EPIC Final Report

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Administrator	San Diego Gas & Electric Company
Project Number	EPIC-3, Project 7, Module 2
Project Name	Demonstration of a Multi-Purpose Mobile Battery at Community Resource Centers
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Attribution

This comprehensive final report documents the Electric Program Investment Charge (EPIC) 3, Project 7, Module 2. The project team that contributed to the project definition, execution, and reporting included the following individuals, listed alphabetically by name:

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Executive Summary

Objectives

The objective of SDG&E's EPIC-3 Project 7 was to perform a pre-commercial demonstration of mobile battery energy storage systems (MBESS) and examine the value proposition from using MBESS across multiple sites and use cases.

Due to the current high cost of leasing or owning and operating energy storage systems, stacking multiple MBESS applications and incorporating added benefits of frequent relocation and quick installation/energization (plug-and-play) to support day-to-day business needs are key demonstration features included in this EPIC project. The remote nature of certain customers located in high fire risk areas of the SDG&E service territory, facing forced outage events for long periods (up to 72 hours) a few times during the fire season, requires a robust, reliable, and easily relocatable power supply solution.

Approach

The project was split into two work modules. This report covers Module 2, which focused on demonstrations at community resource centers. Module 1 focused on other applications and is covered in a separate report. Module 2 covered a series of tasks, including:

- Selection and evaluation of baseline value propositions for an initial set of use cases, such as outage management for customers in a wildfire zone and a wide range of grid supporting or day-to-day maintenance operations.
- Delivery of a pre-commercial MBESS solution that meets the functional specifications after completing the factory and site acceptance tests and initial interconnection verification.
- Supporting the logistical aspects of the project demonstrations at two selected sites (community resource centers) in remote areas of the service territory.
- Demonstration of MBESS uses cases at the sites.
- Collection and analyzing the demonstration results to determine the benefits and value proposition of MBESS in the context of pre-defined benefit categories and available customer sites in remote and vulnerable areas of the service territory.
- Engineering analysis and preparation of the comprehensive final project report, including recommendations regarding commmericial adoption.

Key Accomplishments

The demonstration at the two sites clearly showed the viability and value of utilizing MBESS for supplying the customer loads during a specific period when supply interruption (outage) is expected. The approach alleviates the need for maintaining a stationary backup generation source at a facility year-round. It also showcases an alternative to conventional diesel generators, which are highly prone to noise pollution and greenhouse gas (GHG) emissions.

There is concern with safely transporting fully charged battery cells, when using MBESS. The project showed that mobility could be achieved with proper use of the technology and adequate design to incorporate sensors and monitoring and the technical capability for enabling the solutions.

Key accomplishments in this project include:

- Relocating the MBESS from one place to another could be performed relatively easily, using typical tractor trucks from the utility equipment operations fleet.
- Connection of the MBESS to the customer-generator terminal box at each site was performed swiftly with minimal power interruption to the facilities. It required the connections to be made by a qualified electrician, properly trained to work on medium to low voltage equipment, with their specialized skill and tools.
- Using manual mode and following a few steps, the MBESS was easily started by pressing the "start pushbutton" on the terminal box. The system status and operation could be checked frequently using a user screen on a portable tablet that provides remote access to the unit Human-Machine Interface (HMI).
- External to the MBESS container, the noise emitted during the unit operation was minimal, which is a major advantage of using the MBESS, especially in locations with residential customers. With diesel generators, the noise pollution can exceed 60 dB.
- The unit operation and backup generation supply to a CRC was successfully demonstrated at both sites, for more than 16-hours, with no need to stop or start the unit. With diesel generators, the unit may need to be stopped after 6-8 hours and restarted to meet the hard duration limitation for emergency use of diesel genset (enforced by local jurisdictions in some areas).

Recommendations

- The key recommendation from this project is for SDG&E to adopt MBESS into their commercial operations. The value proposition shown in this Module 2 of EPIC-3 Project 7 and the companion work of Module 1 indicates significant benefits can be derived from the use of MBESS.
- It is recommended that SDG&E's DER group take the lead to commercially adopt MBESS in the SDG&E territory and engage other business units in developing a commercialization plan.
- The use cases demonstrated in the project were limited to the outage management scenarios due to the configuration at the CRC sites. It is recommended to perform additional testing and evaluation at other potential sites to analyze the value proposition in other use cases.
- It is recommended that future projects incorporate both single-phase and three-phase outputs for MBESS to support residential and commercial facilities. The multiple output type will increase the coverage and utilization cases for the system.
- Integration to the dispatch center and remote control or observability were not part of the EPIC project. However, remote dispatch and monitoring will need to be key aspects of the field operation.
- Depending on the number of relocations expected, a combined truck-trailer approach may become more beneficial and convenient than a flatbed trailer in support of multiple use cases and utility applications.
- An MBESS can be equipped with electric vehicle chargers for the additional benefit of supporting customers during outage scenarios. A hybrid MBESS with an onboard charger will significantly improve the business case and come at a low incremental cost.

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List of Acronyms

Acronym	Acronym Description
ATS	Automatic Transfer Switch
BCR	Benefit to Cost Ratio
BESS	Battery Energy Storage System
BMS	Battery Management System
BTM	Behind the Meter
C&I	commercial and industrial
CPUC	California Public Utilities Commission
CRC	Community Resource Centers
DAC	Disadvantaged Community
DER	Distributed Energy Resource
DNP	Distributed Network Protocol
EOL	End of Life
EPIC	Electric Program Investment Charge
E-Stop	Emergency Stop
FAT	Factory Acceptance Testing
GCM	Grid-Connected Mode
GHG	Greenhouse Gas
HMI	Human Machine Interface
IRR	Investment Rate of Return
ITF	Integrated Testing Facility
LFP	Lithium Ferrophosphate
LiFePO4	Lithium Iron Phosphate
MBESS	Mobile Battery Energy Storage System
$MTCO_2e$	Metric Tons of Carbon Dioxide Emissions
MTS	Manual Transfer Switch
NFPA	National Fire Protection Association
O&M	Operation and Maintenance

Acronym	Acronym Description
PCC	Point of Common Coupling
PCS	Power Conversion System
POI	Point of Interconnection
PSPS	Public Safety Power Shutoffs
RFP	Request for Proposal
ROI	Return on Investment
SAT	Site Acceptance Testing
SCADA	Supervisory Control and Data Acquisition
SDG&E	San Diego Gas & Electric
SLD	Single Line Diagram
SOC	State of Charge
UPS	Uninterruptible Power Supply
USD	U.S. Dollar
VPN	Virtual Private Network

1.0 Introduction

The objective of SDG&E's EPIC-3 Project 7 was to perform a pre-commercial demonstration of mobile battery energy storage systems (MBESS) and examine the value proposition from using MBESS across multiple sites and use cases. An MBESS is a battery energy storage system on wheels that can provide multiple use cases based on a single MBESS application or a combination of several applications (stacking of applications) to provide grid support and reliability/resiliency solutions for utility projects at different sites.

This EPIC project was initiated by assessing the potential use cases and benefits of using a mobile battery system when rotated between multiple locations as part of the utility fleets. Customer and utility benefits were investigated from different viewpoints, including reliability and power quality, power system performance, greenhouse gas emission level, cost of operation, and infrastructure investment efficiency.

Based on the outcome of initial investigations and analyses, a baseline methodology was proposed to quantify benefits for mobile energy storage solutions by including the incremental benefits of mobility compared with stationary battery energy storage system (BESS) applications. Various state environmental and energy regulations were considered in the proposed approach.

1.1 Project Objectives

The key project objective was to execute a pre-commercial demonstration of mobile energy storage systems and evaluate the value preposition for utilizing the MBESS in different applications. The project was split into two modules with different mobile MBESS units, sites, and use cases in each module. This report covers Module 2, in which an MBESS was employed at two community resource centers (CRCs) in SDG&E's service territory during planned outages. Module 1 is covered in a separate report, available on the SDG&E public website.

In Module 2, the MBESS demonstration was accomplished at Dulzura and Pine Valley Community Resource Centers. These sites have been equipped with a 120/240 V single-phase generator connection box at the interconnection point (POI). In addition, demonstration data were collected and analyzed at both sites to investigate the mobile battery system performance from safety, reliability, control, and monitoring viewpoints.

The tests carried out in the demonstration show that mobile batteries can be a proper alternative and have potential value for emergency backup power supply sources at CRCs. Likewise, the associated logistical and operational constraints were identified.

A focus of this project was the assessment of a mobile battery's effectiveness for emergency backup power and tradeoffs as an alternative to diesel generators. The goal of the assessment was to determine the value proposition for using mobile batteries in alternative use cases and develop recommendations to SDG&E regarding commercial adoption.

2.0 Issues and Policies Addressed

A mobile storage unit can be used to address various issues and policies, including but not limited to:

Disadvantaged Community (DAC) Policy

The Clean Energy and Pollution Reduction Act of 2015 (known as Senate Bill 350 or SB 350) calls upon the CPUC to help air quality and economic conditions improve in communities identified as "disadvantaged."

Disadvantaged communities refer to the areas throughout California that mostly suffer from a combination of economic, health, and environmental issues such as poverty, high rate of unemployment, air and water pollution, presence of hazardous wastes, and high incidence of asthma and heart disease. State policy directs that EPIC funding prioritizes projects that benefit these disadvantaged communities.

Fire Safety and Public Safety Power Shutoffs (PSPS)

SDG&E is committed to operating its electrical system safely and is authorized to de-energize circuits as a last resort, when needed (such as fire safety events), to protect public safety. SDG&E stands up various community resource centers to assist the public and support customers affected by providing essential food, water, device charging, and outage updates. Currently, these CRCs are powered up through backup diesel generation and could attain benefits from a mobile battery solution.

3.0 Project Focus

The focus of this project was to demonstrate a pre-commercial MBESS capable of supporting the load at the CRCs for up to 72 hours, which is a typical duration for a public safety power shutoff (PSPS); however, power can remain shut off as long as the threat to the SDG&E system and public safety continues. CRCs are single-phase loads with peak loads ranging from 7-35 kW.

A single-phase, 150 kVA version of MBESS was selected for this demonstration. This MBESS was deployed at two CRCs to demonstrate the use cases and policies that can be addressed using this technology and clarify the value proposition for the selected use cases.

