and was a required step before the project could proceed with procurement and installation.

The electrical and hardware engineering designs were developed in multiple stages — three design development iterations, three construction document iterations, and one final backcheck. The design development and construction document sets were assessed at 30-, 60-, and 90-percent completion. Because SRJC is part of the California Community Colleges system, all plan sets were required to be submitted to the Division of State Architects for approval. The Division of State Architects applies recent interpretation of regulations N-4: Modular Battery Energy Storage Systems: 2022 CBC and CFC, which clarify structural, fire, and life safety design requirements for BESS, among others.

Microgrid Controls and Communications

The PXiSE microgrid controller was selected to manage and coordinate campus DERs, including loads, by independently balancing real and reactive power and efficiently dispatching resources to meet resilience, power quality, and utility cost savings objectives. The microgrid controller achieves this through direct control of inverters and generators with enforced, closed-loop feedback at the point of interconnection, including allowing independent control of real and reactive power from DERs. The microgrid controller provides power factor and scheduling control at the point of interconnection, manages battery state of charge, and provides data measurement and control at up to 10 hertz (Hz).

The advanced package from PXiSE was selected because it provided additional functionalities, including autonomous islanding and reconnection to the utility distribution grid, black start capability, fast acting load shedding, and intermittent resource curtailment. The advanced control package also provides ramp rate control and frequency support at the point of interconnection and data measurement and control at up to 60 Hz.

The microgrid controller can communicate a variety of new and existing DERs on campus via multiple different communication protocols. The communication protocols used in this project ended up being Schweitzer Engineering Laboratories (SEL) Fasttalk through IP based communication, DNP3, BacNet IP, and Modbus TCP/IP. The communication protocol speed for receiving and responding to control signals is critical for seamless, safe transitions to islanded mode and for synchronization and reconnection. Modbus TCP/IP, BacNet IP, and ethernet cabling is too slow for these actions, so the project implemented a fiber connection and communication via DNP3 or SEL Fasttalk.

During design, the project team mapped where existing and new DERs were located and what new or existing communication conduits and pathways (for example, ethernet or fiber) were required. The project team decided to leverage the campus' existing IPv4 network for microgrid communications to support maintenance and long-term reliability versus creating a separate network. This had the added benefit of reducing overall project costs by using existing fiber pairs and allowed the PXiSE controller to run on a virtual server as opposed to a field-based server.

Concept of Operations

PXiSE, with input from the other project partners, developed the concept of operations (CONOPS) document that describes the operating characteristics of the microgrid controller. The CONOPS report outlines the main operating objectives of the microgrid and then provides additional information on the software and hardware components of the microgrid controller to achieve the objectives, including the sequence of operation for each use case. A timing study was conducted in relation to the CONOPS report to understand the timing of equipment operations (for example, time for the medium voltage main breaker to open) relative to signaling via various communication protocols, to ensure proper operations for islanding and reconnection actions.

Load Shedding Hardware and Operations

Load shedding was initiated either automatically, based on electrical system conditions, or remotely via communications from the PXiSE controller. Generally, the campus load changes gradually over time and the PXiSE controller can shed and restore buildings based on building priority. Inverters have limited current overload capabilities, so, in the event of a sudden overload (most frequently caused by sudden loss of generation), load shedding must be performed automatically.

Automatic load shedding is armed at each of the 21 campus buildings identified as requiring load shed disconnects. When the load shedding device is closed, the incoming source is energized and remotely enabled by the PXiSE controller. The load shed disconnect is tripped by an undervoltage, event such as loss of generation. When there is sufficient generation or service from the grid is restored, the incoming power to the individual buildings can be remotely restored by the PXiSE controller.

The campus building load shed disconnect devices are electrically operated circuit breakers with electrical trip and close capabilities in addition to open/close status monitoring and bell alarm status monitoring. Several different devices and configurations were used, based on the space available and other constraints. All control power is 120/240 volts supplied by a control power transformer connected to the incoming power connection of the circuit breakers.

Load shed monitoring, control, and communication is provided by an SEL feeder protective relay (SEL-751) installed at each load shed disconnect device location. The SEL-751 has digital inputs for status monitoring and digital outputs for opening and closing the load shed disconnect device. The three-phase voltage inputs are connected to the line side of the load shed disconnect devices and are used in settable voltage elements for shed and restoration control. Communication is by way of an RS-45 ethernet connection on the back of the SEL-751 and via modbus from the SEL-751 to the PXiSE controller.

Tripping of the circuit breakers is possible, up to slightly more than 500 milliseconds after a loss of AC control power without uninterruptible power supply or battery backup. This is accomplished by the circuit breaker trip coil being supplied through a capacitor trip device and the power supply characteristics of the associated SEL-751 trip initiating device, which will ride through a power supply interruption for more than 500 milliseconds with a 240-VAC (volts of alternating current) supply.

Battery and Inverter Requirements

The objectives for the microgrid resulted in several requirements for inverter capabilities. Specifically, the inverter was required to be able to operate in both grid-tied and islanded modes, have black start and grid-forming capabilities, provide active/reactive power and voltage/frequency support, and have all internal operating variables displayed on an internal human-machine interface, preferably a webpage.

The BESS design specified two 1-MW systems, each capable of discharging at their nameplate rating for a minimum of one hour, and that this usable capacity must be maintained over the warranty period of the BESS. The minimum acceptable round-trip efficiency selected for potential BESS vendors was 85 percent, which is typical for lithium-ion batteries.

Regarding the battery energy storage system, the project team specified requirements for a competitive bidding process. Key requirements related to the controls and communication protocols ensured (1) the BESS could be effectively managed by the selected controller, (2) remote monitoring and alarm settings included automated notifications to SRJC about any irregular conditions, and (3) warranty requirements were maintained. The requirements also included adherence to the most recent national and local fire codes as well as a detailed factory acceptance test process.

Black Start

The BESS equipment was installed with black start capabilities. Each 1,000-kW BESS package consisted of four 250-kW parallel power conditioning system (PCS) inverters. Black start was performed with a single PCS inverter. After BESS 480-VAC output was energized, the remaining three 250-kW inverters were synchronized at the 480-volt level. The 480-VAC inverter outputs were also directly connected to the 480-volt winding of the 1000-kVA BESS step-up transformer. The inrush current of energizing the transformer caused the BESS inverter to trip. The BESS vendor made programming changes, such that the inverter output contactor would be closed before inverter startup. The BESS step-up transformer could then be energized by ramping up the inverter output voltage and frequency with the transformer connected.

Microgrid Islanding Requirements

The campus is interconnected with the PG&E Santa Rosa Substation 1105 feeder when the campus 12-kV switchgear main circuit breaker is closed. A basic function of the microgrid is being able to separate as an island from the PG&E system, either manually or initiated automatically as a response to a PG&E grid outage, and then to subsequently perform a controlled synchronization back to grid-connected mode when PG&E service is restored.

The main circuit breaker of the existing 12-kV switchgear did not have the required paralleling capabilities, so SRJC replaced this switchgear with one that had electrically operated circuit breakers with protection, control, and metering features. A new interconnected ground grid was installed for the new 12-kV switchgear. The ground grid established a grounding electrode system for the microgrid grounding transformer/resistor system grounding point and equipment grounding conductors. The remote microgrid controller required ethernet communications with phasor measurement unit data streams for the main breaker protection and control device. Protective relays that were compliant with Institute of Electronic and Electrical Engineers (IEEE) C37.118 linked with a GPS clock, and antennae were installed in the replacement switchgear for this purpose.

A three-phase undervoltage relay provides security against unnecessarily islanding the campus. The normal PG&E voltage operating range throughout the length of the feeder is controlled by a voltage regulating transformer at the +/- 5-percent threshold. A three-phase undervoltage relay is not sensitive to the typical single-phase undervoltage events associated with the typical faults on an overhead distribution circuit. A three-phase undervoltage element is set to trip the incoming main circuit breaker when all three-line voltages drop below 83 percent of the rated operating voltage. These settings provide security against separating the campus under normal system operating conditions and feeder faults that are routinely cleared without de-energizing the feeder.

