

California Community College Addresses Wildfire Related Outages with Microgrid Demonstration Project

Demetra E. Tzamaras P.E., Center for Sustainable Energy (CSE)

Austin Beach, CSE

David Liebman, Santa Rosa Junior College (SRJC)

ABSTRACT

California faces a growing need for resilient, clean energy infrastructure as it aims to meet ambitious greenhouse gas (GHG) emissions reduction targets while preparing communities for increasingly common wildfires. In this demonstration project, a community college district partnered with a non-profit, an electrical engineering firm, and a controls technology provider to design and build a microgrid that will support the 20+ building campus' critical and non-critical loads. This project, located in a wildfire-prone area, leverages solar generation, battery energy storage, and load reduction controls to demonstrate the financial, environmental and resiliency benefits of a flexible microgrid and provide a blueprint for the other 100+ community colleges across California.

This case study summarizes the results of pre-installation modeling which projected that the microgrid would reduce annual GHG emissions by at least 24% by offsetting utility grid electricity consumption with emissions-free solar power and reduce energy costs by over \$500,000 dollars annually through demand charge management and utility energy purchased in regular operating conditions. The one-year Measurement and Verification period began in March 2022, and this paper shares interim operational data including energy consumption (at building and campus levels), GHG emissions, solar generation, battery charge and discharge, and variance of grid-side and campus-side voltage and frequency. Additionally, this paper describes the project's knowledge transfer activities, including the development of a cost-benefit analysis tool that draws upon the California Public Utilities Commission's 4 Pillars of Resiliency concept and uses a scorecard methodology to assess the value of resiliency beyond a purely financial analysis.

Introduction

Wildfires are a growing threat to California communities. While "wildfire season" is not a new concept for the Golden State, wildfires are becoming larger and more destructive. Six of the top ten largest California wildfires occurred in the last two years, 2020 and 2021, and six of the top ten most destructive California wildfires occurred within the past six years, between 2017 and 2021 (CALFIRE 2022). There is growing consensus over the past decade that link anthropogenic climate change with increased wildfire risk and indicate climate change increases the frequency and severity of fire weather in many regions around the world (Smith et al. 2020). This speaks to a need for not only climate change mitigation, but also climate change adaptation, and the Santa Rosa Junior College (SRJC) campus microgrid demonstration project seeks to balance both.

SRJC is a 100-year-old community college with a 100+ acre campus that serves over 60,000 students annually (SRJC 2020). Located in wildfire-prone Sonoma County and part of the

Sonoma County Junior College District (SCJCD), SRJC experienced the impacts of wildfire vulnerability firsthand during the Tubbs Fire in 2017 and then the Kincadee and Glass fires in 2019 and 2020, respectively (Hartlaub 2020). Although the campus itself was not physically damaged during the Tubbs fire, the SRJC community was directly affected by the fire, with more than 600 students and dozens of faculty and staff losing homes to the flames (Romero 2017). All three fires caused the college campus to shut down for up to a week at a time, disrupting classes and student activities. The impacts of natural disasters such as fires, hurricanes and other emergencies that result in temporary shutdowns can lead to decreased enrollment, slowed progress toward graduation and sometimes loss of income for faculty and staff (Mello and West 2020). Colleges and universities also often naturally serve as resource and resiliency hubs to the surrounding community after the event.

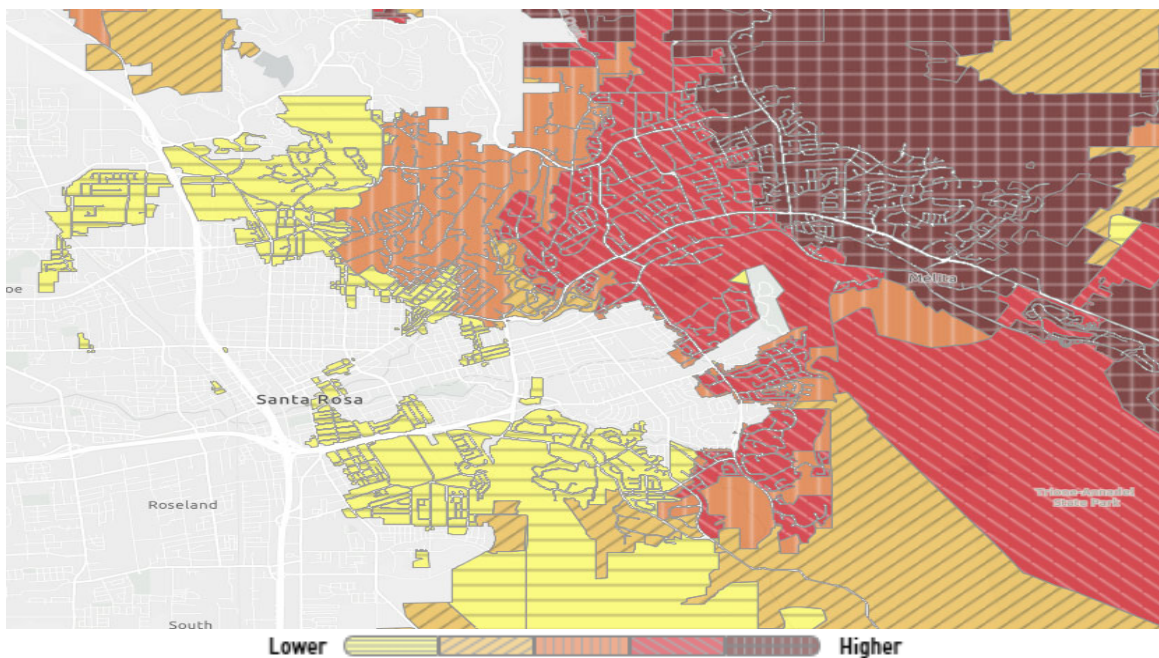


Figure 1. Total Past PSPS Event Count, 2020-2021. *Source:* PG&E 2022.

In addition to direct wildfire impacts, SRJC is also vulnerable to utility public safety power shutoff (PSPS) events, a wildfire mitigation strategy growing in prevalence that can sometimes leave customers without power for a few hours to a few days (Murphy 2021). The SRJC is in the Pacific Gas and Electric (PG&E) service territory and Figure 1 above shows the frequency of PG&E PSPS events in the Santa Rosa community from 2020 to 2021 (PG&E 2022). Although the college itself never experienced loss of power specifically from a PSPS event, only from utility grid blackouts, PSPS events frequently impact the surrounding community. The devastation of past wildfire seasons and continuing threat of future wildfires and utility PSPS events are what inspired SCJC to partner with the Center for Sustainable Energy (CSE), Worley Engineering, PXiSE and multiple technology providers to design and build a flexible campus microgrid on the SRJC campus.