To support more inclusive investigation and verification, all essential data during system operation and demonstration were captured by the MBESS internal datalogger.

3.1 Description of MBESS

The selected MBESS for this demonstration, referred to as the MBESS, is designed for frequent relocation and fast interconnection at a new site, using a standard generator terminal box with Cam-Lok plugs.

The MBESS is a clean alternative for emergency diesel generators. Additionally, using a fully portable platform enhances the value proposition. It increases the utilization factor of the energy storage system by introducing flexibility in capturing the locational benefits of grid support or customer-specific applications.

The MBESS unit selected for the EPIC project is a single-phase system. It includes an onboard 150 kVA isolation transformer to provide a customer-specific connection for 120/240 V split-phase (3 wire). Figure 3-1 illustrates a simplified schematic of the MBESS for this project.

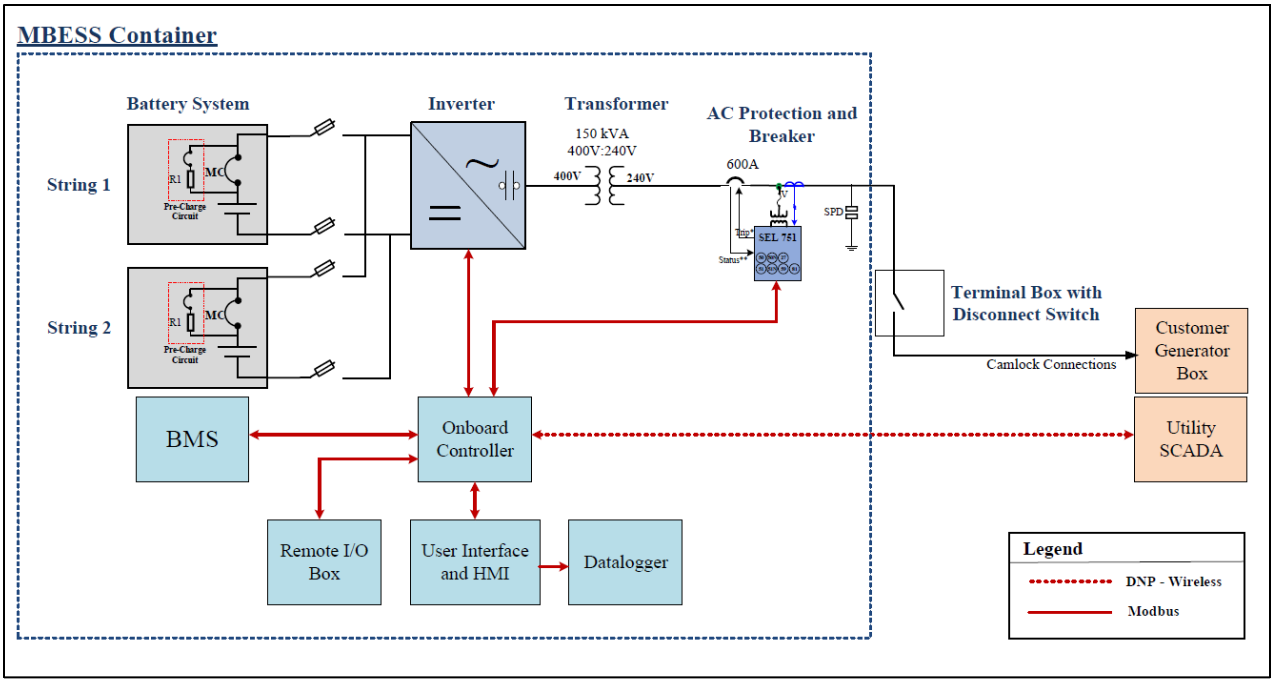

Figure 3-1. Simplified Schematic of MBESS. BMS is the battery management system.

Figure 3-2 presents a picture of the actual MBESS trailer used for this demonstraton.

Figure 3-2. MBESS Container used in the project

3.2 Controls and Applications

The MBESS selected for this demonstration is equipped with a microgrid integrated automation system using an onboard controller that provides a comprehensive set of autonomous controls, optimization schemes, and supervisory capacity for ease of local operation or remote operator access through integration into a utility dispatch center overall grid coordination. Figure 3-3 presents a picture of the home page of the Human Machine Interface (HMI) of the MBESS. Through the HMI, the user can monitor the measurements and control the system operations. Most day-to-day operational measurements can be found on the homepage. The HMI actions that can be taken include starting and stopping the system, adjusting the system setpoints, and changing operation modes.

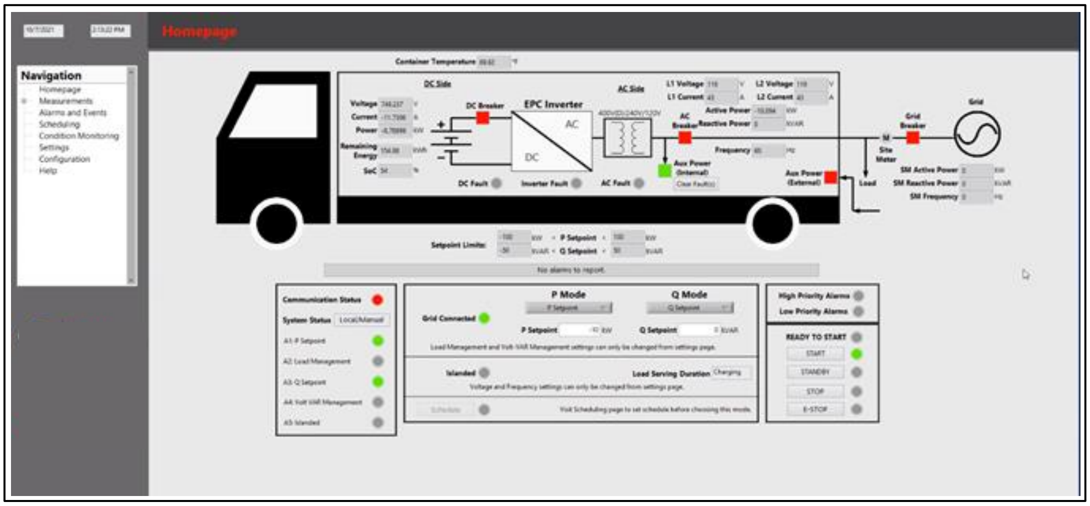

Figure 3-3. MBESS HMI Homepage

It should be noted that for traceability and safety purposes, all inputs provided by the user are logged and recorded in a local data logger; this includes sending commands, pressing buttons, changing setpoints, and switching HMI pages.

The MBESS provides two modes of operation: Grid-connected and Islanded operation.

The user can control how the system handles its P and Q outputs separately in the grid-connected mode. The Load Management mode for active power keeps the power flow within a pre-defined range by the user, and the Volt-VAR mode follows a droop curve provided in the Settings page while providing voltage and reactive power support to the grid. Additionally, the pre-commercial MBESS used in this project is also capable of Islanded operation supplying customer loads off-the-grid and isolated.

MBSS has two control modes: Local and Remote. The local control has Manual and HMI (automatic) mode, and both are performed at the site. A tablet is used for accessing the HMI by the user at the site. For manual control, a selector switch and start/stop pushbuttons are incorporated on the front panel of the terminal box. In remote control, the user or operator can access the HMI screen through a virtual private network (VPN), or the commands can be sent to the MBESS from a Distributed network protocol (DNP) communication route implemented for the remote interface, such as supervisory control and data acquisition (SCADA) access for a dispatch operator.

Both grid-connected and islanded modes rely on communications with certain hardware inside the MBESS container, managed through its internal controller. If communications with devices fail, the system will stop operating and refuse any restart attempt. Pressing the red/green circle next to the "Communication Status" label on the homepage will open a page showing the status of all relevant communication channels in the network, which can be used to find out if a device has stopped operating.

The user can navigate the Settings or Configuration pages to change more specialized operational parameters. Detailed measurements can be found on the Measurements page, where the measurements and graphs are divided based on their sources and types.

Certain alarms are defined by the system, which are grouped based on their severities from high to low. It should be noted that all alarms must be acknowledged by the user and remain in the device's history for future traceability.

4.0 Project Scope Summary

The scope of work for the EPIC project included delivering a fully functioning portable MBESS for single-phase supply of customer load and performing Site Acceptance Testing (SAT) at SDG&E's Integrated Testing Facility (ITF) before deploying to the field for two site demonstrations. The scope also covered associated services and support to facilitate pre-commercial demonstrations at two different CRCs, collecting demonstration tests data, engineering analysis, and reporting.

4.1 High-level overview

The project scope includes the following major tasks:

Task 1: MBESS Delivery

This task covered delivering a pre-commercial portable energy storage system to test and demonstrate a series of use cases for grid support and outage management during forced or maintenance power shutdown affecting customers in remote areas of SDG&E service territory. This task also included the factory acceptance testing (FAT) at Quanta Technology's Sustainability Testing Integration Laboratory before transporting the MBESS to the SDG&E site and transporting the MBESS to the SDG&E ITF at Escondido.

Multiple stakeholders' meetings and workshops were held with the SDG&E team during the execution of this task to finalize the design of MBESS and perform baseline analysis of the benefit areas identified for this EPIC project.

Task 2: Installation Services

During this task, the SDG&E/Quanta Technology team prepared the site installation and interconnection of MBESS at ITF and both CRC sites for demonstration stages.

As part of this work, a set of interconnection single-line diagrams (SLDs) and installation drawings were developed to facilitate the installation at each site.

It should be noted that the MBESS is designed to have a plug-and-play concept by using cables with Cam-Lok connectors to streamline the connection and disconnection of MBESS to existing generator boxes at different sites. In addition, MBESS is equipped with inter-tie protection, circuit breakers, and a visible manual disconnect switch, required by the SDG&E interconnection standard at POI for connecting MBESS as a distributed energy resource (DER) to distribution systems.

Task 3: Site Acceptance Testing (procedure and testing)

Upon delivering the device to ITF, the team tested various device operation modes. It verified the operation of MBESS before relocating the MBESS to customer sites for the use case demonstration.

Task 4: Relocation Services

As part of this task, the project team supported the de-energization and relocation of MBESS between different sites.