On a detection of the failure of the PG&E source by way of a three-phase undervoltage, the main incoming circuit breaker is directly tripped, bypassing the circuit breaker lockout relay. The instantaneous undervoltage is sensed by the BESS controllers, which causes them to switch from grid-following to grid-forming operating mode. The PXiSE system controller monitors the open/closed status of the campus main circuit breaker.

When the PG&E service is restored but the campus is still islanded, the PiXSE controller adjusts the campus 12.47-kV system voltage to match that of PG&E and sets the campus electrical frequency to 0.001 Hz faster than the PG&E frequency. The PiXSE controller then arms the synchronism check element in the SEL-351. With the PG&E and campus voltages matched, the slip frequency less than 0.05 Hz, and the phase angle between the islanded campus and PG&E less than 10 electrical degrees, the SEL-351 gives a main circuit breaker close command. The SEL-351 compensates for the three-cycle operating time of the circuit breaker so that the breaker closes when PG&E and the islanded campus are electrically in phase. An auxiliary contact from the campus main circuit breaker is monitored by the PiXSE controller, and the BESS inverters change from grid-forming to grid-following mode when the circuit breaker is closed.

Delays in Completion of Design

The finalization of the electrical and civil design for the BESS scope was delayed by five months due to additional grounding studies for islanding capability. This delay prevented the project team from engaging electrical and civil subcontractors until the summer. By the time the team was reaching out to contractors, many of the potential bidders were completely booked up for the summer. A number of the individuals who did respond bid at a much higher rate.

This delay also pushed the construction, commissioning, and testing phases of the project into the fall, after classes resumed on campus. Although the campus was open to only about 30 percent capacity due to COVID 19, the start of classes created an additional scheduling consideration for campus outages for installation and testing activities that the project team had to plan around.

Procurement and Installation

As a California public entity, SRJC is subject to the California Public Contract Code in addition to procurement-related policies created by a locally elected board of trustees. Various procurement mechanisms were used for different elements of the project, spanning civil, electrical, and demand response service provision.

Two large requests for proposals (RFPs) using the college's electronic process were used to procure a design-build contractor for the 2.4-MW solar carports and the 1-MW/2-MWh BESS. The formal bid process is required for purchases exceeding approximately $115,000, including advertisement in the newspaper for two consecutive weeks. The RFPs included high-level specifications, minimum standards, and qualifications as well as provided geotechnical reports related to areas where the carports could be installed. SunPower was selected to perform this scope of work for the project and was approved by the SRJC Board of Trustees. A formal RFP process was also used for the installation of the 12-kV switchgear at the point of interconnection.

Procurement of load shed disconnect devices proceeded through a cooperative contract from the Foundation for California Community Colleges Administrative Services Agreement with an electric supplier. The contract allowed the project team to work with a switchboard manufacturer to develop specific intercept solutions. The same contracting mechanism was used to procure relays, field controllers, and other assorted electrical equipment.

All construction and installation activities followed standard informal bidding processes, through which scopes were developed based on near-final construction documents and shared with a list of pre-qualified contractors with different trade licenses. All electrical work was completed by licensed electrical contractors.

Procurement of a demand response service provider was done through single source bidding because the scope included integration of the existing HVAC controls into the microgrid controller. Single source bidding occurs only under specific conditions that involve campus standardization, specialty equipment under a single standard, and proof of a single authorized dealer in a given area, which is documented.

Integration of All System Components Into PXiSE System

After all the microgrid assets were installed and commissioning was complete, the assets were integrated into the PXiSE microgrid controller following the microgrid testing plan. Data quality and scaling were checked, and testing was conducted on each asset individually to validate read and write commands. Examples of the testing included P and Q setpoint commands sent to each BESS, and open, close, and shunt trip commands to the load-shed disconnect devices.

Interconnection and Electrical Studies

The interconnection of the BESS on campus was subject to the PG&E Rule 21 requirements, and the replacement of the 12-kV switchgear was subject to PG&E Rule 2. The project required coordination studies for the 12-kV replacement as well as an ark flash/short circuit study to align with energy and power flow modeling. There were multiple field visits and witness testing for the BESS and the switchgear that were done separately and not coordinated, resulting in inefficiencies in the interconnection and energization process. PG&E also recommended that the new switchgear be tested before the old one was de-energized, which was not possible as they were in the same physical location, so pre-energization testing of the new switchgear was performed during the five-day campus outage scheduled for installation.

Procurement and Installation Challenges and Lessons Learned

There were numerous challenges that occurred during procurement and installation. Principally, COVID-19 and related shelter-in-place practices occurred during this phase of the project, which significantly disrupted both manufacturing of equipment as well as availability of installation services. These disruptions resulted in project delays and increased costs.

Additionally, procurement was executed in multiple phases and with multiple scopes of work to accomplish the various activities in this technology demonstration project. This required SRJC to manage multiple contracts for equipment and labor and multiple bidding processes simultaneously. Future microgrid projects should consider using a design-build contracting process, a progressive design-build contracting process, or an engineering, procurement, and construction contract format.

Additional project delays in procurement and installation stemmed from design challenges related to speed of control, which required additional design efforts, including speaking with device manufacturers about their equipment's response time. Unforeseen 12-kV grounding transformer protection that was needed in island mode further contributed to delays and design modifications. Nonetheless, these design improvements were important to address in support of a successful installation.

During the course of the project, new Rule 21 requirements for inverters went into effect, requiring the equipment used in this project to be UL-certified to meet additional smart inverter functionalities. Due to COVID, UL certification was delayed, preventing listing on the California Energy Commission (CEC) certified equipment list. Listing was eventually achieved, and then the project could move forward in the Rule 21 interconnection process.

Finally, there were a number of challenges navigating the interconnection and energization processes, including the fact that the Rule 2 and Rule 21 application and inspection processes were generally independent and not coordinated. The team found that the current Rule 21 interconnection forms were not well suited for microgrid projects. PG&E asked SRJC to make modifications to the template form to accommodate the project. The project team also found that the system design and testing requirements for interconnecting the microgrid were not well documented or communicated. The college referred to the PG&E Greenbook for design requirements but found this insufficient, and the Greenbook did not always align with what was communicated by interconnection and distribution engineers. It remains unclear if PG&E has made modifications to its Rule 21 forms to reflect the learnings from this project.

CHAPTER 3: Project Results

The project team started collecting microgrid performance data for the official 12-month measurement and verification (M&V) period after PG&E granted the college conditional permission to operate in September 2022. Accordingly, the performance period used for analysis in this report is September 2022 through August 2023. When compared to the baseline period of July 2017 to June 2018, the microgrid achieved a reduction in emissions, a reduction in peak demand from the grid, utility bill savings for the campus, and improved resilience resulting from the microgrid's ability to island from the grid.

Energy Consumption and Power Demand Benefits

When operating in grid-connected mode, the microgrid is designed to reduce peak demand from the campus, lowering energy costs through avoided demand charges as well as reducing overall electricity consumption from the grid. The advanced metering infrastructure deployed in this project was used to evaluate microgrid performance in both grid-connected and islanded modes.

Baseline Energy and Power From Grid

PG&E utility meter data was used to analyze electricity consumption (kWh) and power demand (kW) from the grid for the entire campus to establish a baseline for comparison between July 2017 and June 2018. This was before the installation of solar PV, and it aligned with the fiscal year of the college. Table 1 provides monthly data, showing that the campus consumed about 10.3 million kWh during the baseline period during a typical weather-dependent seasonal variation with a monthly consumption peak in September 2017 of over 1.0 million kWh. The average demand for the year was about 1,170 kW, with a maximum peak demand of 2,740 kW, which also occurred in September 2017.