With funding from a multi-year California Energy Commission (CEC) Electric Program Investment Charge (EPIC) grant, the project team developed a microgrid system that incorporates three different types of distributed energy resources (DERs), including battery energy storage, solar photovoltaic (PV) generation, and load management and control devices.

The SRJC microgrid demonstration project aims to make a clear business case for a campus microgrid project based on environmental, social, and economic value streams. The project scope spans from concept development to implementation. It included modeling, engineering design, procurement of system components, installation, testing, commissioning and finally, measurement and verification. The microgrid began operating at the beginning of March 2022 and is currently in its measurement and verification stage.

This case study summarizes the design and unique components of the SRJC microgrid, including the technologies installed and expected value streams. The paper explores the predicted operational outcomes from the modeling phase and the baseline energy profiles established during the metering phase compared to the data gathered to-date during the on-going measurement and verification period. This paper aims to provide insight into the preliminary lessons learned from this case study and how the project team is leveraging key findings to influence industry perceptions of the benefits and robust business case for microgrids, including reframing the concept of resiliency.

Microgrid Design

Microgrid Configuration

The campus owns and maintains its own on-site electrical infrastructure, a 12kV switchgear and feeder network, which is connected to the PG&E grid at a single point of interconnection (POI) located near Doyle Hall. From the POI, electricity is delivered to the campus buildings via five feeder lines. This electrical infrastructure forms the campus microgrid in the event of islanding from the utility grid. There are over 20 existing campus buildings (nearly 1.2 million square feet) supported by the microgrid, and future buildings, such as the STEM building and new Student Housing building, will be incorporated into the system as well.

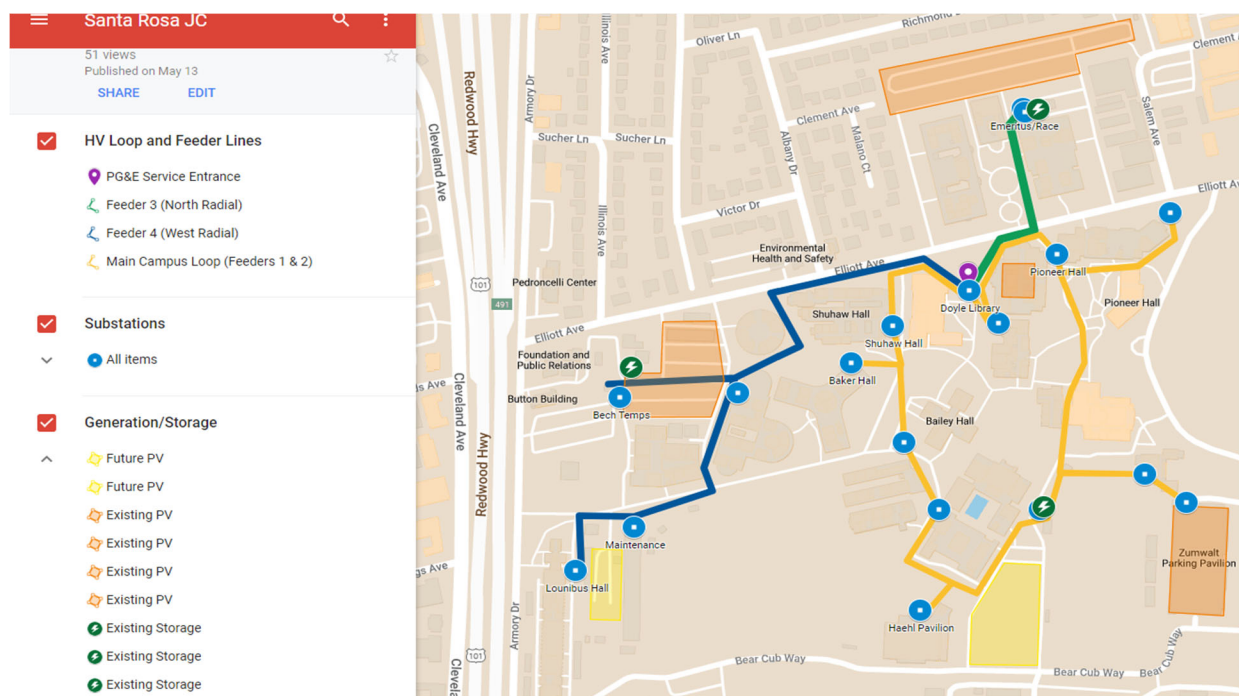


Figure 2. Santa Rosa Junior College Electrical Infrastructure Map. *Source:* SRJC

The microgrid system relies solely on renewable energy technologies and is composed of three different DER technologies which include four sets of solar PV systems, three electrochemical battery energy storage systems (BESSs) and a variety of load shed disconnect devices. All the DER technologies are controlled by a single PXiSE microgrid controller. Figure 2 is a Google Maps view of the campus with the electricity lines and DER technologies superimposed. Note that there are only four out of five feeders visible in this map because the fifth feeder runs solely from Doyle Hall to its chiller. The following section provides an overview of each technology used in the microgrid system.

Technologies

Microgrid Controller. All components of the microgrid system will be controlled by a single, high-speed microgrid controller (MGC) manufactured by PXiSE. The PXiSE MGC is software-based and provides advanced frequency and voltage support that is currently not supported by other microgrid control software on the market. PXiSE is the first microgrid controller software to earn the Sunspec certification for IEEE 2030.5 for large-scale DER management. The microgrid system will calculate the variance of grid-side and campus-side voltage and frequency and report on power quality monthly. The controller is configured using the load profiles developed from the metering system and will optimize energy use and maximize utilization of the solar generation and energy storage systems. The system is flexible in its optimization around cost savings, GHG emission reduction, or resiliency (e.g., maximizing battery state of charge for potential outages). Additionally, as a software-based controller, PXiSE controller can serve as a supervisory controller linking together multiple new and existing controllers from other equipment to work in unison.

Solar Photovoltaic (PV) Generation. The campus has roughly 2.3 MW of solar capacity across four PV systems, with one rooftop array installed in 2007 and three carport systems installed in 2018 and 2019. Figure 3 below shows the carport PV system installed outside of Bech Hall.