Task 5: Demonstration Support

Quanta Technology and SDG&E performed use case demonstrations at two different CRC sites. This task included the demonstration efforts and the data collection at each site.

Task 6: Data Analysis Support

Upon completing the demonstrations, the team focused on organizing and analyzing the data collected from each site. This task included the following efforts:

- Assimilation of test results
- Analysis of demonstration results

Task 7: Engineering Support

In this task, the team performed a set of studies based on demonstration results to assess the value proposition of key applications for prospective commercial adoption of MBESS.

Task 8: Reporting and Documentation

This task covered all logistics related to the reporting aspects of the project, including a comprehensive final report, meetings, monthly technical and progress reports, and project management.

5.0 Project Approach

Various benefits are associated with utilizing MBESS across the utility service territory. However, the applications may vary depending on the characteristics of sites where the device is deployed and the use case(s) specific to a customer. Hence, the initial task in the project execution plan covered the investigation and identification of the potential key use cases and customer sites that can demonstrate various value streams associated with the MBESS.

In addition, appropriate performance metrics were defined to evaluate the success/ failure of each use case and the overall benefits from deploying MBESS.

Once the use cases, sites, and performance evaluation metrics were determined, the team performed a detailed baseline analysis to be further evaluated and adjusted based on results from site demonstrations. Comparing the data gathered from a real-world demonstration of the use case with baseline analysis result, the team was able to quantify the benefits and prove the value-added of MBESS.

This section of the report presents a list of selected use cases for the MBESS, followed by a list of selected metrics for the device operation and results from the baseline studies of the benefits associated with MBESS in the context of each use case. Additionally, this section of the report also provides information regarding the pre-commercial demonstration at two selected CRCs and the process for data acquisition and analysis from the field.

5.1 Use Cases

Table 5-1 presents a brief overview of the target use cases for a single-phase MBESS considered in this project. Additionally, this table provides a list of initial assumptions associated with each use case for performing baseline analysis of different benefits associated with the MBESS technology.

Table 5-1 Single-Phase MBESS Use Cases with Their Descriptions

#	Use Case	Description
1	Planned outage management for PSPS support	Public Safety Power Shutoff program
2	Unplanned outage management	An unexpected loss of the utility source
3	Maintenance outage management	System upgrades related outages, scheduled in advance, such as service transformer upgrade, cable replacement, pole replacements

Regarding energy capacity, a typical PSPS duration lasts 72 hours, and the customers are alerted as far in advance as 10 days and as short as 48 hours before a scheduled event. In the worst-case scenario, they will be announced at least 1 hour in advance. This time duration is enough for the MBESS to be transported and connected to supply the critical customer loads as a clean alternative for mobile diesel generators.

Additionally, the mobility aspect of the MBESS provides a unique opportunity for the utility for stacking of use cases based on the time of year and at different locations within the service territory. Below is a sample of a seasonal stacking of use cases for the MBESS:

- **Fall/winter months:** Planned outage management for PSPS events. It should be noted that most PSPS outages happen during these months.
- **Summer:** Load and unplanned outage management.
- **Spring:** Maintenance outage management.

5.2 Baseline Studies/Fact-Finding

Benefits associated with the MBESS can be categorized into six groups (presented in **Figure 5-1**.

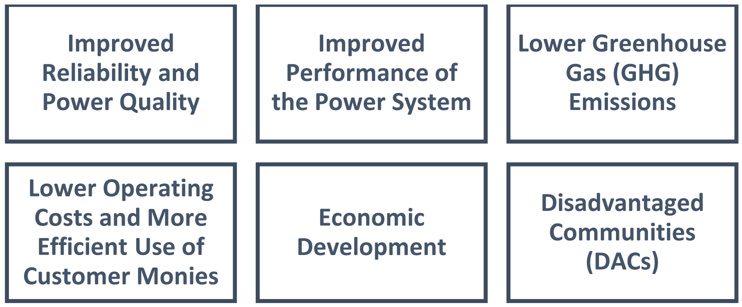

Figure 5-1. Initial Benefit Areas of MBESS

The above benefits can also be associated with a stationary battery energy storage system. However, utilizing a mobile battery solution provides the capability to the operator to deploy the system at various sites throughout the year to maximize the benefits.

5.2.1 Benefit Areas Associated with MBESS

Safety

The solution utilized for the project complies with required safety codes for energy storage systems and using mobile solutions on the road. Some criteria which were well-thought-out in the demo assessment are ease of transportation using heavy-duty trucks and vehicles commonly used by utility fleets, fire safety, utility interconnection, electrical safety, and some local permitting requirements. Below is a list of key safety and fire prevention features associated with MBESS design:

- Visual and audible fire alarms
- Physical emergency stop (E-stop) that de-energizes the entire system
- Full separation of DC system (battery cells and components) and AC system (inverter and switchgear)
- Ungrounded DC and AC with the use of an isolation transformer
- Equipped with a state-of-the-art battery management system (BMS), with UL1973 certification.
- One of the safest battery chemistries in the industry is based on lithium iron phosphate ($LiFePO_4$), or LFP for short.
- Total kWh energy per battery enclosure is well below 50 kWh recommended by NFPA 855
- STAT-X spot smoke detector and arc-triggered fire-suppression system
- Capable of condition monitoring and preventative (predictive) asset evaluation with use of real-time measurement at the component level (cells and inverter) and data analytics

One vital point is that the designated safety approaches in this project require the team to investigate and report any safety incidents when installing, operating, or transporting MBESS. Additionally, customers and utility personnel are provided with adequate training to ensure the safe procedure of the MBESS deployment. All these constraints assure the safety aspects of the projects in all operation times and stages.

However, these requirements apply to any generation resources that will be used at customer sites, and as a result, MBESS is not providing any specific added benefit in this area. To this end, the project focused on evaluating the additional benefits associated with MBESS in the other categories presented in Figure 5-1 while, same as any other generation resources. It complied with all the applicable codes and standards for safety.

Appendix A lists safety and operational standards that the MBESS selected for this module complies with.

Improved Reliability and Power Quality

The MBESS provides excellent opportunities for localized reliability enhancement by preventing planned and unplanned outages and providing alternative solutions for customers requiring emergency supplies. In addition, the MBESS can be used to improve power quality issues at sites with known problems such as over/under voltages, flicker, and/or excessive reverse flow.

Reduce Greenhouse Gas (GHG) Emissions

The GHG emission reduction is a key benefit associated with MBESS because this device can replace diesel generators as a clean and quiet sustainable solution.

In addition, the energy storage system can reduce the need for electric generation by reducing the losses across the system, storing energy from renewable sources during off-peak hours, and offsetting consumption during periods where higher-emission sources would be required.

Lower Operating Costs and More Efficient Use of Customer Monies

Energy storage systems can flatten the profile and reduce peak load durations. This will shift utility-delivered consumption to lower-cost periods, which in turn reduces the operating costs for the customers

Additionally, utilizing energy storage systems can defer or eliminate certain utility infrastructure investments and ultimately mitigate potential rate increases.

Economic Development

A sustainable and clean source of low-cost, high-quality, and reliable electric power is essential to economic development in California. The potential energy and cost savings from avoided procurement and generation costs, peak load reduction, and customer bill savings can also contribute to economic development within the state.

Disadvantaged Communities (DACs)

Replacing diesel generators in disadvantaged communities with a clean system, such as the MBESS, can significantly reduce GHG emissions and benefit these communities.

5.2.2 Initial Selection of Metrics

This report section presents a list of selected metrics used throughout the project to evaluate the system's successful operation. These parameters are either generic or use case-specific.

Table 5-2. Selected Metrics for MBESS Benefit Analysis

Metrics	Definition	Unit
Change of State of Charge (ΔSOC)	The degree to which the battery SOC has been changed compared to the SOC at the beginning of the test.	%
Minimum/maximum effective SOC	The minimum/maximum SOC that the MBESS can reach without derating the output power (reducing discharge rate).	%
Available full charge capacity	Total energy charged (kWh) from minimum to maximum SOC.	kWh
Available full discharge capacity	Total energy charged (kWh) from maximum to minimum SOC.	kWh
Actual energy	Present value of the energy capacity of the MBESS. Actual energy capacity is also called "remaining energy capacity."	kWh
Cumulative charge (total)	The real energy is absorbed from the grid by MBESS during the device's lifetime.	MWh
Cumulative discharge (total)	The real energy is injected into the grid by MBESS during the device's lifetime.	MWh
Throughput (daily, monthly, annually)	The cumulative battery discharge and charge amount during a specific duration (kWh).	kWh
MBESS availability	Percentage of the time that the MBESS can respond to a signal and perform any target application (excluding the scheduled maintenance time).	%
Response time	The total time the MBESS system needs to reach the state where the power at Point of Interconnection comes to (and stays) within a certain accuracy band of the target value (for example, within 2%) after an internal or external trigger (such as a setpoint command or a grid event).	ms
Cost of outages	Costs associated with unserved business and missed opportunity for economic gain.	$/kWh
SDG&E Service Territory Emissions Factor	The amount of CO_2 emissions per MWh generated energy within SDG&E service territory.	$MTCO_2e$ /MWh
$MTCO_2e$/MWh	The amount of CO_2 emissions per MWh generated energy by diesel generators.	$MTCO_2e$ /MWh
The upfront cost for MBESS	The total initial cost for employing the MBESS in a system includes transportation, maintenance, etc.	$

Throughout the operation of the MBESS, key parameters of the system were monitored, measured, and recorded by the internal datalogger of the MBESS. **Table 5-3** presents the list of logged data, the designated data category (e.g., measurement, status, alarms), and the devices providing the information (source).

Table 5-3. Required Monitoring Data for MBESS

Data Source	Data Category	Register List
Battery Management System	Measurements/Status	Cell level voltage
		Cell level temperature
		String level current
		String level SOC
		Remaining capacity
		Battery Health
	Alarms	Overvoltage
		Undervoltage
		Over-temperature
Power Conversion System (PCS)	Measurements/Status	AC voltage
		AC current
		Operation mode
		Inverter health
	Alarms	Over-voltage
		Over/under frequency
		Loss of main voltage
		Communications failure
		Inverter failure
Onboard Controller	Measurements/Status	Temperature
		Humidity
		Smoke detector status
		Gas detector status
		HVAC status
	Alarms	Over-temperature
		Under-temperature
		Smoke detection
		Gas detection
		HVAC failure
	Data Analytics	SOC
		Remaining capacity

Data Source	Data Category	Register List
		Cumulative charge
		Cumulative discharge
		Full and partial cycle charges
		Container health

5.2.3 Initial Benefit Estimate and Value Proposition

One of the key objectives of the MBESS demonstration was to determine its value proposition and quantify its benefits. This information will support making investment decisions relative to the prospective commercial adoption of MBESS.