Table 1: Baseline Monthly Campus Energy and Demand

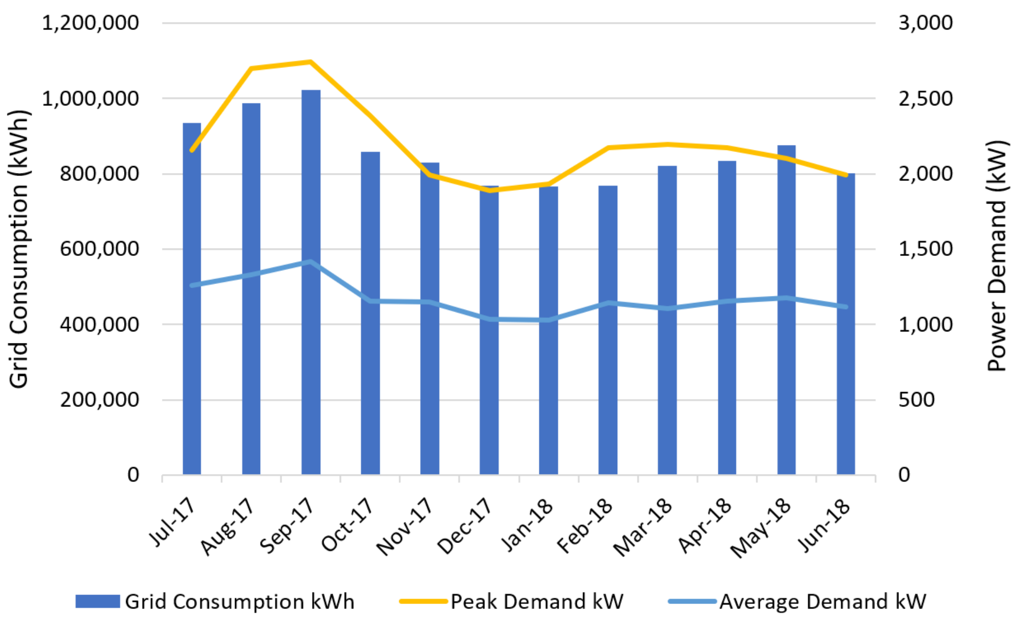
Month-Year	Grid Consumption (kWh)	Peak Demand (kW)	Average Demand (kW)
Jul 2017	935,356.0	2,155.0	1,257.2
Aug 2017	987,818.0	2,700.0	1,327.7
Sep 2017	1,021,507.4	2,740.3	1,418.8
Oct 2017	857,967.3	2,387.5	1,153.2
Nov 2017	828,802.8	1,991.5	1,151.1
Dec 2017	769,582.8	1,887.8	1,034.4
Jan 2018	765,983.5	1,933.9	1,029.5
Feb 2018	768,255.5	2,174.4	1,143.2
Mar 2018	821,361.1	2,197.4	1,105.5

Apr 2018	833,507.1	2,174.4	1,157.6
May 2018	875,690.6	2,100.2	1,177.0
Jun 2018	802,278.4	1,992.2	1,114.3
Baseline Total	**10,268,110.4**	**2,740.3**	**1,172.3**

Source: SRJC

The same baseline data is shown graphically in Figure 6, with grid electricity consumption (blue bars, left axis), peak power demand (yellow line, right axis), and average power demand (blue line, right axis). This baseline data was used as a basis of comparison to evaluate the energy and emissions and the economic and other benefits of the microgrid installed in this project.

Figure 6: Baseline Monthly Campus Energy and Demand



Source: SRJC

Measurement and Verification Period Energy and Power

PG&E utility meter data was combined with submetering data to analyze campus electricity consumption (kWh) and power demand (kW) from the grid as well as on-site solar PV production (kWh) for the M&V period (September 2022–August 2023), following commissioning of the microgrid. Table 2 shows that the campus had a net consumption of about 10.1 million kWh over this period, again showing a typical weather-dependent seasonal variation. The monthly peak consumption occurred in August 2023, with more than 1.1 million kWh consumed. The average demand from the grid was about 750 kW, with a maximum peak demand of 2,008 kW in January 2023. The peak demand occurring in January had to do with a mixture of COVID impacts to building usage and the usage of an electric boiler to provide thermal energy at the campus central plant.

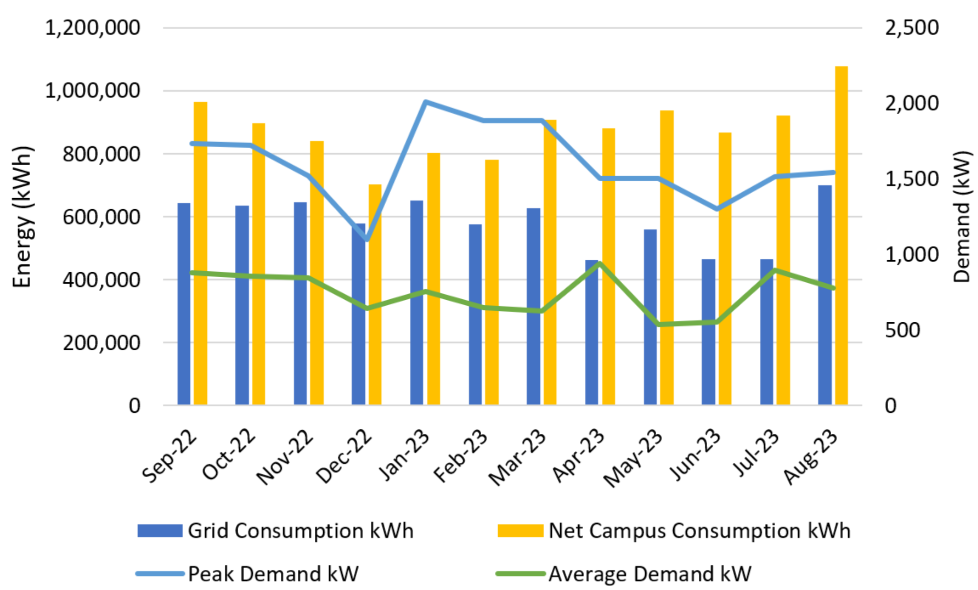
Table 2: M&V Monthly Campus Electricity Consumption and Power Demand

Month-Year	Grid Consumption (kWh)	Grid Export (kWh)	Total PV Production (kWh)	Net Campus Consumption (kWh)	Peak Demand (kW)	Average Demand (kW)
Sep 2022	644,302.6	2,073.6	321,196.1	965,498.6	1,737.6	879.4
Oct 2022	636,563.4	4,530.0	260,620.0	897,183.3	1,725.6	859.0
Nov 2022	645,262.8	7,189.2	195,050.2	840,313.0	1,519.0	846.0
Dec 2022	579,175.2	8,128.8	123,267.9	702,443.1	1,099.0	642.4
Jan 2023	652,760.4	4,622.4	151,031.6	803,792.0	2,008.8	753.9
Feb 2023	575,960.4	10,192.8	204,519.9	780,480.3	1,887.0	648.8
Mar 2023	627,286.8	25,105.2	280,441.5	907,728.3	1,887.0	626.3
Apr 2023	461,456.4	46,503.6	419,491.1	880,947.5	1,506.0	942.6
May 2023	559,833.6	33,571.2	379,122.5	938,956.1	1,506.0	533.7
Jun 2023	466,215.6	27,945.6	403,073.3	869,288.9	1,303.0	551.1
Jul 2023	465,013.2	26,649.6	456,759.1	921,772.3	1,515.6	898.2
Aug 2023	700,243.2	3,147.6	378,623.4	1,078,866.6	1,545.6	780.5
M&V Total	**7,014,073.6**	**199,659.6**	**3,573,196.7**	**10,098,213.5**	**2,008.8**	**746.6**

Source: SRJC

The solar PV installed in this project produced about 3.6 million kWh over the M&V period, the majority of which was consumed on site, with a net export of 199,660 kWh to the grid. This data is shown graphically in Figure 7, with electricity consumption from the grid (blue bar, left axis), net electricity consumption (yellow bar, left axis), peak power demand (blue line, right axis), and average demand (green line, right axis).

Figure 7: M&V Monthly Campus Energy Consumption and Power Demand



Source: SRJC

Comparison of Energy Consumption and Power Demand Across Baseline and M&V Periods

With the implementation of the microgrid, there was an overall reduction in PG&E grid-related energy consumption and demand due to on-site generation and battery storage assets. Despite the addition of several new buildings on campus and an increase in required energy, there was still a utility grid savings of about 3.3 million kWh between the baseline and the M&V periods. Additionally, the campus experienced a reduction in peak demand of about 730 kW. The campus electricity consumption and peak demand data for the two periods are summarized in Table 3.