Figure 3. Carport PV Panels at the Bech Hall Parking Lot. *Source:* Santa Rosa Junior College

Battery Energy Storage Systems. Three electrochemical batteries make up the microgrid's energy storage component. The two lithium iron phosphate Enerport batteries, considered the

“power batteries,” have 1 MW power capacity and 1 MWh energy capacity each and will be used to provide islanding ancillary services and demand response capabilities for demand response programs. All three batteries will primarily charge from on-site solar PV generation and will allow the campus to offset energy usage and shave peak demand. The inverter technology deployed at each of the Energport batteries, GoElectric LYNC Secure, is programmed to autonomously transition from grid-following to grid-forming mode during a voltage sag. The technology was selected for its ability to change from grid following to grid forming mode in around 30 milliseconds. In actual operation, the project team is observing a larger time duration, and this functionality is being further troubleshooted. This capability was intended to allow the microgrid system to switch quickly and seamlessly to islanding mode in the event of a planned or unplanned outage. The project team defines “blinkless” or seamless transition as a transition from grid following to grid forming mode in under two cycles. The third battery in the microgrid is the lithium-ion Tesla battery, considered the “energy” battery, and it has 1 MW power capacity and 2 MWh energy capacity. The energy battery primarily provides demand charge management, meaning it helps the campus reduce its peak energy demand to minimize monthly demand charges from the utility. Additionally, due to its larger capacity, the Tesla battery will discharge during a microgrid event to support the GoElectric LYNC secure battery inverters which form the campus grid. Figure 4 shows the Energport battery and LYNC Secure inverter system installed at Emeritus Hall.



Figure 4. Energport Battery System and GoElectric Inverter at Emeritus Hall. *Source:* Santa Rosa Junior College

Demand Side Management (DSM). The microgrid system not only collects data at the building level, but also has the capability to shed load at the building level due to the load shed devices installed at each building in the system. As part of the microgrid design, SRJC developed a load shed schedule that grouped the buildings from lowest to most critical priority, and in the event of an outage, the microgrid will be able to automatically connect and disconnect these groups of building loads based on the available battery state of charge. The ranking of buildings also creates flexibility should a building’s program or intended use change in the future. The college can assign a different ranking and attribute the building to a different load shed group as needed. There are a variety of different disconnect technologies implemented based on the vintage of the existing electric infrastructure in the system and available technologies on the market. Some of the building electrical breakers were retrofitted with breaker modifications, like the General

Electric (GE) motor operator mechanism, to allow the breaker to remotely switch open and closed. However, some breakers needed to be replaced entirely to allow for automatic opening and closing. Each building received either a protection relay and breaker modification components (shunt trip, aux contact, motor operator mechanism) or a switchboard intercept to provide automation and control capabilities through an integrated switchboard with both relay and stored energy breaker.

Advanced Metering. To gain insight into the energy load profiles at the individual building level of the microgrid, metering was crucial. The college installed high accuracy Acuvim power meters at each building in the microgrid system to provide real-time data on building energy consumption. The meters were integrated into the campus energy management system and were used to establish a more granular baseline energy profile than the full campus energy consumption data. Meters were also installed at each DER in the system. Additionally, beyond the scope of the microgrid project, the metering at the building level will also inform the building performance evaluation and deployment of future Energy Conservation Measures (ECMs) such as LED lighting and controls retrofits and HVAC control upgrades (Sevilla et al. 2022). This also includes the participation in new, whole-building metering programs under development in California such as Monitoring Based Commissioning, Net Metering Energy Conservation, and Existing Building Commissioning.

Automatic Demand Response (ADR). SRJC already had a global, campus-wide energy management system (EMS) that communicated with the individual building EMS to set heating and cooling profiles based on pre-set schedules. As part of the project, the campus-level and building-level EMS systems are being updated to create new global triggers and local programs so the buildings each have performance settings for a variety of scenarios, including demand load shedding (in the case of a demand response event), microgrid islanding events, and COVID (100% outside air pre purge & post purge modes) and fire-safety modes. Demand load shedding is based on a global temperature setback of 6 degrees Fahrenheit (for both heating and cooling) and microgrid islanding events turn off all heating and cooling systems (pumps, fans, & compressors). Both activities function as a first level of demand side reduction allowing the microgrid to reduce the building load before having to fully disconnect a building from the microgrid. To allow the microgrid to participate in ADR programs, an OpenADR software client is being added to the EMS system so the microgrid can receive ADR 2.0 communications. The campus is currently exploring options for utility demand response (DR) program participation and will likely participate, at a minimum, in PG&E's Emergency Load Reduction Program (ELRP) that can be layered with a traditional DR program like the Capacity Bidding Program (CBP).

Performance Objectives

The SRJC microgrid system is an innovative, first of its kind, fully renewable-energy-based microgrid that will provide both energy efficiency and resiliency benefits to the campus. Energy efficiency for the microgrid project refers to the reduction in transmission losses through utilization and optimization of solar and storage on-site generation and consumption, i.e., using electrons closest to where they are generated. In regular operating conditions, also known as “blue-sky” operating mode, the PXiSE microgrid controller's optimization of energy storage state of charge (SOC) will improve the energy efficiency of the entire campus energy system.

Optimization can be based on either economic criteria, forecasting expected load and PV generation and scheduling deployment of the batteries for the best return on investment (ROI), or on environmental criteria, leveraging the expected load and PV generation forecasts to minimize the net import of power from the utility grid. The PXiSE MGC generates 24-hour optimization schedules and re-optimizes at 15-minute intervals to adjust to real-time operating conditions. The microgrid is designed to disconnect and reconnect seamlessly from the grid, meaning that the campus can transition from following the utility grid to forming its own grid without any noticeable impact for the campus occupants. The blinkless islanding capability in the event of planned or unplanned outages provides the campus with reliable power in the case of an emergency, allowing it to play a critical role in the community in the event of a disaster. The loadshedding capabilities of the microgrid system also help the campus microgrid balance resiliency and energy efficiency by prioritizing critical loads during an outage to allow the campus to island for longer durations as needed. The SRJC microgrid helps mitigate the identified wildfire and power outage risk without sacrificing the energy performance of the overall campus system. This demonstration project provides multiple potential value streams from the flexible campus microgrid system, including environmental, resiliency, economic, and energy efficiency benefits.

Environmental. Of the three performance objectives of the microgrid system, reducing the environmental impact of the campus, and more specifically reducing the overall greenhouse gas (GHG) emissions, is the college's priority. The environmental benefits of the microgrid help address the root cause of the campus's wildfire risk by helping mitigate climate change. During the modeling phase, the XENDEE model indicated that the available 2.3 MW solar capacity alone would be able to reduce SRJC's annual carbon emissions by 24% (Fahy et al. 2022). The goal is for the microgrid to leverage the solar generation and battery storage systems to support up to 40% of the campus annual electricity consumption with emissions-free solar energy. The PXiSE microgrid controller is also expected to yield peak demand reduction and energy efficiency improvements through its optimization settings.