In this regard, a comprehensive cost-benefit analysis was carried out to reveal the significance of employing the MBESS for primarily PSPS outage management use cases and other use cases identified in Section 5.1. Throughout this project, five major steps were taken to evaluate the benefits associated with the MBESS as follows:

1. Developing a list of viable use cases for single-phase MBESS.
2. Establishing a baseline for MBESS utilization and benefit calculation method based on the stacking of multiple use cases.
3. Calculating the benefits and cost of the MBESS for baseline to determine benefit-cost ratio (BCR) and investment rate of return (IRR), the results associated with this step are presented in this section.
4. Performing demonstration of use cases at pre-selected sites to gather real field data associated with each use case.
5. Projecting the data from the demonstration to annual operation over the effective life of the MBESS to verify the baseline with new BCR and IRR. The results associated with this step are presented in Section 6.2.

Assumptions and Approach

The following key assumptions are considered for baseline analysis:

- The MBESS is connected Behind-the-Meter (BTM) and can be operated parallel with the grid for certain use cases.
- The nameplate rating of a unit used for the estimate is 100 kW, 1000 kWhac (End of Life (EOL)), 120/240V, single-phase.
- The effective life is 10 years, based on 150 full cycle charges per year, or 150 MWh throughput.
- The typical PSPS duration is 72 hours, and customers are notified (maximum 10 days and minimum 1 hour in advance), giving enough time to roll out an MBESS to a critical customer site [1].
- The MBESS is utilized for use cased identified in Section 5.1.

Additional assumptions were made regarding the MBESS unit utilization throughout the year. Figure 5-2 demonstrates a high-level overview of seasonal stacking of use cases. This has been assumed based on the following:

- Most PSPS events occur during peak season in the fall/winter months.
- Peak load occurs in the summer months, while there is also the chance of unplanned outages.
- The maintenance program is scheduled for low-activity seasons.

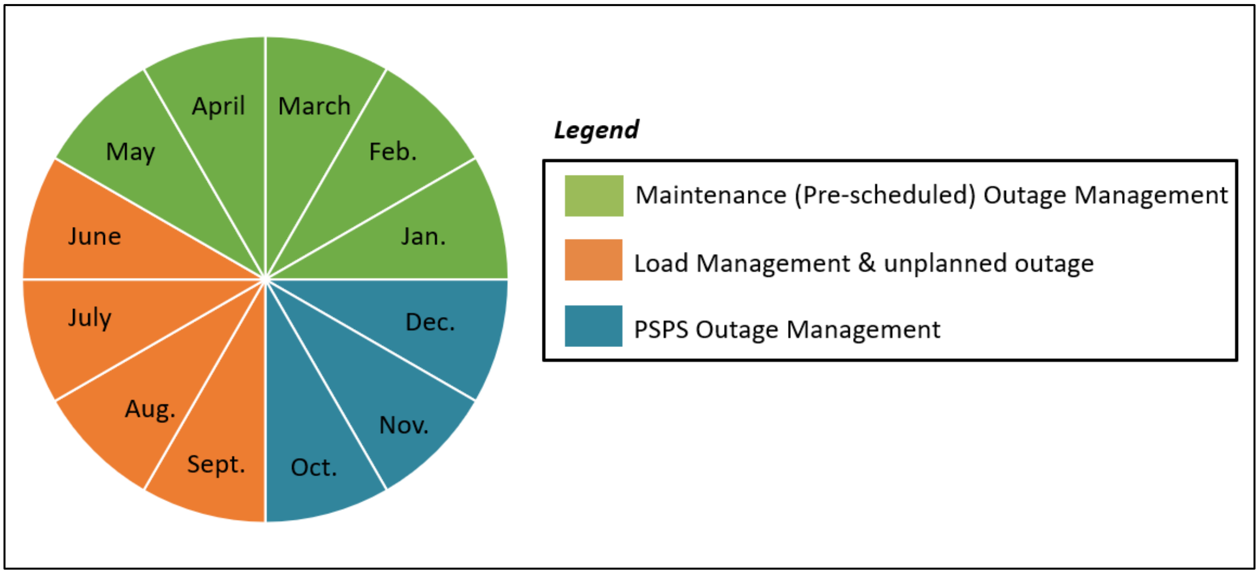

Figure 5-2. High-Level Overview of MBESS Utilization

Based on the general utilization described, assumptions were made regarding the number/duration of outages and the load profile during different seasons. The table provides a summary of these assumptions.

Table 5-4. Summary of Use Case Assumptions

#	Use Case	Assumption
1	Planned outage management for PSPS support	The fall season, 3 outage events, up to 72 hours
2	Unplanned outage management	3 outage events, maximum 4 hours each
3	Maintenance outage management	Avoiding 4 hours of outage associated with a maintenance program for up to 8 customers per 50 kVA service transformer; up to 2 maintenance events are scheduled per day; 4 days per week, 20 weeks per season

#	Use Case	Assumption
4	Load management (at a customer location or a service center)	Charge in super off-peak time (12 AM to 6 AM), discharge in peak time
5	Voltage management for feeder ends	Assumed soft benefit for the system during low activity seasons

Finally, assumptions were made regarding the CO_2 emissions content associated with SDG&E service territory and diesel generator as well as the cost of an outage based on the noted references:

Table 5-5. Assumptions on Carbon Emission and Cost of Outage. $MTCO_2e$ is metric tons of carbon dioxide emissions.

Parameter	Value
SDG&E Service Territory Emissions Factor ($MTCO_2e$/MWh) [2]	0.1362
Diesel Generator ($MTCO_2e$/MWh) [2]	0.4176
Cost of Outage ($/kWh) [4]	9

The following sections describe the procedure for estimating initial benefits in each benefit area identified in Section 5.2.1.

Improved Reliability and Power Quality

Utilizing the MBESS provides an opportunity for preventing planned and unplanned outages and increasing localized reliability and power quality. To quantify these benefits, the following approach was proposed and followed for initial baseline analysis and updated baseline analysis after demonstration:

1. Tracked number of hours and percentage of time that mobile battery was connected and available to provide backup power.
2. Tracked number of outages supported, duration of these outages, the amount of backup power provided, and the duration of any charging activities.
3. Assessed whether the mobile battery adequately supported a site during the entire emergency event.

Table 5-6 lists the desired targets for baseline based on the defined metrics and the projected annual savings associated with this area based on the initial assumptions. It should be noted that during the demonstration of the project, the assumptions were updated based on the actual information considering both CRCs.

Table 5-6 Desired Targets Based on Defined Metrics for Improving Reliability and Power Quality

Metric	Target
Avoided number of PSPS outages	3 (216 hours)
Avoided number of unplanned outages	3 (12 hours)
Avoided number of maintenance outages	160 (5120 hours)
Avoided customer outage duration	5348 hours
Load served during the outage	35,762 kWh
MBESS availability	98%
Cost of outages	$9.00/kWh
Annual savings from outage mitigation	**$321,858**

For evaluation of benefits in reliability/power quality improvement:

- The technical capability of the MBESS to successfully supply the load during an outage is captured through metrics such as availability percentage and several avoided outages and kWh load served.
- The financial revenue generated associated with avoided outage costs is captured.

As summarized in **Table 5-6**, assuming $9.00/kWh cost of the outage and a total of 35,762 kWh load-serving during the outage, the baseline analysis estimates approximately $322k in annual savings from outage mitigation.

Reduce Greenhouse Gas Emissions

One of the key benefits of the MBESS is to provide a clean alternative for diesel generators. Noticeably, lessening the role of diesel generators will reduce greenhouse gas emissions. To evaluate the benefits associated with reduced GHG emissions, the following steps were taken during the baseline and demonstration phases of this EPIC project:

1. Captured and tracked the evaluation metrics, including:
    a. The number/duration of outages
    b. The amount of backup power provided
    c. The duration/amount of battery charging activities and associated electricity charges
2. Estimated the GHG emissions resulting from battery charging operations using the latest annual emission intensity factor for SDG&E.
3. Estimated the equivalent emissions of GHG and other air pollutants resulting from a diesel generator alternative.

Table 5-7. summarizes the baseline target values for CO_2 reduction based on the defined evaluation metrics.

Table 5-7. CO_2 Reductions Considering System Loading

Metric	Target
Total kWh (stacked application)	35,762
Total duration	5,348 hours
Total kWh (stacked application), excluding maintenance	3,762
Total duration	228 hours
CO_2 reduction in PSPS	0.890 $MTCO_2e$
CO_2 Reduction in an unplanned outage	0.168 $MTCO_2e$
CO_2 Reduction in the maintenance	13.365 $MTCO_2e$
Total CO_2 reduction ($MTCO_2e$)	**14.423**

The MBESS operation leads to a total CO_2 reduction of 31772.44 lbs. per annum based on initial analysis.

Lower Operating Costs and More Efficient Use of Customer Monies

Another key area of investigation while considering new technology is evaluating its financial feasibility specifically compared to other alternatives. In this initial analysis, the costs/savings associated with both MBESS technology and an alternative diesel generator is estimated to assess the financial business case:

1. Tracked the costs associated with a mobile battery and the appropriate diesel generator alternative, including up-front equipment costs, lease or rental costs, up-front setup and administrative costs, transportation costs, fuel costs, and other operations and maintenance costs.
2. Performed financial analysis for the business case that compares the battery and diesel solutions and estimated key financial performance metrics such as return on investment, internal rate of return, and complete life cycle costs.

Table 5-8. summarizes the results of initial analysis and metrics associated with overall upfront costs, operating costs, total savings as well as IRR percentage for both technologies. The IRR for both investments is close which implies that the MBESS is a compatible option from financial perspective, although it is a recent innovation of technology, if it is utilized efficiently for use cases defined earlier. It should be noted also that in this analysis soft benefits of environmental impact (e.g., emission/noise reduction), societal impacts and others are excluded.