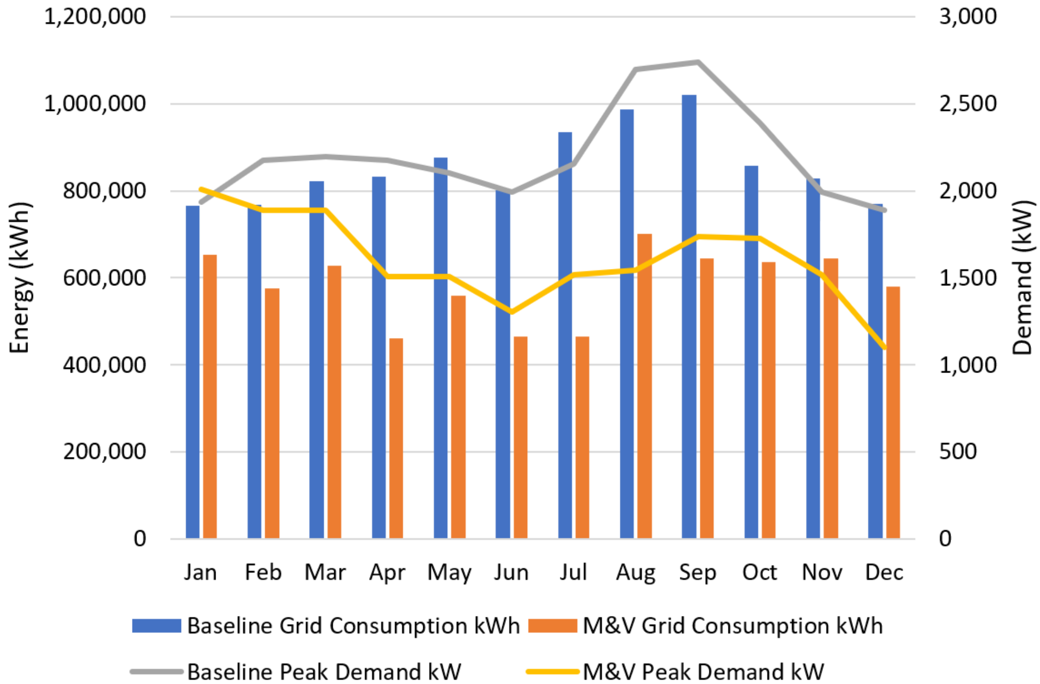
Table 3: Grid Energy and Demand Comparison — Baseline Versus M&V Period

Month	Baseline Grid Consumption (kWh)	M&V Grid Consumption (kWh)	Change in Grid Consumption (kWh)	Baseline Peak Demand (kW)	M&V Peak Demand (kW)	Change in Peak Demand (kW)
Jan	765,983.5	652,760.4	113,223.10	1,933.9	2,008.8	-74.90
Feb	768,255.5	575,960.4	192,295.10	2,174.4	1,887.0	287.40
Mar	821,361.1	627,286.8	194,074.30	2,197.4	1,887.0	310.40
Apr	833,507.1	461,456.4	372,050.70	2,174.4	1,506.0	668.40
May	875,690.6	559,833.6	315,857.00	2,100.2	1,506.0	594.20
Jun	802,278.4	466,215.6	336,062.80	1,992.2	1,303.0	689.20
Jul	935,356.0	465,013.2	470,342.80	2,155.0	1,515.6	639.40
Aug	987,818.0	700,243.2	287,574.80	2,700.0	1,545.6	1,154.40
Sep	1,021,507.4	644,302.6	377,204.80	2,740.3	1,737.6	1,002.70
Oct	857,967.3	636,563.4	221,403.90	2,387.5	1,725.6	661.90
Nov	828,802.8	645,262.8	183,540.00	1,991.5	1,519.0	472.50
Dec	769,582.8	579,175.2	190,407.60	1,887.8	1,099.0	788.80
Total	**10,268,110.4**	**7,014,073.6**	**3,254,036.80**	**2,740.3**	**2,008.8**	**731.50**

Source: SRJC

This data is shown graphically in Figure 8, with energy consumption for the baseline (blue bar, left axis) and M&V (orange bar, left axis) periods as well as peak demand for the baseline (grey line, right axis) and M&V periods (yellow line, right axis).

Figure 8: Energy Consumption and Peak Power Demand Comparison

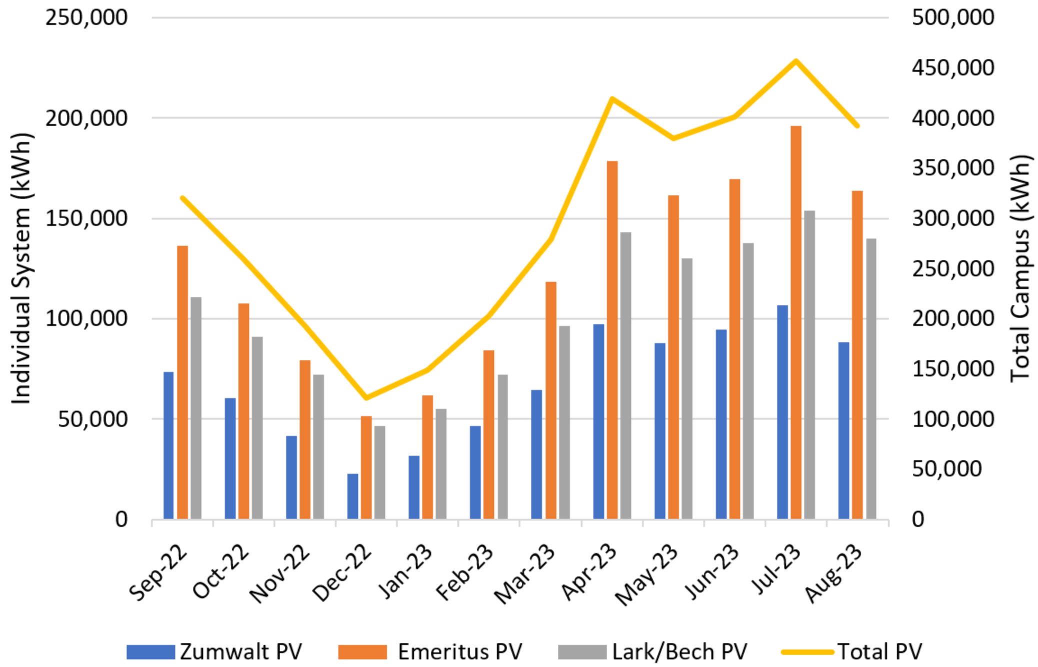


Source: SRJC

Solar PV System Performance

Figure 9 shows the monthly solar PV production for each of the three arrays installed in the project (left axis) and campus-wide (right axis). The total production for all systems during the M&V period was 3.6 million kWh, with a peak energy output of 456,983 kWh in July 2023. The on-site PV systems primarily served campus loads and were used to charge the BESS. Any remaining excess PV energy was exported to the utility grid, for which the campus received a credit of $41,129.88 on electricity bills based on kWh exported. Solar PV production followed a seasonal pattern, with the lowest total production in winter months and highest in summer months.

Figure 9: Solar PV Production During M&V Period



Source: SRJC

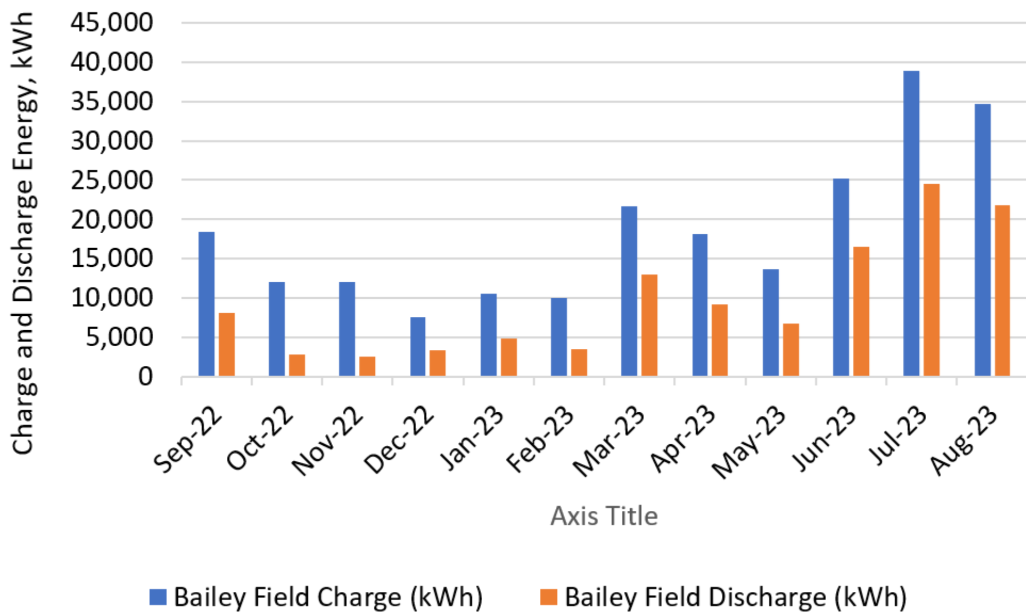
BESS Performance

Figures 10 through 12 show the monthly charge (blue bars) and discharge (orange bars) energy (kWh) for each BESS installed in this project. When grid-connected, these systems were programmed to primarily perform campus-level demand charge reduction, then energy price arbitrage as a secondary objective, followed by demand response participation.