Resiliency. SRJC is in a highly vulnerable region of northern California, which has been impacted by multiple wildfire events within the past five years. The microgrid's islanding capability will allow the campus to maintain reliable power during a planned outage, like a PSPS event, or an unplanned outage, like a natural disaster or extreme weather event. Keeping the lights on means that the campus can continue to support its students, faculty, and staff, as well as the adjacent community. These resiliency benefits translate directly into monetary benefits for the university because the microgrid allows SRJC to continue to hold classes and maintain mostly regular operating conditions, but there are also social benefits of maintaining power when the adjacent community has gone dark. For example, during the construction phase of the project, in preparation for the new 12kV switchgear equipment, the campus had to develop a list of crucial loads that could not lose power during the scheduled 1-week outage required for installation activities. One of the loads identified by the college was power supplied to a refrigerator containing doses of the COVID-19 vaccine. The added resilience of the campus being able to continue to provide power to crucial end uses in the event of an outage contribute to deeper benefits than can be demonstrated by a direct dollar value. Quantifying the value of resiliency beyond the direct financial impacts is an ongoing industry-wide challenge, and the

project team is tackling this through data collection for this microgrid project and through knowledge transfer activities.

Economic. The combination of solar PV generation and energy storage will reduce the energy consumption from the utility grid, ultimately reducing the campus energy costs. The increase in battery energy storage capacity allows for energy arbitrage in addition to demand charge management. Modeling indicated that the microgrid would yield a little over half a million dollars savings in campus energy costs per year. Additionally, participation in PG&E demand response programs could provide an additional \$48,000 annual revenue stream to the campus. The energy use optimization and decrease in grid instability will extend the life of the college electronic assets which is a value that couldn't be calculated. Modeling showed a project return on investment (ROI) of 14 years based on multiday outage events. However, for no outage, brief outage, and demand response only events, the ROI was longer than the estimated life of the equipment. There are multiple factors that impact the modeling of the anticipated payback period, and one is the cost of resiliency for public institutions such as universities. Public agencies looking to prioritize resiliency must choose how to value it and accept the tradeoff on its impact on the ROI. Another factor is how to represent utility rate escalation. For example, previous utility escalation was modeled off 3% increase annually. However, PG&E's general rate case submitted to the CPUC for 2023 requested a 9.6% increase in total company revenue after an already 22% increase in rates in 2022. And lastly, the State of California Self Generation Incentive Program has the potential for significant impact on ROI with respect to additional battery storage rebates both in the market rate track and resiliency track.

Energy Efficiency. The SRJC utilizes the loading order framework and prioritizes energy conservation, then efficiency to reduce load energy and power consumption, followed by demand shifting, storage and then lastly generation. There are multiple energy efficiency efforts conducted by the college to significantly reduce both kilowatts and annual kilowatt-hours of consumption that are not included in the microgrid grant scope. The outcome of these efforts will support the success of the overall microgrid project and include campus-wide LED lighting retrofits, installation of lighting controls, variable frequency drive installation on both fan and pump motors, installation of ground source geo exchange wells, electrification of space heating and efficient cooling. All these projects are projected to collectively reduce overall campus demand by 15% which in turn will allow for greater match between existing load and generation as well as create head room for additional building loads when new buildings are incorporated into the microgrid system. Additionally, discussions about energy use and access to building level energy consumption data through the microgrid project are encouraging a behavior change in energy conservation across campus, and the more building occupants conserve energy the more buildings and longer duration outages the microgrid can support.

Microgrid Performance Outcomes

Modeling and Baseline Submetering

The SRJC microgrid was designed to support the campus through short duration planned or unplanned outages and longer outages when loadshedding is employed. During the design of the microgrid, the project team utilized XENDEE modeling software to run various scenarios and determine the sizing of the battery system to support both critical and non-critical campus

loads through partial-day and multi-day outages. The models used primarily 2017 utility data because the baseline metering data at the building level was not available during the modeling phase. The modeling results indicated that a fully charged 4 MWh battery energy storage system could sufficiently support the campus demand during a midday outage for nearly 3 hours. For a 3-hour outage, the system should support the campus if the lowest priority loads are curtailed (Fahy et al. 2022). Figure 5 illustrates the anticipated performance of the microgrid during a 3-hour outage on a worst-case scenario day. The outage day modeled for this simulation was a mid-day September outage which is the worst-case for impact on business continuance because September has the highest power demand while classes are also in session. Please note that the “Energy Battery” refers to the Tesla battery and the “Power Batteries” refers to the two Energypart batteries.

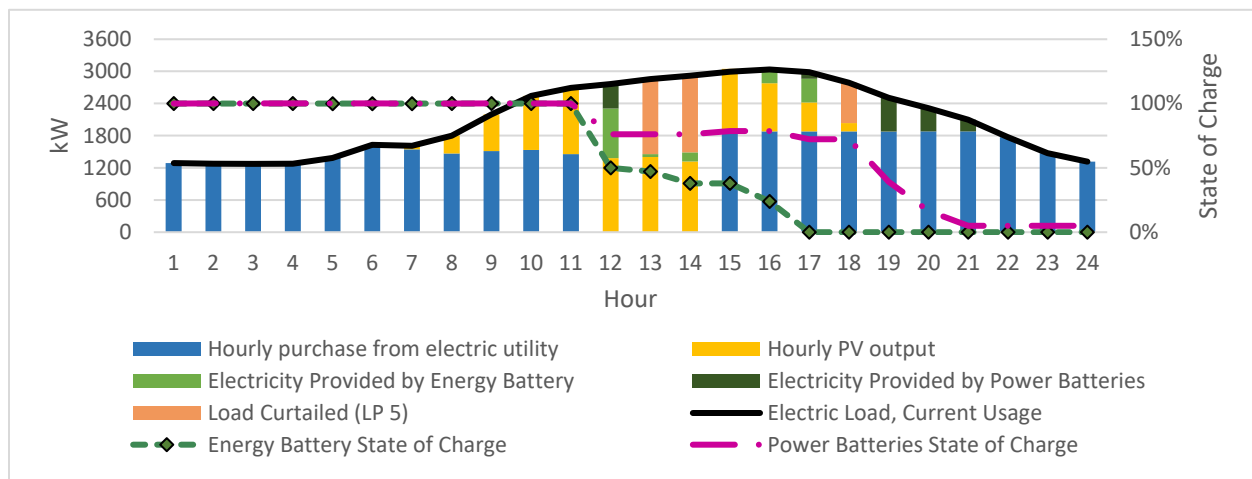


Figure 5. Modeled Microgrid in a 3-Hour Extreme Demand Day Outage. *Source:* Modeling and Engineering Report

After meters were installed, the project team began collecting baseline metering data to develop granular building level electrical demand profiles prior to microgrid installation and operation. The baseline submetering phase was originally scheduled to run for a full year before the microgrid was deployed. However, due to installation delays, the meters did not begin consistently trending data until March 2021, and most of the buildings were not reliably metered until May. Figure 6 shows the meter data collected up to the start of blue-sky operations in March 2022. For meters that were missing a few months of data, the project team simulated demand and consumption for these buildings based on PG&E data. Additionally, although the project team originally intended to collect baseline submetering data at all campus buildings included in the microgrid, there are some buildings, like the Bertolini Student Center, that do not have reliable meter data due to faulty equipment installation and are not included in Figure 6.