Table 5-8. Desired Targets Based on Defined Metrics for Lowering the Operating Costs

Metric	Target
The upfront cost for MBESS	$750k
Annual operating cost for MBESS	$95.50k
Annual savings for all use cases	$346.10k
Upfront cost for diesel	$30k
Annual operating cost for diesel	$4.20k

Metric	Target
IRR for MBESS	33%
IRR for diesel	35%

It should be noted that the IRR calculation for MBESS is developed based on use cases described previously. It has been calculated for a 10-year project lifetime. The total saving estimated for all use cases is $346,113.00 (savings from outage management PSPS, maintenance, and unplanned scenario is $321,858.00 plus the saving in the load management, which is $24,255.00). Considering the saving and the total cost, the benefit to cost ratio has a value of approximately 2.03 which states that the benefit is more than twice all the costs associated with the MBESS. **Table 5-9** summarizes parameters associated with a cost-benefit analysis for the MBESS.

Table 5-9. Benefit to Cost Evaluation for Deploying the MBESS

Parameter	Value
System rating	100 kW
72-hour load	1054 kWh
Load serving duration	72
Project lifetime	10 years
Capital cost	$750,000.00
Total utilization	40262 kWh
Operation cost per kWh	$2
Operation cost per kW	$150
Annual capital cost	$75,000.00
Annual operation cost (variable)	$80,524.00
Annual operation cost (fixed)	$15,000.00
Annual savings	$346,113.00
Benefit to cost ratio	**2.03**

Economic Development

This benefit area considers MBESS's impacts on minimizing power outages and increasing economic attractiveness for the businesses. The approach for quantifying benefits in this area is as follows:

1. Performed a survey of affected businesses/communities to assess the project's impact on affected communities and their local businesses.
2. Determined the population within a 1-mile radius of the CRC to evaluate the expected number of people that would have access to the CRC during an outage.
3. Determined number and type of businesses within one block around the CRC that would be visited by people coming to CRC.

Table 5-10 summarizes the metrics captured for baseline. For estimating the business gain associated with serving the population during outages, $590.08 is assumed as the cost of outage for a small commercial and industrial (C&I) customer. The overall business gain and economic improvement estimated is at 17,702.4 USD.

Table 5-10. Desired Targets Based on Defined Metrics for Reducing Greenhouse Gas Emissions

Metric	Target
Number and duration of outage events	228 hours
The average population within 1 mile	105
Number of businesses within 1-block of CRC (direct benefit)	5
Estimate for business gain	**$17,702.4**

Disadvantaged Communities (DACs)

One of the potential benefit areas identified early in the project was serving disadvantaged communities and supplying them utilizing the MBESS during outages. The MBESS can be operated within disadvantaged communities, achieve GHG benefits that support state goals, and reduce emissions from sources located within these communities.

The following approach was proposed for quantifying the benefits:

1. Tracking the number of operating hours and percentage of operating hours that the mobile battery operates within a disadvantaged community.
2. Tracking the total project investment amount and the prorated investment amount associated with operations within the disadvantaged community.
3. Calculating the total GHG emissions impact of the project and the prorated GHG impact associated with operations within the disadvantaged community.
4. Calculating any GHG emission impact from sources located within the disadvantaged community.

Table 5-11 Table summarizes the proposed metrics to perform the initial baseline analysis. However, the initial target values could not be established due to a disadvantaged community's lack of operating the MBESS under this module. It is noteworthy to mention that none of the CRCs within SDG&E territory are currently located in a DAC. The associated benefits of utilizing MBESS within DACs would benefit from further investigations by the industry.

Table 5-11. Metrics Table for Capturing DAC Advantages

Metric	Target
Outage duration for a DAC CRC	Opportunities will be investigated

Metric	Target
Capital investment for DAC CRC specific to this project	Opportunities will be investigated
Investment for operation cost	Opportunities will be investigated
Avoided cost of using diesel genset	Opportunities will be investigated
Avoided GHG emission by not using diesel genset	Opportunities will be investigated

Incremental Benefits of a Mobile Solution

This project aims to achieve incremental benefits over the diesel generator alternatives. The incremental benefits are compared with incremental costs to determine a return on investment for the MBESS solution. The metrics associated with incremental benefits of the MBESS consider financial evaluation of benefits the MBESS provides beyond what a mobile diesel generator can offer. The use cases that the MBESS can perform beyond a mobile diesel generator are load management and maintenance outage management. It has been assumed that the MBESS is only utilized for incremental use cases to calculate the operating costs and savings. The following approach establishes metrics:

1. Tracked the incremental benefits achieved with the mobile battery over the appropriate diesel generator alternative.
2. Tracked the costs associated with a mobile battery and the appropriate diesel generator alternative.
3. Evaluated an incremental return on investment (ROI) by considering incremental benefits and incremental costs.

The evaluation metrics and target values are summarized in **Table 5-12.** Based on the incremental ROI calculated (30%), MBESS provides considerably high benefits beyond the mobile diesel generator.

Table 5-12. Desired Targets Based on Defined Metrics for Incremental Benefits of A Mobile Solution

Metric	Target
Incremental benefits of MBESS (annual)	$312,255
Incremental costs of MBESS (annual)	$84,250
Interest rate	6.5%
Incremental ROI	**30%**

5.3 Description of Pre-Commercial Demonstration

A pre-commercial demonstration of the MBESS was performed at two separate CRC sites, i.e., Dulzura and Pine Valley. The primary use case for both demonstrations was outage management. The following subsections provide more details regarding the demonstration at each site.

5.3.1 Location

CRC 1: Dulzura CRC

Address: 1136 Community Building Road, Dulzura, CA 91917

Figure 5-3 shows a photo of the MBESS at this site during the first demonstration. **Figure 5-4** shows the connection of the MBESS to the CRC through the permanent connection box located at the side of the building. Additionally, as can be seen from this picture, during the demonstration period, an independent Drantez meter was used to verify the data reported by MBESS.

Figure 5-3. Picture of the MBESS in Front of the Dulzura CRC for Demonstration 1

Figure 5-4. MBESS Connected to the Permanent Connection Box at Dulzura CRC

CRC 2: Pine Valley CRC

Address: 28890 Old Highway 80, Pine Valley, CA 91962

Figure 5-5 shows a photo of the MBESS at this site during the second demonstration, while **Figure 5-6** presents the connection of the MBESS to the CRC through the permanent connection box located at the side of the building.

Figure 5-5. Picture of the MBESS in Front of the Pine Valley CRC for Demonstration 2

Figure 5-6. MBESS Connected to the Permanent Connection Box at Pine Valley CRC

5.3.2 Use Case Demonstration

During this EPIC project, the outage management use cases were demonstrated at both CRCs, and relevant data was captured.

5.3.3 Equipment Requirements

In addition to the MBESS system itself, the following equipment requirements for demonstration of this EPIC project at each CRC were:

- **Permanent connection box:** this is required on the utility/customer side to establish an interconnection point to the MBESS at the CRC building for each site.
- **Cam-Lok cables:** A set of 400 A Cam-Lok cables were needed for connecting MBESS to the CRC permanent connection box. It should be noted that proper Cam-Lok cables are located inside MBESS to accelerate the interconnection process.
- **Auxiliary cables:** A set of auxiliary cables to connect to the 120/240V auxiliary input. These cables are also located inside the MBESS terminal box. Please note that during the demonstration portion of this project, at CRC 1, the device utilized internal auxiliary power. In contrast, the auxiliary power required for the operation of the MBESS at CRC 2 was directly supplied from the grid using the terminal box available at the site.

It should be noted that there have been minimal equipment requirements for interconnection of the MBESS to utility/customer facility considering the fully integrated design of MBESS.

5.3.4 Software Requirements

A robust onboard monitoring and control platform is implemented in the MBESS, which has all the required software associated with the operation and monitoring of the unit. There is no additional software required on the utility/customer side.

5.3.5 Supporting SDG&E Infrastructure and Data Requirements

Based on the defined use cases for the MBESS, the following infrastructure and data requirements from SDG&E were proposed originally:

- SCADA integration to the MBESS through Cybersecure access point accommodated in the MBESS
- POI breaker status information (to be utilized for detection of operation mode in automatic as grid-connected or islanded)
- POI power flow information (active and reactive power) for load management application

It was decided to perform all controls locally and avoid the SCADA integration part for demonstration purposes. Thus, remote control, which should be performed through SCADA, was not tested and verified. As part of the demonstration, no communication infrastructure and data were required from the SDG&E side.

5.3.6 Factory Acceptance Testing

Factory Acceptance Test of the MBESS was performed at Quanta Technology's testing laboratory before transporting the unit to SDG&E. The focus of FAT was on functional verification and type test of MBESS (capacity test, efficiency test, and response time). **Table 5-13** summarizes the test categories performed during the FAT and the overall pass/failure based on expectations on MBESS performance on each test category. The first category of tests (inspection and energization) evaluates individual components of the unit by inspecting the overall system verifying the health of the components, and then proceeding with the preparation of the system and energization. The application testing validates control and monitoring features of the MBESS for different modes of operation and applications. The anti-islanding test verifies the inverter anti-islanding performance in disconnecting from the grid upon detection of an outage.

Table 5-13. FAT Test Categories and Scenarios

Category	Test Case	Pass/Fail	Date
Inspection and Energization	Setup Overview	☒/☐	09/24/2021
	Setup Walkthrough	☒/☐	09/24/2021
	HMI Operation Review	☒/☐	09/24/2021
	Container Energization	☒/☐	09/24/2021
Local/Manual Mode	Grid-Connected Mode (GCM): P/Q Setpoint	☒/☐	09/24/2021
	Grid-Connected Mode: Load Management	☒/☐	09/24/2021
	Grid-Connected Mode: Volt-VAR Management	☒/☐	09/24/2021

Category	Test Case	Pass/Fail	Date
	Islanded (SAM)	☒/☐	09/24/2021
Anti-Islanding test		☒/☐	09/24/2021

5.3.7 Test System Design

For accurate simulation of the setup at CRCs, a manual transfer switch (MTS) was considered part of the test setup for switching between the generation sources at CRC (i.e., grid connection and MBESS). Two setups were considered to perform all applications, including load management during grid-connected. **Figure 5-7** represents the first setup where the load bank was connected to the MBESS, and the automatic transfer switch (ATS) was switched to Position 1 for performing all grid-connected tests, including:

- HMI operation review
- Container energization
- Grid-connected Mode: P/Q setpoint
- Grid-connected Mode: Load management
- Grid-connected Mode: Volt-VAR management
- Anti-islanding test

The MBESS was then reconnected to input 2 MTS to simulate the system configuration for islanded applications, shown in **Figure 5-8**.