These systems followed a general seasonal trend, with more charging hours during the summer, when there were excess solar production and lower campus demand conditions.

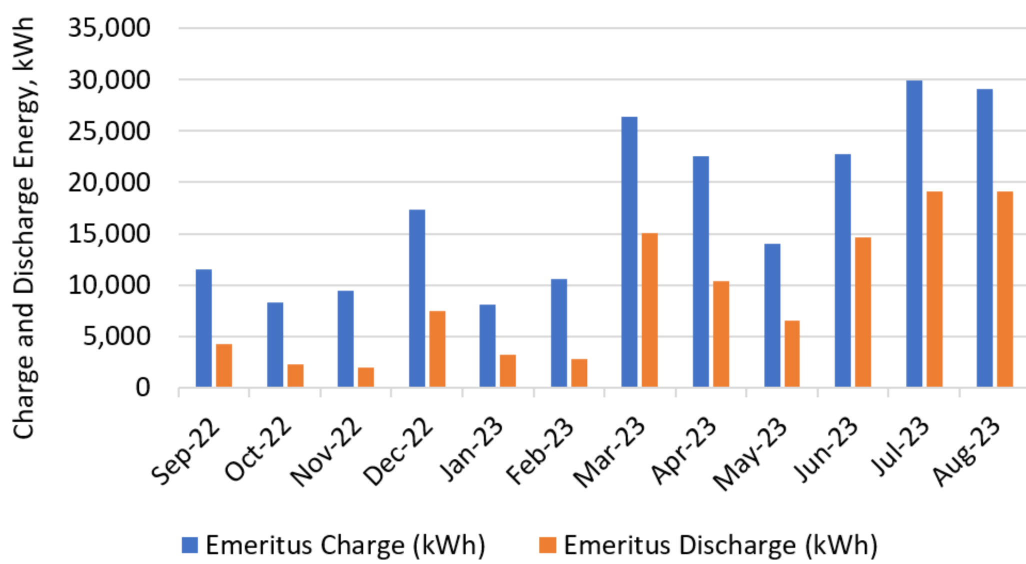
The round-trip efficiency found during the M&V period ranged between 50 and 65 percent for the three different BESS installations. This did not match the manufacture's literature for minimum round-trip efficiency. During the course of the M&V period, the Emeritus and Bailey Field BESS experienced inverter inefficiencies due to failing motor operator breakers caused by the inverter circuit opening under load when a fault was detected. Additionally, the battery string started having uneven energy balancing that disconnected an internal battery string. The battery manufacturer has since updated its battery management system fault system to prevent open circuits under load from nuisance alarms as well as updated its battery charging program to help the battery strings achieve more uniform balancing. This should significantly improve the round-trip efficiency of the system.

Figure 10: Bailey Field BESS Performance During M&V Period



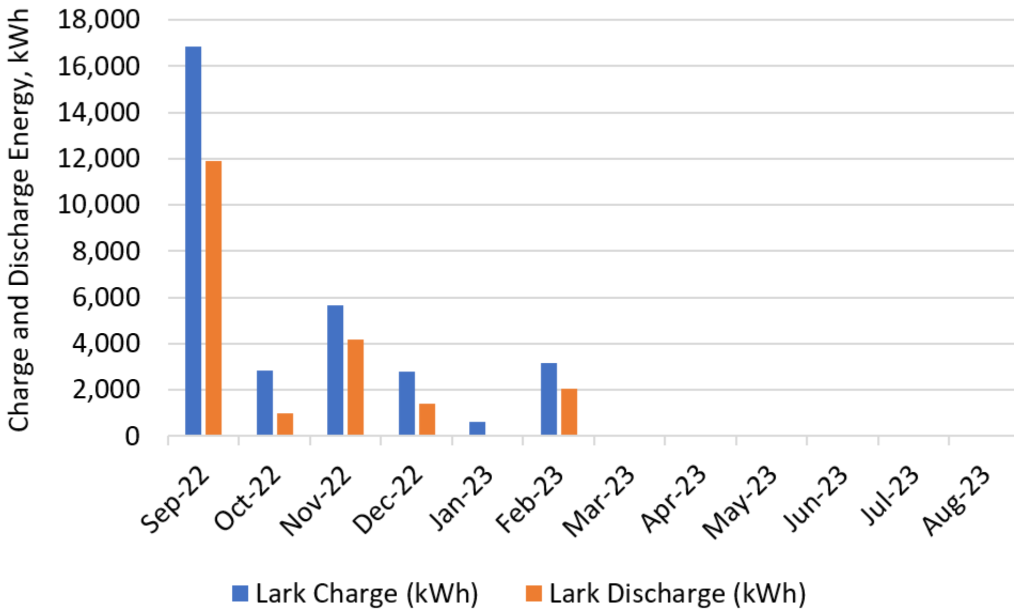
Source: SRJC

Figure 11: Emeritus BESS Performance During M&V Period



Source: SRJC

Figure 12: M&V Period Lark Battery Storage System Performance



Source: SRJC

As shown in Figure 12, the Lark BESS experienced some technical issues in February 2023 and remained non-operational for the remainder of the M&V period. During this time, the main controller that accepted commands from the microgrid controller to the Lark BESS failed. A replacement controller was provided by Total Energies, which, through contract, managed the performance guarantee for the Lark BESS. Due to internal organizational changes at Total Energies, the new Lark BESS controller was not installed and commissioned until the end of 2023, after the M&V period.

Environmental Benefits

The college's primary goal for the microgrid project was to reduce campus GHG emissions. In the original grant proposal, the project team projected potential GHG emission reductions of 1,050 metric tons per year. Utility consumption data was collected for both the baseline and the M&V periods to estimate grid-related GHG emissions in metric tons of carbon dioxide equivalent (MTCO2e). Solar PV kWh production was captured by utility meters connected to each array and was used to estimate avoided grid-related emissions. These kWh values were multiplied by the U.S. Environmental Protection Agency's 2022 eGRID subregion output emission rate of 499.3 MTCO2e/MWh for California (U.S. Environmental Protection Agency 2023). As shown in Table 4, emission reductions during the M&V period showed a reduction of approximately 1,590 MTCO2e, more than 68 percent when compared to the baseline period.

Table 4: GHG Savings Analysis

Parameter (Units)	Value
EPA eGRID emissions rate, 2022 (MTCO2e/MWh)	0.226
Baseline Period	

Parameter (Units)	Value
Net Grid Consumption (MWh)	10,268.1
Net GHG Emissions (MTCO2e)	2,325.0
M&V Period	
Net Grid Consumption (MWh)	7,014.1
Grid GHG Emissions (MTCO2e)	1,588.2
Net Grid Export (MWh)	199.6
GHG Savings From Grid Export (MTCO2e)	45.2
Solar PV Consumed (MWh)	3,573.2
Avoided GHG From PV Consumed (MTCO2e)	809.1
Net M&V GHG Emissions (MTCO2e)	**733.9**
Total GHG Emissions Savings (MTCO2e)	**1,591.1**

Source: SRJC

Economic Benefits

The financial return on investment for a microgrid is important for longer-term technology adoption, particularly that the payback time for the initial investment is reached within the lifespan of the installed equipment. The project team estimated utility bill savings for the microgrid using a blended rate from the M&V period, including energy, demand, transmission and delivery, and miscellaneous costs. The campus received commodity and demand charges from Direct Energy for the energy consumed by the campus as well as transmission and delivery charges from PG&E for a blended rate of $0.206/kWh during the M&V period. Table 5 shows the utility consumption and cost breakout for the M&V period.