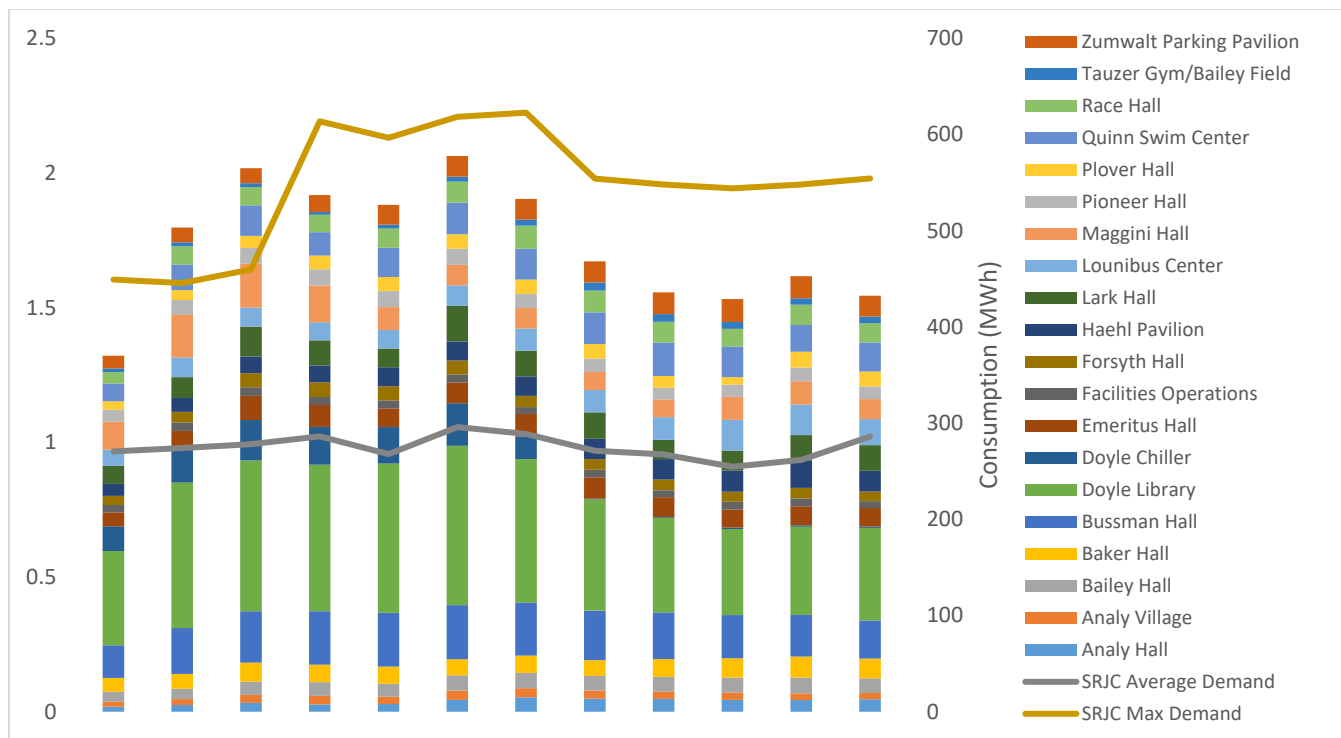


Figure 6. Baseline Metering Data Collected at Building Level. Source: CSE

The project team will use the baseline data collected during the submetering phase as a point of comparison to analyze the microgrid’s performance and how deployment of the solar and storage microgrid changes the overall campus average and maximum energy demand as well as the typical energy use at the building level. This data will also be used to validate demand side reduction from load shed disconnect devices and Automated Demand Response.

Preliminary Operational Data

The microgrid began its measurement and verification period on March 1, 2022 and is operating in “blue sky” operating mode. This means that the PXiSE microgrid controller now has full command over the system and the batteries are actively charging and discharging per PXiSE optimization. The PXiSE MGC is the data historian for the project and is collecting and storing a variety of quantitative data, including campus-wide utility consumption, submetered building consumption, solar generation, battery charge and discharge, battery state of charge, grid-side power quality, and GHG emissions. Throughout the data collection period, the project team is also collecting qualitative data to establish lessons learned for microgrid implementation that can be disseminated. This includes activities such as documenting operational constraints observed by SRJC staff during normal and emergency operating conditions and interviewing students and staff to gather information on occupant experience during islanding and loadshedding events.

Figure 7 and Figure 8 illustrate preliminary data collected during the measurement and verification period so far. Figure 7 demonstrates the power batteries charge and discharge, solar generation, and utility energy use over a 24-hour period. The yellow and green lines indicate the state of charge of the two Energport “power” batteries at Emeritus and Bailey field, respectively, and show the batteries charging mid-day when solar generation is at its peak. The light blue line

indicates the energy provided by the utility grid; it decreases during the mid-day when solar generation is charging the batteries.