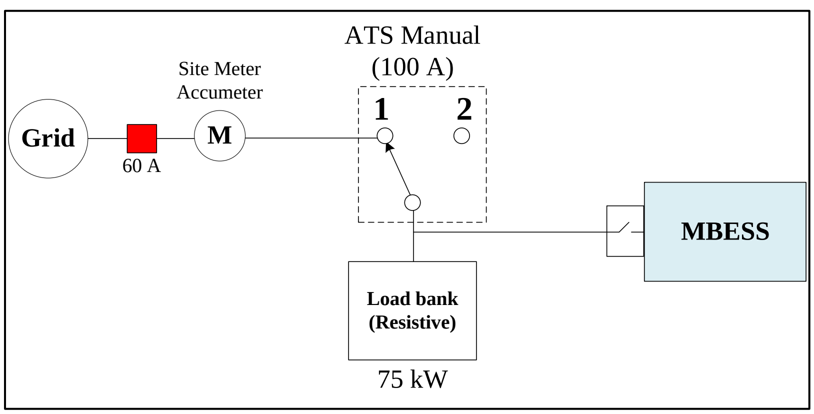

Figure 5-7. FAT Setup 1

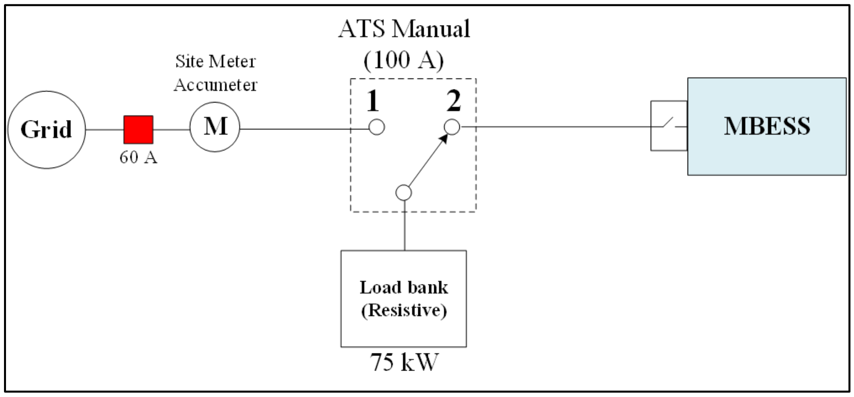

Figure 5-8. FAT Setup 2

5.3.8 Site Acceptance Testing

Site Acceptance Testing of the MBESS was performed in SDG&E Integrated Test Facility at 650 Alpine Way, Escondido, CA 92069. **Figure 5-9** shows a photo of the SAT at the ITF.

Figure 5-9. Photo of the MBESS at ITF during the SAT

During the SAT, a pair of setups were used. The first was for low power grid-connected charge and discharge test, and the second was for high power charge and discharge using a diesel generator and larger load bank. The low and high-power test setups used during the SAT are presented in **Figure 5-10** and **Figure 5-11**, respectively.

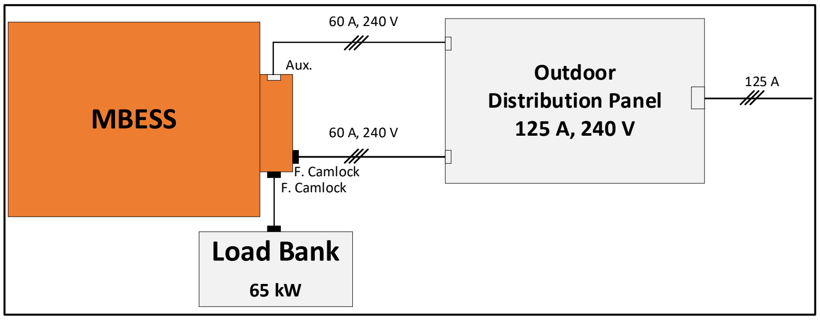

Figure 5-10. Low Power/Current Test Setup Used during SAT

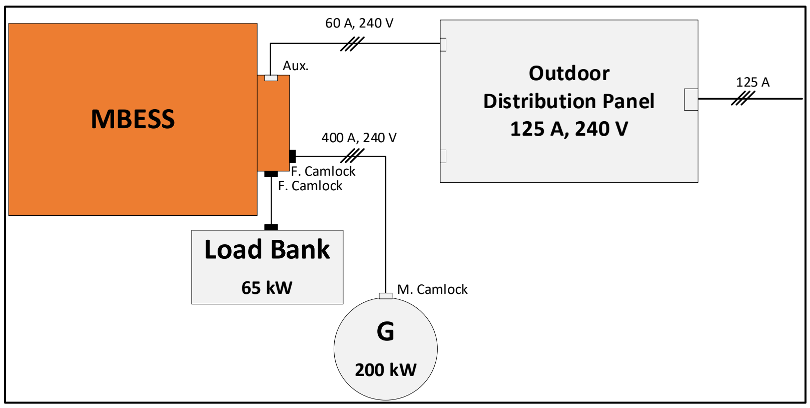

Figure 5-11. High Power/Current Test Setup Used during SAT

Table 5-14 presents a list of performed tests and the results during the SAT of the MBESS at the ITF.

Table 5-14. Test Result List and Summary from SAT of the MBESS at the ITF

SR. No.	Test	Expected Results	Pass/Fail	Date
1	Emergency Stop (E-Stop)	E-Stop operates as intended, and the real power charge drops to 0 kW.	☒/☐	10/15/2021
2	Island Mode—Blackstart Enabled	PCS runs Blackstart to be enabled. The system runs in Island Mode. Adjust setpoints Island remains stable.	☒/☐	10/15/2021
3	Parallel Mode—Four Quadrant Test	Verify MBESS reacts in all quadrants to specified numbers in Table 7.	☒/☐	10/15/2021
4	Anti-Islanding Mode—Charge	The system will not island, and PCS will disconnect per IEEE 1547.	☒/☐	10/15/2021
5	Anti-Islanding Mode—Discharge	The system will not island, and PCS will disconnect per IEEE 1547.	☒/☐	10/15/2021

SR. No.	Test	Expected Results	Pass/Fail	Date
6	Uninterruptible Power Supply (UPS)	UPS operates as intended after the loss of power.	☒/☐	10/15/2021
7	Human Machine Interface Login and Command Operation	Successful customer login and command operation.	☒/☐	10/15/2021
8	Roundtrip—Full Discharge	MBESS discharges to 65%.	☒/☐	10/15/2021
9	Roundtrip—Full Charge	MBESS charges 90%.	☒/☐	10/20/2021

5.3.9 Test System Integration

The MBESS selected for this demonstration is designed for frequent relocation and fast interconnection at a new site, using a standard generator terminal box with Cam-Lok plugs. The interconnection aspects at the destination sites are minimal due to the fully integrated design of MBESS:

- Onboard isolation transformer
- Onboard protection device
- Generator terminal box with Cam-Lok connection points
- On-board Cam-Lok and auxiliary cables for connection
- On-board UPS for auxiliary supply during external power disconnection
- Onboard control and monitoring platform with remote access capability

Upon delivery of the MBESS to a new site, the only steps to follow for integration and energization include:

- Complete the inspection checklist for post-delivery, verifying the system has not been damaged in transportation and is ready to be energized
- Connect auxiliary supply feed (if available)
- Connect the MBESS to the permanent connection box using Cam-Lok cables
- Verify the cables are connected safely, energize the MBESS

5.3.10 Execution of Demonstrations

One of the key MBESS technology features, which needs to be evaluated and verified, is its mobility, meaning the MBESS should be relocated from one site to another safely and redeployed quickly at the new site. To evaluate the mobility aspect, the demonstration included the operation of the MBESS at two CRCs within SDG&E's territory. **Figure 5-12** presents a map of the road taken for the transportation of the unit. It shows that the unit was transported safely for approximately 150 miles on local roads throughout this demonstration.

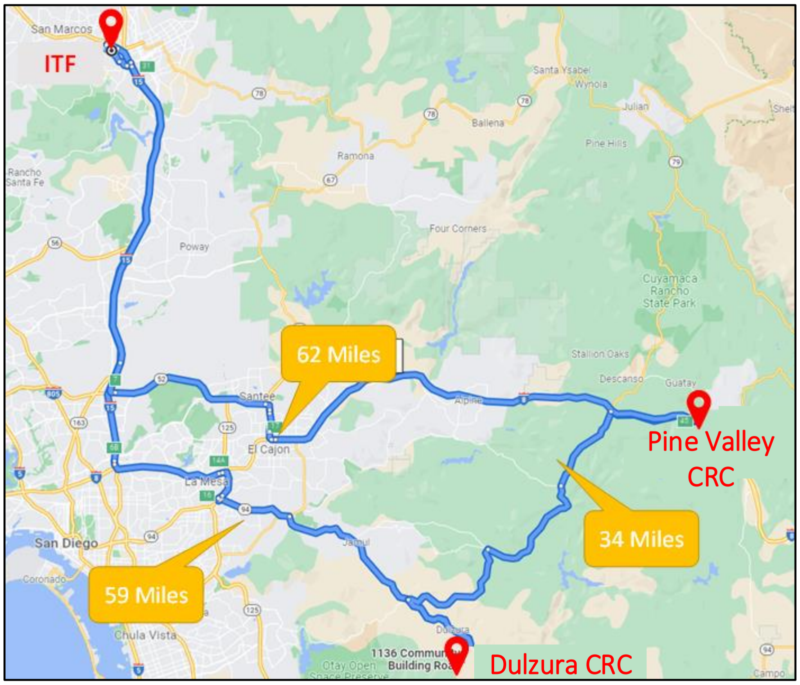

Figure 5-12. MBESS Transportation Map for EPIC Project Demonstrations

Table 5-15 presents the execution steps for the MBESS demonstration. Additional details regarding the results obtained from this demonstration and lessons learned are presented in the following sections.