Table 5: M&V Period Utility Consumption and Costs

Parameter, Unit	Value
Utility Energy, kWh	6,763,326
Utility Peak Demand, kW	2,008.8
PG&E Transmission and Delivery Costs, $	779,968
Direct Energy Costs, $	$613,335
Total Utility Cost, $	$1,393,302
M&V Blended Rate, $/kWh	$0.206/kWh

Source: SRJC

This blended rate was applied to the utility consumption during the baseline period to compare costs using a similar energy rate and to calculate the estimated utility savings between the baseline period and the M&V period. The estimated savings of the microgrid were approximately $670,000 per year, just over 31 percent, as shown in Table 6. This annual savings amount is expected to increase based on the upward trend of utility energy costs, which increased by around 67 percent from the baseline year to the M&V year. The net present value of the system, shown in Table 7, shows that the system has a positive value over the life of the system, even considering end of life replacement of inverters and batteries.

Table 6: Estimated Annual Cost Savings

Parameter, Unit	Value
M&V Period Blended Rate, $/kWh	0.206
Baseline Grid Consumption, kWh	10,268,110
Baseline Grid Cost, $	2,115,317
M&V Grid Consumption, kWh	7,014,074
M&V Grid Cost, $	1,444,958
Estimated Annual Cost Savings, $ (%)	670,359 (31.7%)

Source: SRJC

Table 7: Calculated Net Present Value

Parameter, Unit	Value
Based on annual cost savings ($)	$670,359.00
Baseline blended rate ($/kWh)	$0.13
Annual electricity cost inflation (%)	9%
Inverter replacement starting at year 10-15	Estimated to cost $1,788,000.00
Battery replacement starting at year 10-15	Estimated to cost $500.000.00
Controller & software replacement starting at year 10-15	Estimated to cost $110,000.00
Life span of the overall system (years)	25
Discount rate (%)	2.5%
Initial system cost ($)	$14,900,000.00
Net present value	$5,706,694.12

Source: SRJC

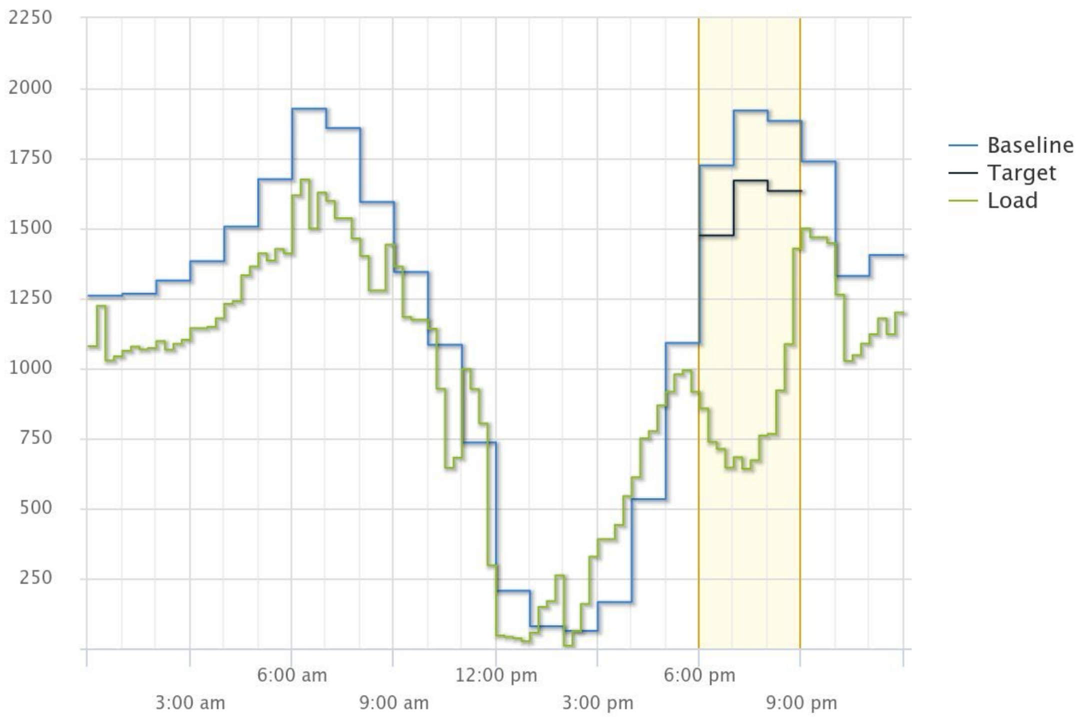
Demand Response Participation

Additional economic and grid value can be realized through participation in demand response programs with the microgrid. Demand response programs encourage customers to reduce their electricity usage, primarily during peak demand periods, in exchange for financial incentives or other benefits. These programs help to balance the grid, reduce reliance on fossil fuels, and potentially lower electricity costs. SRJC participated in two different demand response programs, with Olivine serving as the aggregator.

SRJC participated in the California Independent System Operator (California ISO) Emergency Load Reduction Program (CPUC 2023a) in 2023 and 2024, which is part of a broader statewide strategy to manage electricity demand and support further decarbonization of the electric sector. In this program, the college earned $2,316.20 from 18 events, with an average reduction of 645 KW for four hours in 2024.

Through the duration of participation in California ISO programs, the project team found that the way the California ISO establishes a demand response baseline is significantly different than how the microgrid controller calculates a rolling demand baseline based on real time data. Moving forward, the microgrid will use a new demand response signal carrying the California ISO expected demand baseline. Additionally, a number of microgrid BESS inverter failures were identified, which caused systemwide capacity reductions from expected kW discharges during program events. After the battery failures were repaired through warranty and the system brought up to 100 percent capacity, a demand response test was conducted on July 24, 2025. This event showed around 1 MW in demand reduction for the duration of the event. This corresponds with around $58,800 in potential annual revenue assuming 18 events. Figure 13 shows data from the test event.

Figure 13: California ISO Demand Side Grid Support Event Data



Source: SRJC

Based on Figure 13, between 6:00 p.m. and 9:00 p.m. on July 24, 2025, the microgrid reduced campus load beyond the baseline and the target by almost 1 MW, showing significant potential in market participation when the system is at 100 percent-capacity. Additionally, the graph shows the potential in battery storage to reduce the duck curve and limit the increase in demand as the sun goes down and solar PV production drops.

More recently, the college participated in the CEC's Demand Side Grid Support (DSGS) (CEC n.d.) Option 2 program in 2025. DSGS offers incentives to electric customers that provide reduction of load through dispatch of backup generation to support the state's electrical grid during extreme events, reducing the risk of blackouts. SRJC participation earned $44,900.00 in 2025 through nine participating events, with 18,235 kWh of energy saved.

Social Benefits

Another key driver for this microgrid project was to provide resiliency benefits to the campus and the broader SRJC community. While this was an important aspect of the project and a significant value stream of the microgrid, the value of resiliency and social impacts are notoriously challenging to measure and quantify.

California-Based Cost Benefit Analysis Tool

As part of this project, the team designed a California-specific cost-benefit tool to assess the social, environmental, and economic benefits of microgrid deployments. This tool's scope evolved to be more than a simple cost-benefit analysis tool but sought to incorporate the California Public Utility Commission's (CPUC's) microgrid proceeding, specifically the discussions around the value of resiliency and the 4-Pillars methodology. The team leveraged the concepts of the 4-Pillars of Resiliency methodology (CPUC 2023b) to operationalize the resiliency scorecard portion and integrate those principles, creating the Site Equity Resiliency Assessment (SERA) tool.

The SERA tool is an Excel-based tool that leverages the National Renewable Energy Laboratory ReOpt Lite tool for modeling and sizing solar and storage equipment. ReOpt Lite is a publicly available tool; however, it requires foundational knowledge of the electricity industry that the average facility or sustainability manager may lack. While ReOpt Lite already had outputs for assessing technical, financial, and resiliency results, the SERA tool added the consideration of site vulnerability and equity metrics, such as the social cost of carbon and the average energy burden. The SERA tool also aimed to consolidate a variety of existing resources in one place, to help users navigate a site assessment and generate results that inform initial decision making on the suitability of a microgrid for their site.