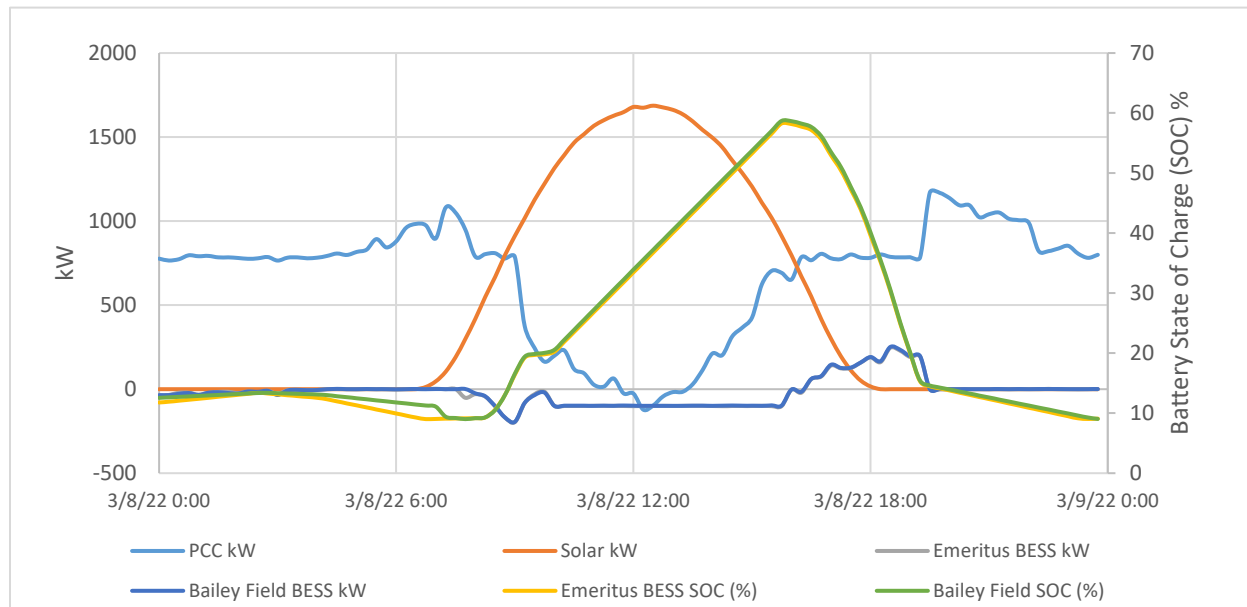


Figure 7. Microgrid Operation During “Blue Sky” Mode on March 8, 2022. *Source:* CSE

Figure 8 shows the microgrid operation from Sunday March 6, 2022, to Saturday March 12, 2022, in the early stages of its operational period. This graph illustrates the cycling of the batteries (yellow and green lines) changing with solar generation (orange) day to day.

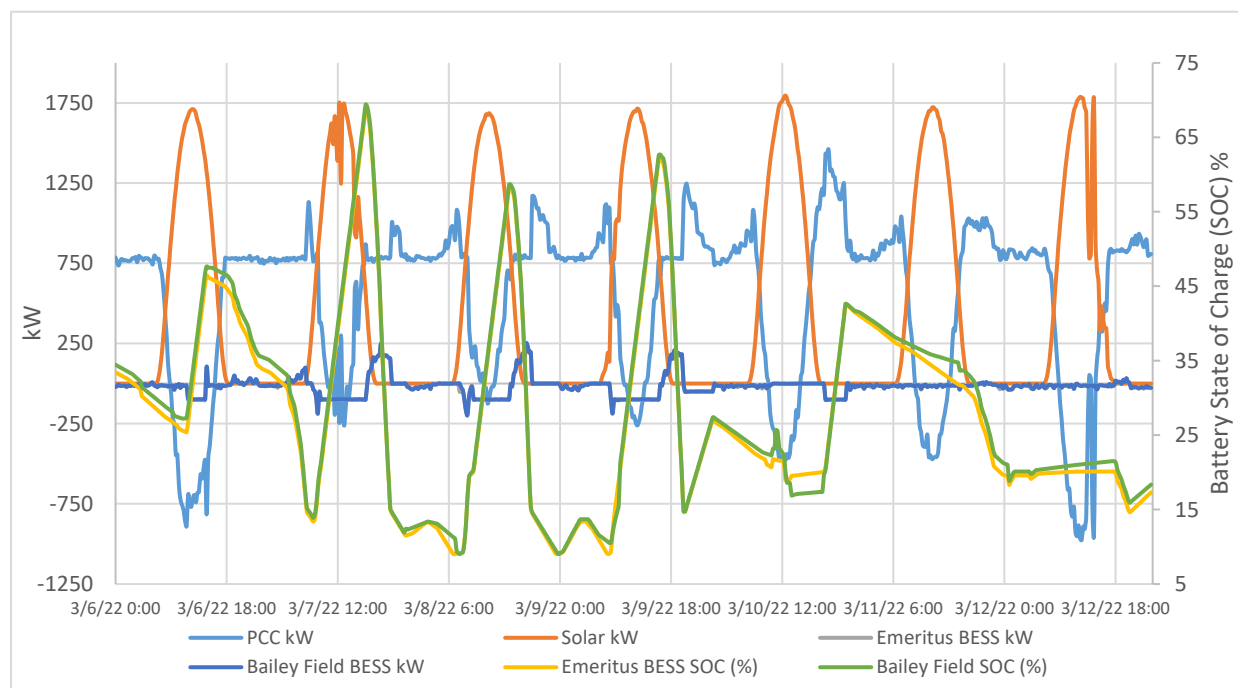


Figure 8. First Full Week of “Blue Sky” Operation. *Source:* CSE

To date, the microgrid has been operating for a little over three months. Ultimately, the microgrid will trend data regarding the displacement of GHG emissions and grid stability; however, at the time of this report, these features are still in development. The project team encountered some unforeseen performance issues in the microgrid during the beginning of “blue sky” operating mode. There have been three campus outages so far where the microgrid has failed to successfully auto-transfer and island the campus load. In the first two cases, the two lithium iron phosphate batteries, at Bailey Field and Emeritus Hall, tripped offline after auto-transfer due to an error in the frequency setpoint which triggered the batteries’ internal safety controls. A fault in the second outage created issues with communication between one of the GoE inverters and the battery at Emeritus Hall which in turn necessitated the unit to be shut down before the third outage. During the third outage, the frequency setpoint issue occurred again and additionally with only one lithium iron phosphate battery online the auto transfer event could not hold the grid up at partial capacity.

The project team is conducting additional testing to understand and resolve the frequency setpoint issue. It unfortunately was not encountered during the testing phase. It is important to note that testing is a very time and labor-intensive process involving multiple planned outages of multiple buildings over a duration of time. For public institutions, this is even more difficult since it involves working around normal works day, scheduled programs and events, fire life safety systems, sensitive equipment and the continual checking of building systems after power restoration to make sure no electronics were damaged or in need of reset. Additionally, the project team continues to troubleshoot a second item in the auto-transfer observed during testing. The auto-transfer functionality catches a voltage drop preemptively, but this requires the campus main breaker to be sensitive to utility voltage drops which means more islanding events to ensure the campus islands seamlessly. However, if the auto-transfer fails, the college is susceptible to nuisance tripping from utility voltage drops to 80% of nominal voltage. These nuisance trips occurred in the first two outages while the third was a long-term outage caused by utility equipment failure.