Table 5-15. Demonstration Schedule of MBESS EPIC-3 Project

Activity	Dates	Comments
Transportation 1	11/03/2021	Between ITF to CRC 1 (59 miles). Transported at full capacity (i.e., SOC = 100%).
Demonstration 1	11/03/2021-11/04/2021	Islanded operation of MBESS at CRC 1 and supplied the total load for approximately 24 hours.
On-site charging	11/04/2021	Upon completing the first demonstration, the unit was put in charge at the site to prepare for the second demonstration.
Transportation 1	11/08/2021	Between CRC 1 to CRC 2 (34 miles). Transported at 80% SOC.
Demonstration 2	11/08/2021-11/09/2021	Islanded operation of MBESS at CRC 2 and supplied the total load for approximately 19 hours.
Transportation 2	11/09/2021	Returning the device to ITF at 30% SOC to complete the demonstration.

Figure 5-13 shows a photo of the MBESS while being transferred from CRC 1 to CRC 2.

Figure 5-13. Photo of MBESS on the Road during Transportation from CRC 1 to CRC 2

5.3.11 Use Case Execution

Among the use cases identified in Section 5.1, the MBESS demonstration focused on PSPS outage management. Due to timeline constraints and other logistical aspects, performing an actual PSPS outage management was impossible. Therefore, the outage management use case was demonstrated through a simulated outage by disconnecting the CRCs from the grid and utilizing the MBESS in islanded mode to supply the full load for each site.

5.3.12 Updated Metrics

Based on the FAT and SAT performed, the originally defined metrics were updated to reflect the change of demonstration plans (including targeted use cases) at both CRCs. **Table 5-16** presents the list of updated metrics.

Table 5-16. Updated Metrics for Demonstration at CRC 1 and 2

Metrics	Unit
Change of State of Charge	%
Minimum/maximum effective SOC	%
Available full charge capacity	kWh
Available full discharge capacity	kWh
Actual energy	kWh
Cumulative discharge (total)	kWh
Throughput (daily, monthly, annually)	kWh
MBESS availability	%

5.3.13 Data Acquisition

One of the key features of the MBESS was its comprehensive data acquisition platform. Data collection is done through onboard monitoring and control platform, and all system data is then logged and captured into a datalogger platform. Throughout the demonstration at CRCs, this data acquisition method was utilized to collect the data for further investigation and analysis. It should be noted that the resolution of the data saved by the data logger is 1 sample every 20 seconds, and a new log file is generated every hour for easy access to logs.

5.4 Data Analysis

Data analysis was performed to support the development of findings, conclusions, and recommendations regarding prospects for commercial adoption. The results of the data analysis have been presented in Section 6.0.

6.0 Project Results

In this section, the results of MBESS testing during several stages of Site Acceptance Testing and demonstration testing have been summarized and presented: in the order of i) SAT at ITF, ii) demonstration at CRC 1, and iii) demonstration at CRC 2. Additionally, the benefit analysis has been updated to reflect demonstration results.

Finally, a list of commercialization activities and associated costs have been described in Section 6.3, and a high-level cost estimate for commercial adoption of the MBESS is provided.

6.1 Results Discussion

6.1.1 Sample Test Results from SAT at ITF

The MBESS was first relocated to the ITF for Site Acceptance Testing. During SAT at the ITF, several aspects of MBESS were tested and verified, as described in Section 5.3.7.

Table 6-1. presents the sample test result for a grid-connected four quadrant operation of the MBESS at ITF during the SAT. The boundaries of the power output were limited to 60 kW because of the load bank size available for testing. **Table 6-1** shows that the MBESS successfully provided the requested active and reactive power at the POI and followed the commanded setpoint for charge/discharge.

Table 6-1. Sample Test Results for Parallel State, Four-Quadrant Operation of the MBESS at ITF during the SAT

Test Commands		Expected Results		Actual Results		Voltage +/- 5% of nominal
P (kW)	Q (kVar)	P (kW)	Q(kVar)	P (kW)	Q (kVar)	L-L/L-N
60	0	60	0	59.46	-0.7	120/120
40	0	40	0	40.9	1.5	120/119
30	0	30	0	30.07	-0.67	119/119
20	0	20	0	20.042	0.55	119/119

Test Commands		Expected Results		Actual Results		Voltage +/- 5% of nominal
P (kW)	Q (kVar)	P (kW)	Q(kVar)	P (kW)	Q (kVar)	L-L/L-N
10	0	10	0	10.188	-0.52	119/118
0	0	0	0	-0.41	-0.55	120/120
-10	0	-10	0	-9.96	0.07	120/120
-20	0	-20	0	-19.76	0.529	119/119
-30	0	-30	0	-29.66	0.128	119/119
-40	0	-40	0	-39.65	-0.16	119/119
-50	0	-50	0	-49.86	-0.11	119/118
-60	0	-60	0	-59.71	-0.45	119/118
-70	0	-70	0	-69.93	0.12	119/118
-80	0	-80	0	-79.93	0.56	119/117
-90	0	-90	0	89.92	0.7	119/117
-80	-10	-80	-10	-79.95	-9.76	119/117
-70	-20	-70	-20	-70.12	-20.05	119/117
-60	-30	-60	-30	-60.083	-29.92	119/117
-50	-30	-50	-30	50.12	-30.34	119/118
-40	-30	-40	-30	-40.51	-30.04	119/118
-30	-20	-30	-20	-30.156	-20.65	119/118
-20	-10	-20	-10	-19.98	-9.99	119/119
-10	-5	-10	-5	-9.98	-5.4	120/119
0	0	0	0	0.002	-0.004	120/120
10	-5	10	-5	9.93	-5.02	119/118
20	-10	20	-10	19.91	-10.22	119/118
30	-20	30	-20	29.99	-19.55	119/118
40	-30	40	-30	40.01	-29.89	119/118
50	-30	50	-30	49.98	-29.81	119/119
60	-30	60	-30	59.98	-30.12	119/119

6.1.2 Sample Demonstration Results at CRC 1

During the demonstration stage at CRC 1, the PSPS outage management use case was tested and verified. The MBESS was utilized in islanded applications to supply CRC 1 load. **Table 6-2** summarizes the overall performance of the MBESS during load supply at CRC 1 demonstration from 8:32 AM (November 3, 2021) until 9:12 AM (November 4, 2021) for a total duration of 24:40 hours.

Table 6-2. MBESS Performance Metrics for CRC 1 Demonstration

Metrics	Unit	Value—CRC 1
Change of State of Charge (ΔSOC)	%	52
Minimum/maximum effective SOC	%	46/98
Available full discharge capacity	kWh	281.26
Actual energy	kWh	250
Cumulative discharge (total)	kWh	149.0
MBESS availability	%	100

Figure 6-1 to **Figure 6-4** present the total active/reactive power at the POI, cumulative injected kWh at the site, and the SOC of the MBESS during the demonstration at CRC 1. During this demonstration, the islanded operation of the MBESS was used to simulate a PSPS outage and verify the operation. It should be noted that generation convention is used for MBESS output, i.e. (i) positive means delivering at POI-discharge for active power and inject for reactive power, and (ii) negative means receiving at POI-charge for active power and absorb for reactive power.