CHAPTER 4: Technology and Knowledge Transfer

The general objective of this project's knowledge transfer activities was to raise awareness of the microgrid project and technologies broadly with other campus energy managers and to provide them with the knowledge and tools necessary to be successful in pursuing such a project. The project team developed a technology and knowledge transfer plan that identified target audiences for outreach.

About half the technology and transfer efforts were aimed at facility and sustainability managers, who are primarily responsible for making facility energy management decisions and promoting internal organization environmental goals. The remainder of the outreach efforts were split between engineers, contractors, and community choice aggregators, as summarized in Table 8. Beyond the target audiences, technology and transfer activities reached additional audiences, including the CPUC to help inform policies and programs related to DERs and microgrids.

Table 8: Targeted Audiences for Knowledge Transfer

Audience	Role	Goal of Engagement	Percent of Outreach
Facilities and Sustainability Managers	• Make facility management decisions • Promote sustainability initiatives • Implement campus projects	Learn how to implement a similar project at their facility	50%
Engineers and Contractors	• Guide customers in deter-mining what technology solutions and systems work best for their needs • Drive change in the energy industry	Understand the business opportunity of increased demand in microgrid and DER installations	25%
Community Choice Aggregators	• Provide customers with clean energy alternatives to traditional utility service	Leverage DERs and microgrids to contribute to meeting state-mandated emissions and efficiency targets	25%

Source: SRJC

Broader Sharing Through Dedicated Project Website

To efficiently disseminate learnings from the project, the project team developed a dedicated project website to serve as a landing page and primary resource for information on the project

(Center for Sustainability Energy, n.d.). The website facilitates ongoing and updated knowledge transfer and education beyond the term of the project. The home page includes a brief project description and email sign-up for project updates and report releases, and it provides background information on the project site and the surrounding community and data on the performance of microgrid assets. Beyond the project-specific website, SRJC also houses a webpage on its website, under the Sustainability group, specific to the microgrid project, with similar information as the project microsite (SRJC n.d.).

On-Campus Microgrid Tours

SRJC hosted a number of campus microgrid tours to show key components and functionalities. The following groups received tours.

- Local Government Sustainable Energy Coalition
- Environmental Studies classes at SRJC
- SRJC staff and faculty at Professional Development Day
- Northern California Construction Manager Association Chapter
- California Energy Commission staff
- City of Santa Rosa Planning Department
- County of Sonoma Capital Projects Department
- Northern California Construction Management Association
- Sonoma Water staff

Webinars, Presentations and Workshops

Over the course of the project, the team participated in multiple in-person and virtual events to share lessons and recommendations from the project, as listed in Table 9.

Table 9: Webinars, Presentations, and Workshops

Presentation/ Webinar	Date	Topic(s) Covered	Audience	No. of Attendees
Microgrid Project Overview	12/01/2019	Presentation to Assemblyman Jim Wood and his staff on the microgrid demonstration project	Assemblyman Jim Wood	5
CEC Staff & CPUC Staff Microgrid Overview	11/25/2019	Presentation to CEC Vice Commissioner & CPUC Commissioner of SRJC microgrid demonstration project	CEC staff & CPUC staff	12

Presentation/ Webinar	Date	Topic(s) Covered	Audience	No. of Attendees
Microgrids and Energy Systems	3/03/2021	Presentation to SRJC Engineering 10 class	Engineering 10 class at SRJC	30
Microgrid Project Overview and Planning	1/24/2019	Presentation to Fort Bragg public officials on microgrid project, design & considerations	Fort Bragg public officials	5
Microgrid Project & Microgrid Batteries	11/07/2019	Presentation at ESNA about microgrid design & operation	Energy Storage North America	60+
Resiliency Energy Systems	11/21/2019	Presentation to the Local Government Coalition invited Northern California city & county officials about SRJC microgrid project	Local Government Coalition	30+
Community College Microgrid Design	8/14/2020	Presentation to fellow community colleges about microgrid design	Gridscape – Chabot College	5
Microgrid Cost of Resiliency	2/20/2022	Presentation on the value of resiliency to local government agencies	CPUC, Sonoma Clean Power, Sonoma Water	12
Community College Microgrid Design & Planning	12/07/2021	Presentation to California Community Colleges facilities professionals on microgrid design	Community College Facilities Coalition/CCC Sustainability staff	30+
SRJC Microgrid Implications for Contracts	11/12/2019	Presentation to law firm that specializes in solar & battery contracts for public entities on considerations for new microgrid technology	DWK construction law firm	3
SRJC Microgrid Design & Operations Review	6/02/2022	Presentation to SRJC Facilities Operations department on new microgrid system and operations & maintenance	SRJC Facilities Operations Department	15
California Community	6/01/2023	Introduction to microgrids and purchasing	Foundation for California	15

Presentation/ Webinar	Date	Topic(s) Covered	Audience	No. of Attendees
College Foundation Purchasing/Contracts Presentation		considerations for Master Request for Proposal and Request for Qualifications	Community Colleges Purchasing/Contract Group	
Resiliency Planning and Evaluation – 4-Pillar Methodology	10/19/2023	The value of resiliency and how the CPUC's 4-Pillar Methodology relates to the SRJC microgrid project	CPUC Energy Division; general public	60+

Source: SRJC

In addition to these events, the project team presented the microgrid project to a diverse set of audiences at formal conferences, as listed in Table 10.

Table 10: Conferences

Conference	Description	Date	Target Audience
American Council for an Energy-Efficient Economy (ACEEE) 2022 Summer Study	The 2022 theme continues to be urgent: "Climate Solutions: Efficiency, Equity, and Decarbonization." Buildings, which account for about a third of United States GHG emissions, will play a critical role in decarbonizing the economy and creating a clean energy future. With smart technologies, programs, policies, and behaviors, this sector can reduce harmful pollution, protect health, and lower utility bills.	8/21/2022 to 8/26/2022	Energy industry professionals, national labs, utilities
National Association of State Energy Officials (NASEO) 2022 Annual Meeting	The 2022 conference theme: *State Clean Energy Partnerships for Resilience, Affordability, and Growth*. State energy offices and their private sector partners are poised for action in deploying innovative clean energy solutions across America's infrastructure — grid, buildings, transportation, manufacturing, and agriculture. In partnership with local communities, businesses, and investors, states are targeting workforce development to open opportunities for higher-paying, skilled energy jobs, expanding financing	10/12/2022	State energy officials

Conference	Description	Date	Target
	and investment programs to meet the needs of underserved communities, and supporting businesses in accelerating high-impact decarbonization initiatives in every sector of the economy.		
RE+ 2023	RE+ 2023 covered a wide spectrum of renewable energy education topics. The event made history by shattering records, drawing in 40,000 attendees and more than 1,350 exhibitors. This record-breaking week provided a comprehensive showcase of the entire clean energy industry, encompassing diverse sectors such as solar, storage, grid-edge technologies, hydrogen, fuel cells, EV charging infrastructure, and wind energy, both on and off the show floor.	9/11/2023 to 9/14/2023	Contractors, engineers, technology providers, consultants
Statewide Energy Efficiency Collaborative (SEEC) 2019	The conference covered statewide energy efficiency and renewable energy presentations for local governments, from policy to engineering & project implementation.	6/26/2019 to 6/27/2019	Consultants, public officials, policy writers
Microgrid Knowledge 2021 (California)	Microgrid Knowledge California 2021 was a one-day forum covering many topics related to microgrid design, technology, implementation, and policy.	10/05/2021	Contractors, engineers, technology providers, consultants
Energy Storage North America (ENSA)	This North America conference on energy storage covered a wide array of topics. Session title: DERMS, Microgrids, and the Future of Grid Management.	11/05/2019	Contractors, engineers, technology providers, consultants

Source: SRJC

Role of the Technical Advisory Committee

SRJC established a technical advisory committee (TAC) composed of experts across the electricity sector; it leveraged their expertise to inform implementation of this project demonstration as well as to more effectively transfer knowledge and learnings. The TAC members are shown in Table 11, and a summary of TAC meetings and key discussion topics is shown in Table 12.