Industry Impacts

Quantifying the Value of Resiliency

California Senate Bill (SB) 1339, enacted in 2018, directed the California Public Utilities Commission (CPUC) to undertake activities to further develop policies related to microgrids. In 2019, the CPUC initiated a new rulemaking to consider how to best implement the requirements of SB 1339 (CPUC 2021). As part of the rulemaking, the CPUC established a working group to explore a range of barriers to microgrid commercialization such as measuring resiliency and reliability, microgrid tariffs, and interconnection. Since one of the main performance objectives of the SRJC project is to demonstrate the resiliency benefits of a flexible campus microgrid, the project team attended, but did not formally engage the CPUC Value of Resiliency (VoR) working group meetings, which ran from May 2021 to August 2021, to identify potential tie-ins with the project lessons learned. During these workshops, the CPUC Energy Division staff presented a 4 Pillars of Resiliency Valuation methodology concept for optimizing grid investments to maximize resiliency benefits. The four pillars are: 1) establishing a baseline assessment identifying hazards, 2) developing potential mitigation measures, 3) leveraging a resiliency scorecard to assess mitigation measures against costs and benefits, and 4) post-response assessment (Energy Division 2021).

The ideas presented throughout the VoR workshops were abstract, and upon meeting with Energy Division staff in July 2021, the project team learned that the CPUC staff had not made any conclusions on how best to implement this methodology in practice. The project team seeks to operationalize the CPUC's 4 Pillars of Resiliency methodology, specifically the resiliency scorecard concept, to help capture the value of resiliency beyond the pure financial benefits of avoided loss of revenue. As part of the SRJC microgrid project, the project team is developing a California-specific cost-benefit-analysis (CBA) tool for assessing the costs and benefits of microgrid projects. This tool can be used by sustainability managers or other interested parties to explore the high-level impacts of a potential microgrid project before investing in more comprehensive modeling tools.

The CBA tool is a multi-tab spreadsheet that helps guide the user through an analysis using the free National Renewable Energy Lab (NREL) ReOpt Lite tool while also incorporating vulnerability and social impacts. The first step is a questionnaire that ranks qualitative site information, such as how losing functionality of the facility impacts occupants or how important the facility is to maintaining human health and safety, and identifies the locational risks to natural disasters such as earthquakes, wildfires, or flooding. Rankings for each characteristic are low, medium or high where each ranking is assigned a number value with high risk at a weight of 3, medium risk at a weight of 2 and low risk at a weight of 1. The sum of all these scores yield the site's vulnerability score. The second tab collects basic information on the site and quantitative data such as site energy load information. Using data collected in the two previous tabs, the CBA tool then provides instructions on how to fill out ReOpt Lite and the data needed to do so. Based on input data collected throughout the spreadsheet questionnaire, the ReOpt tool will provide suggested system sizing for solar PV and battery energy storage required for specified outage duration.

The concept behind this tool is to leverage an existing microgrid analysis platform while incorporating additional features around the social impact of resiliency. Additionally, the tool makes a ReOpt analysis accessible for someone with a limited knowledge of modeling software. Figure 9 and Figure 10 show screen captures of the inputs tab of the most recent prototype of the CBA tool. The project team continues to troubleshoot how best to incorporate the social cost of GHG emissions and is also developing functional ReOpt interaction page.

Qualitative Site Information			
Factor	Criteria Description	Rating Description	Ranking (High / Medium / Low)
Internal Continuity Ranking	Measured in terms of the ability of Site to deliver minimum essential service for it's students and staff if the critical asset is degraded or incapacitated by the worst reasonable case power outage.	A high ranking means that loss of the facility has high impact to building occupants. A medium ranking means that loss of the facility has moderate impact to occupants. A low ranking means that loss of the facility has low impact to building occupants.	Select
Regional Continuity Ranking	Measured in terms of the ability of Site to deliver minimum essential public services and ensure public health and safety if the critical asset is degraded or incapacitated by the worst reasonable case power outage.	A high ranking means that loss of the facility has high impact to the region. A medium ranking means that loss of the facility has moderate impact to the region. A low ranking means that loss of the facility has low impact to the region.	Select
Existing Community Resource	Consider the proximity to nearest emergency shelter or an existing designation as a community resource? For example, if community includes an abundance of schools with emergency shelter-in-place designations, the need for critical infrastructure is lower.	A high ranking means no other emergency shelters serve the surrounding community. A medium ranking means that the region includes some, but relatively few emergency shelters. A low ranking means the region includes an abundance of pre-established emergency shelters.	Select
Life Safety	Life safety focuses on the nature of the facility's role with respect to maintaining or protecting human life and safety. For example, schools designation as a shelter location/cooling center/secondary or primary triage location for EMS.	A high ranking means that the facility is critical to maintaining human health and safety in the region. A medium ranking means that the facility is moderately important to human health. A low ranking means that loss of the facility would not impact human health.	Select
Economic Impact	Economic Impact specifically focuses on the economic contribution of the particular facility on the region.	A high ranking means that a disruption to the facility would have high economic impact on the region. A medium ranking means that loss of the facility has moderate economic impact to the region. A low ranking means that loss of the facility has minimal economic impact to the region.	Select
Existing Resiliency	Existing on-site generators (renewable or fossil based) provide power to the site in the event of a grid disruption event. Consider the existing resources already serving the facility.	A high ranking means the site has no back-up generators and is entirely dependent on grid electricity. A medium ranking means the site includes a back-up generator that serves a small emergency "critical load" bank during a grid outage. A low ranking means the site includes existing back-up generator and/or solar & storage systems with ability to serve most of the site during a grid outage, an operation mode referred to as "islanding".	Select
Locational Risks Survey			
	Criteria Description	Rating Description	(High / Medium / Low)
Earthquake	What is the facility's risk of experiencing operational disruptions due to earthquakes? Based on proximity to faults and Recency of Movement (https://maps.conservation.ca.gov/cgsf/amf)	A high ranking means the region's susceptibility to an earthquake is fairly high. A medium ranking means the region contains moderate risk of disruption due to earthquake. A low ranking means earthquakes are relatively uncommon in the region.	Select
Landslide	What is the facility's risk of experiencing operational disruptions due to landslides? Based on local landslide risk (https://maps.conservation.ca.gov/cgsf/EQZApp/)	A high ranking means the facility's susceptibility to landslides is fairly high. A medium ranking means the facility is at moderate risk of disruption due to landslide. A low ranking means landslides are relatively unlikely to impact the facility or surrounding area.	Select

Figure 9. Qualitative Input Section of Resiliency Tool Prototype. *Source:* CSE

Existing Site Conditions															
Factor		Criteria Description					Input								
Weekly Site Operation (hrs/day per week)		Hours per day per week that the facility is operation.					24/7								
Fuel for Addressable Thermal Load							50%								
Duration of Backup		How long will existing backup last in the event of an outage?					Select One								
Fuel Availability		How is energy (natural gas, electricity, etc.) sourced?					Select One								
Emissions Level		What is the sites GHG emissions?					Select One								
Energy Billing Information															
		29	31	29	28	31	29	31	29	31	29	29	32	29	
Billing days per month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
		31	28	31	30	31	30	31	31	30	31	30	31	365	
Electricity Bill Data:															
Monthly Electric Use kWh		566,135	608,170	857,753	899,701	891,913	934,783	972,383	1,013,630	919,618	805,136	863,910	665,276	9,988,408	
Monthly Peak Demand kW		1,301	2,891	1,992	2,660	2,373	2,540	2,065	2,740	2,570	4,335	1,992	3,325	2,565	
All-in Monthly Cost (Commodity plus T&D)		\$35,541	\$39,232	\$54,687	\$66,319	\$79,127	\$80,543	\$74,416	\$90,487	\$84,088	\$69,742	\$54,861	\$45,947	\$774,989	
		\$/kWh	\$0.0628	\$0.0645	\$0.0638	\$0.0737	\$0.0887	\$0.0862	\$0.0765	\$0.0893	\$0.0914	\$0.0866	\$0.0635	\$0.0691	\$0.0775
Fuel Bill Data:															
Fuel Type		Nat Gas													
Monthly Fuel Use		Therm	5,588	5,935	4,323	3,937	2,569	2,742	2,443	2,589	2,256	2,456	3,204	5,237	43,279
Monthly Fuel Cost		\$	\$6,304	\$6,494	\$4,929	\$4,290	\$2,751	\$2,924	\$2,601	\$2,749	\$2,395	\$2,586	\$3,599	\$5,633	\$47,255
Average Cost of Fuel		\$/MMBtu	\$11.2817	\$10.9422	\$11.4027	\$10.8955	\$10.7084	\$10.6632	\$10.6476	\$10.6195	\$10.6167	\$10.5285	\$11.2319	\$10.7559	\$10.9187
Addressable Thermal Load Fuel		MMBtu	279	297	216	197	128	137	122	129	113	123	160	262	2,164
		MMBTU/hr	0.38	0.44	0.29	0.27	0.17	0.19	0.16	0.17	0.16	0.17	0.22	0.35	0.25
Site Load Considerations															
Loads		Criteria Description					End-Use					Input			
List "Tier 1" loads		Tier 1 are mission-critical and life-sustaining loads, crucial to keep operational at all times, including during grid outages. Is this facility designated as cooling/heating centers as a community resource? If so, heating/cooling would be considered Tier 1					Describe the types of Tier 1 loads at the facility. I.e. Emergency lighting, emergency outlets in admin office, emergency ventilation, emergency heating or cooling					10%			

Figure 10. Part of the Qualitative Input Section of Resiliency Tool Prototype. *Source:* CSE

Creating a Blueprint

A crucial part of the SRJC microgrid project is sharing relevant knowledge gathered during the project process to encourage the deployment of solar and storage microgrid projects across California. There are over 100 California Community Colleges across the state that could pursue similar microgrid projects in the future, and this project aims to serve as an example for other microgrid projects across California.

Lessons learned from project design to commissioning and operation can inform the development of a blueprint for a flexible 100% renewable-driven microgrid which can be replicated at campuses across the nation. The project team has already begun sharing knowledge with a large audience, including facilities managers and directors, public school boards, municipal water and utility departments, California Community Colleges, University of California and California State University Sustainability officers, architects, engineers, and representatives from the California Public Utilities Commission and the CEC.

Not only can the learnings from this project be used as a blueprint for other community colleges, but the knowledge gathered can also make a case for scalable solar and storage microgrid systems that can help California meet its ambitious renewable energy goals. For example, in September 2021 the project team provided written comments in response to the CPUC Email Ruling on Potential Microgrid and Resiliency Solutions for Commission Reliability Action to Address Governor Newsom's July 30, 2021 proclamation of a State of Emergency. Through this letter, the team shared load reduction considerations at the SRJC project as well as recommendations for leveraging existing microgrid projects to reduce utility grid load (Gunther and Ninow 2021).

Conclusion

The SRJC microgrid project has demonstrated best practices in approach, design, engineering, and modeling and aims to validate the benefits of a 100% renewable energy future without any rotating generating assets in its operations. As California and the rest of the country grapple with grid reliability and seek to increase the deployment of solar and storage microgrids, the following best practices and lessons learned from the SRJC microgrid project can be leveraged to simplify and accelerate the installation of future renewable microgrid projects:

- Early identification of critical loads is key. Work to analyze critical loads that always need power and their associated spaces. Space planning can allow for centralization of loads and systems that need 24/7 power which in turn can lead to power optimization.
- Work with the local utility to plan early on how the new microgrid system can become a grid asset. Additionally, understand the utility interconnection pathway and rules around existing or new service connections and connection of generation and storage assets on customer side of the meter. (In California, this is Rule 2 and Rule 21).
- Develop microgrid-ready design elements into construction to allow for integration of new buildings into the existing microgrid. This includes HVAC demand response programming, microgrid relay, a load shedding device, and planning of emergency loads.
- Be aware that testing of microgrid operations on existing buildings will require extensive power shutdowns. This involves ongoing communication between building occupants and testers. Additionally, a system needs to be in place to identify loads that cannot lose power as well as systems that need to be re-started after an outage.
- Ensure the system includes a reliable communication line that can communicate voltage, amperage, and frequency points from the point of common coupling to all inverters that are forming the grid in island mode.
- Energy and communication systems work hand in hand. Designs should include fault tolerance for the power sources of all communication systems that help DER assets communicate with the microgrid controller. It is recommended to hardwire all microgrid controlling assets and include home runs back to the microgrid controller location. This approach minimizes the number of nodes that must be powered to have communication continuity and supports the speed of communication needed for advanced synchrophasor-based control.

We hope this paper helps generate exposure of the SRJC microgrid project and inspires sustainability managers at other community colleges and similar organizations to pursue a microgrid project.

Project Next Steps

This project is a multi-year CEC EPIC-funded grant project ending in March 2023. At the time of publication, June 20, 2022, the microgrid has been collecting data for about three months. The project team is excited to share preliminary results as well as lessons learned. In the next few months, the team will be finalizing and publicly sharing CEC reports detailing the various stages of the project, including the metering phase, modeling efforts, hardware engineering, and procurement and installation. More information about the project can be found on the project website at santarosamicrogrid.energycenter.org/.

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