Table 11: Technical Advisory Committee Members

Name	Organization	TAC Meetings Attended
Ryan Stoltenberg	Stone Edge Farm	1
Peter Klauer	California ISO	1–4
John Griffiths	CONTECH	1–4
Beth Reid	Olivine	1–4
Daniel Soto	Sonoma State University	1, 2
Cordell Stillman	Sonoma Clean Power	1, 2
Sean Sevilla	MCE	3, 4
Pierre Bull	Packetized	3, 4
Kelsey Albers	Energy Solutions	4

Source: SRJC

Table 12: Summary of Technical Advisory Committee Meetings

Meeting	Date	Topics Discussed	No. of Attendees*
#1	September 24, 2019	Provided a project overview and reviewed microgrid use cases and design. Discussion questions included modelling considerations, microgrid value streams, and load shed strategy.	7
#2	June 2, 2020	Reviewed modelling results and hardware design and shared procurement status. Discussion questions included identifying new value stream opportunities and options for helping to facilitate fast trip response times.	6
#3	August 18, 2021	Reviewed metering status, hardware engineering, and microgrid integration coordination. The discussion section aimed to gather critical feedback on the Data Collection and Measurement and Verification plans.	6
#4	September 27, 2022	Provided updates on project progress, including equipment installation, testing and interconnection, data collection, and lessons learned.	4

*Attendee numbers do not include individuals from the project team.
Source: SRJC

CHAPTER 5: Conclusion

Summary

The SRJC Microgrid Demonstration Project successfully designed, installed, and operated an advanced campus microgrid that integrated solar photovoltaic generation, battery energy storage, and flexible load controls under a unified microgrid controller. The project was implemented between 2019 and 2026 with funding from the CEC's EPIC program, and it demonstrated how DERs can improve grid resilience, reduce GHG emissions, and lower electricity costs for public institutions. During the one-year measurement and verification period, the microgrid reduced campus grid electricity consumption by more than 3.2 million kWh, lowered peak demand by approximately 730 kW, and reduced GHG emissions by approximately 1,591 metric tons of CO_2 equivalent annually. The system produced approximately $670,000 in annual utility cost savings and achieved a positive net present value over the life of the assets. Beyond campus benefits, the project provides a replicable blueprint for microgrid deployment across California community colleges, universities, and public facilities while supporting the state's energy reliability, decarbonization, and climate resilience goals.

Policy Impacts

This project directly engaged with several timely policy and program developments, including several proceedings at the CPUC. Specifically, the project informed Rulemaking R.19-09-009, opened in response to SB 1339, on microgrids and the value of resiliency. The proceeding provided a policy venue for disseminating lessons and best practices, as the project aimed to provide an example for other projects.

In August 2021, the CPUC administrative law judge issued a ruling for Track 4 of the proceeding to provide guidance for proposals to address reliability and resiliency concerns in advance of the summers of 2022 and 2023. The ruling (CPUC 2025) outlined a variety of topics on which the CPUC was seeking proposals and comments, from prevention versus mitigation of system capacity shortfall to microgrid tariffs and potentially new microgrid programs. The Center for Sustainable Energy, on behalf of the SRJC microgrid project, submitted comments in response that were specifically focused on two questions regarding how to leverage existing microgrid and resiliency programs.

Track 5 of the microgrid proceeding was focused on exploring the concept of the "value of resiliency," to capture broader benefits not reflected in traditional cost-benefit analyses. Through this exercise, the CPUC staff developed and presented its 4-Pillar Methodology to serve as a framework for factoring in resiliency benefits and as a guide for assessing the impact of microgrid projects. The project operationalized aspects of the 4-Pillars Methodology in later stages of the project, including in development of the Site Equity Resiliency Assessment tool. In October 2023, the project team had the opportunity to present the SRJC microgrid project and how it connected to the 4-Pillars Methodology at a CPUC workshop.

Benefits to California Ratepayers

The SRJC Microgrid Demonstration Project provides multiple benefits to California electric ratepayers and ratepayers in Pacific Gas and Electric territory by advancing technologies and operational strategies that improve grid efficiency, reliability, and affordability. By reducing campus peak electricity demand by approximately 730 kW, the microgrid lowers stress on the local distribution system and helps defer or reduce the need for costly grid infrastructure upgrades that would otherwise be borne by ratepayers. The integration of 2.4 MW of solar generation and energy storage reduced annual grid electricity consumption by more than 3.2 million kWh. Lower grid demand helps utilities manage system loads more efficiently and reduces the need for additional generation capacity. The microgrid's battery storage and flexible load controls allow the campus to participate in demand response programs, providing up to approximately 1 MW of demand reduction during grid stress events. These capabilities support statewide grid reliability and help prevent blackouts during extreme conditions. The microgrid can operate independently during grid outages, allowing critical campus services and community functions to remain operational. Maintaining these services during emergencies reduces societal costs and enhances public safety during disasters such as wildfires and extreme weather events. By documenting design, operational, and economic performance, the project provides a scalable model for other campuses and public facilities across California. Replication of similar systems can multiply the grid, economic, and environmental benefits for ratepayers statewide.

List of Terms/Glossary

Term	Definition
AC	alternating current: electric current that reverses its direction at regularly recurring intervals
BESS	battery energy storage system
California ISO	California Independent System Operator: the entity that organizes and integrates utilities within the Western Grid
CEC	California Energy Commission
CONOPS	concept of operations
CPUC	California Public Utilities Commission
DER	distributed energy resources are energy producing, storing, or load devices connected in decentralized locations
DSGS	Demand Side Grid Support program
ethernet	ethernet communication is a set of rules (a network protocol) for connecting devices in a local area network (LAN) using wired (ethernet cables) or fiber optic connections, enabling data transfer at high speeds.
EPIC	Electric Program Investment Charge: created by the California Public Utilities Commission in December 2011, it supports investments in clean energy technologies that benefit electricity ratepayers of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company.
GHG	greenhouse gas
HVAC	heating, ventilation, and air-conditioning: systems that modify environmental conditions, including air flow, temperature, and humidity
Hz	hertz: a measure of frequency
IEEE	Institute of Electronic and Electrical Engineers: a leading standards organization for electrical and electronic devices and communications
kV	kilovolt: a standard measure of voltage, equivalent to 1,000 volts
kW	kilowatt: a standard measure of power, equivalent to 1,000 watts
kWh	kilowatt-hour: a standard measure of electrical energy, equivalent to power consumption of 1,000 watts for one-hour light-emitting diode (LED).
M&V	measurement and verification
MT CO2e	metric tons of carbon dioxide equivalent

Term	
MW	megawatt: a measure of power equal to 1,000,000 watts
MWh	megawatt-hour: a measure of energy equal to 1,000 kWh
PCC	point of common coupling: the location where the generation or DER systems connect to site systems
PCS	power conditioning systems: hardware tools that modify power, including converting alternating current and direct current power
PG&E	Pacific Gas and Electric Company: one of the three investor-owned utilities in California
phasor measurement unit	detects and reports power flows, with added value of location and time-stamping
point of interconnection	the location where the generation or DER systems connect to site systems
PV	photovoltaics: the conversion of solar energy to direct current power
RFP	Request for Proposals: solicitations for services
SEL	Schweitzer Engineering Laboratories
Self-Generation Incentive Program	Allows deployments of approved energy storage technologies to receive incentive payments based on system sizing and performance
SERA	Site Equity Resiliency Assessment tool
SRJC	Santa Rosa Junior College
U.S. EPA	United States Environmental Protection Agency
VAC	volts of alternating current

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Project Deliverables

- Baseline, Measurement, and Submetering Report
- Modeling and Engineering Report
- Baseline Cost Benefit Analysis Report
- Post-Installation Cost Benefit Analysis
- Microgrid Engineering Report
- Procurement and Installation Report
- Data Collection Plan
- Measurement and Verification Plan
- Microgrid Test and Analysis Report
- Microgrid Value Report
- Business Case Report
- Kick-off, Mid-term, and Final Benefits Questionnaires
- Technology Transfer Plan
- Technology Transfer Report

Project deliverables and interim project reports for this agreement, are available upon request by emailing pubs@energy.ca.gov.