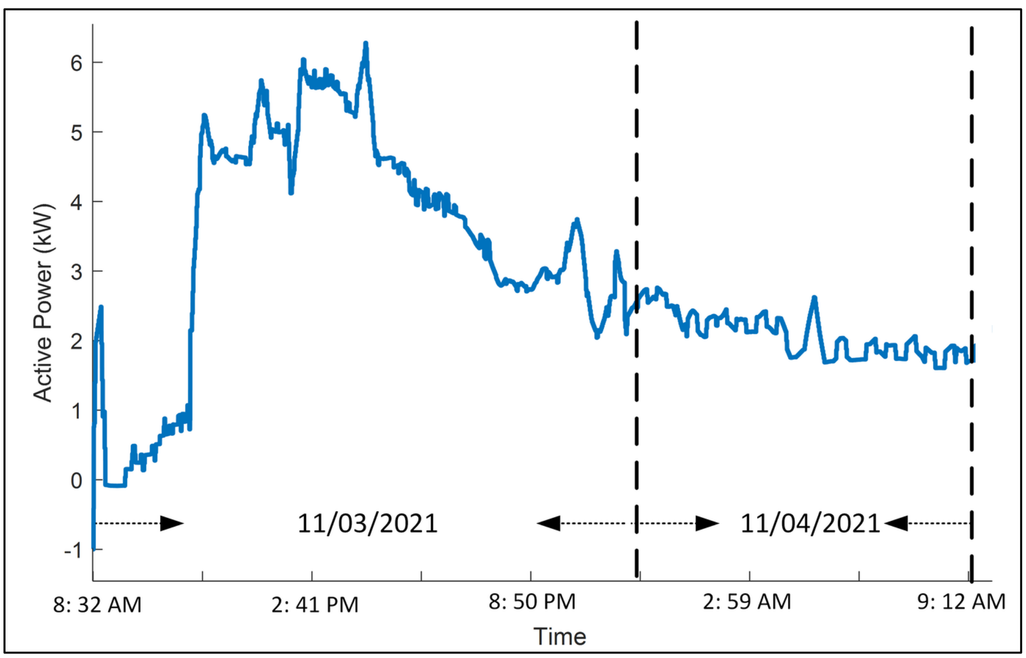

Figure 6-1. kW Supplied by the MBESS at POI at CRC 1

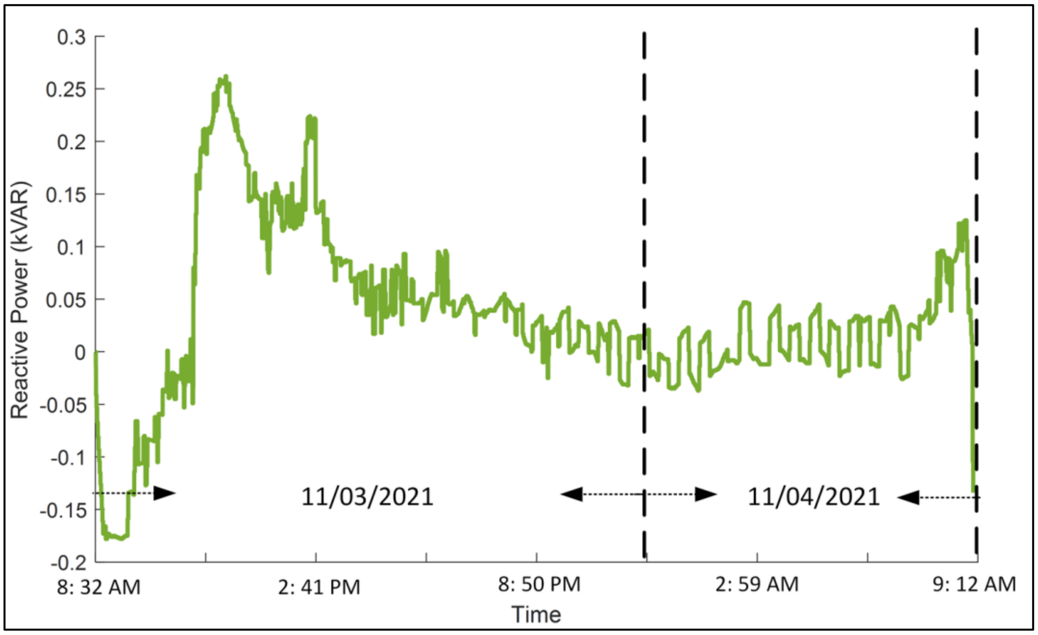

Figure 6-2. kVAr Supplied/Absorbed by MBESS at POI at CRC 1

Based on the total discharged energy (150 kWh) during load supply and the SOC change associated with that (around 52%), the available energy capacity can be estimated at around 280 kWh per one string.

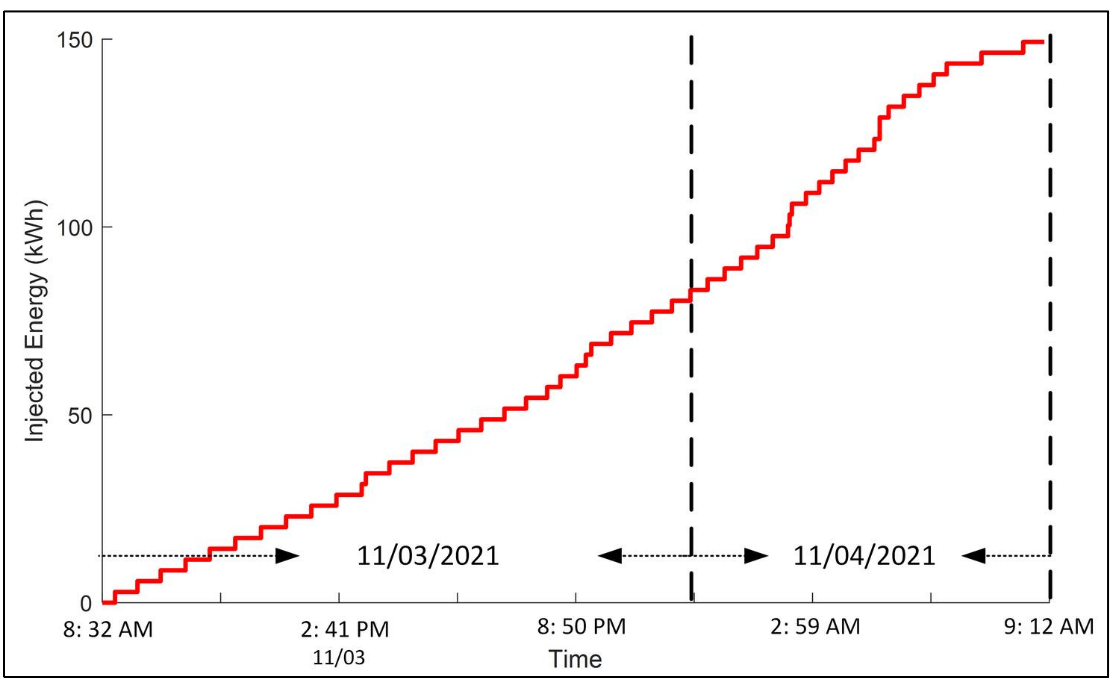

Figure 6-3. Cumulative Injected kWh at POI at CRC 1

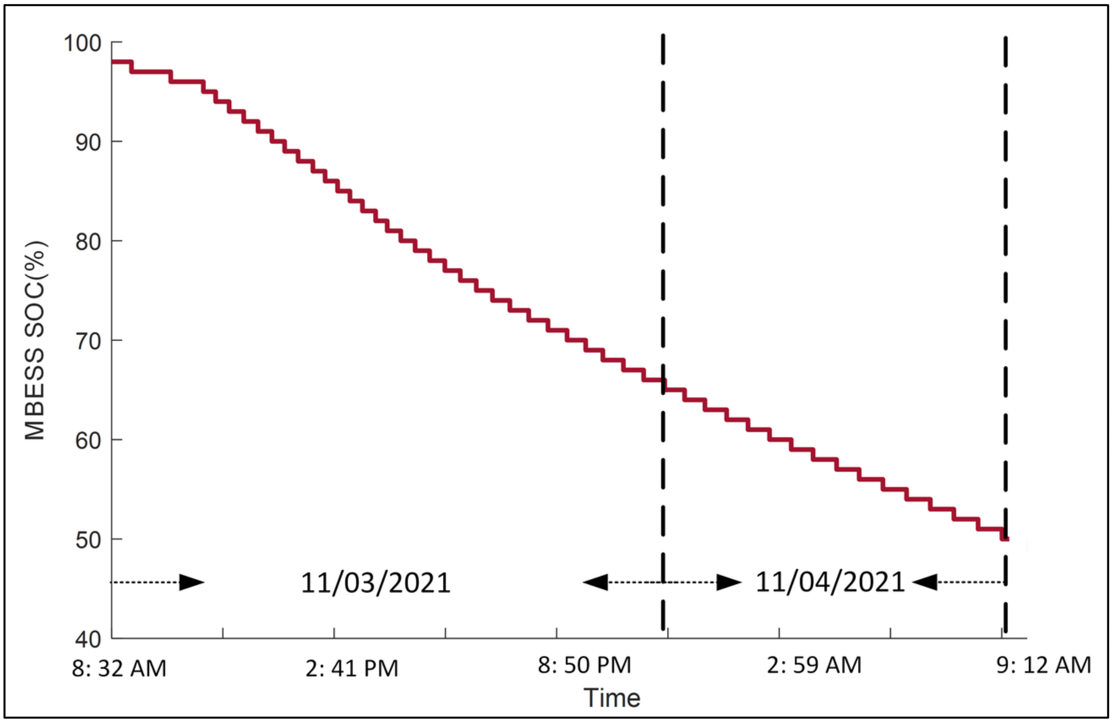

Figure 6-4. MBESS SOC during the Demonstration at CRC 1

It is noted that the voltage and frequency of the island were maintained despite load variations and the MBESS was able to supply the load successfully throughout this demonstration.

6.1.3 Sample Demonstration Results at CRC 2

During the demonstration stage at CRC 2, the PSPS outage management use case was tested and verified. The MBESS was utilized in islanded applications to supply CRC load. **Table 6-3** summarizes the overall performance of the MBESS during load supply at CRC 2 demonstration from 2:30 PM (November 18, 2021) until 9:08 AM (November 19, 2021) for a total duration of 18:38 hours.

Table 6-3. MBESS Performance Metrics for CRC 2 Demonstration

Metrics	Unit	Value—CRC 2
Change of State of Charge (ΔSOC)	%	53
Minimum/maximum effective SOC	%	27/80
Available full discharge capacity	kWh	229.60
Actual energy	kWh	250
Cumulative discharge (total)	kWh	152.1
MBESS availability	%	98

Figure 6-5 through **Figure 6-8** present the total active/reactive power at the POI, cumulative injected kWh at the site, and the SOC of the MBESS during the demonstration at CRC 2.

During this demonstration, the islanded operation of the MBESS was used to simulate a PSPS outage and verify the operation. It should be noted that generation convention is used for MBESS output (i.e. (i) positive means delivering at POI-discharge for active power and inject for reactive power, and (ii) negative means receiving at POI-charge for active power and absorb for reactive power).

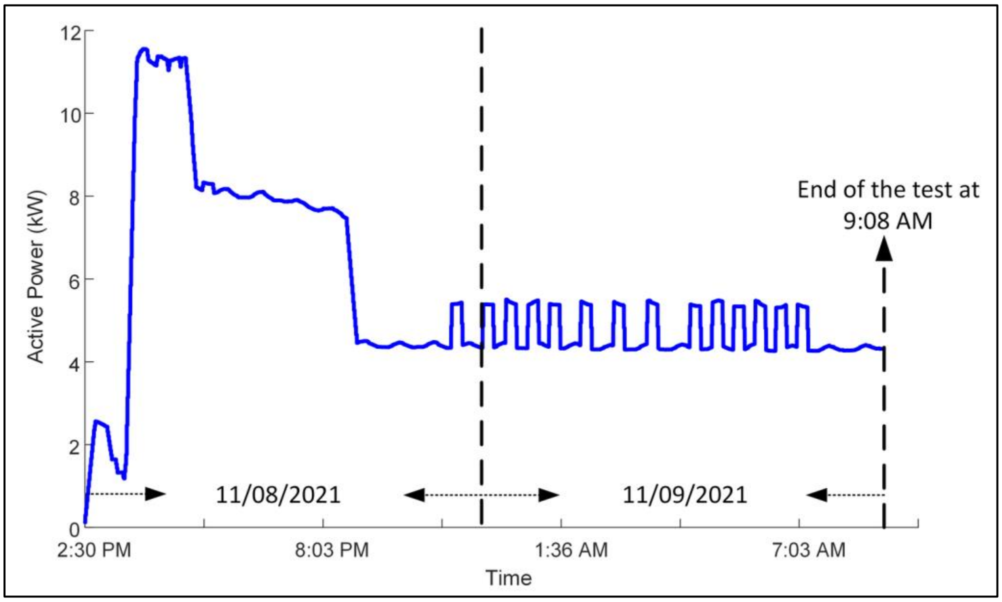

Figure 6-5. kW Supplied by MBESS at POI at CRC 2

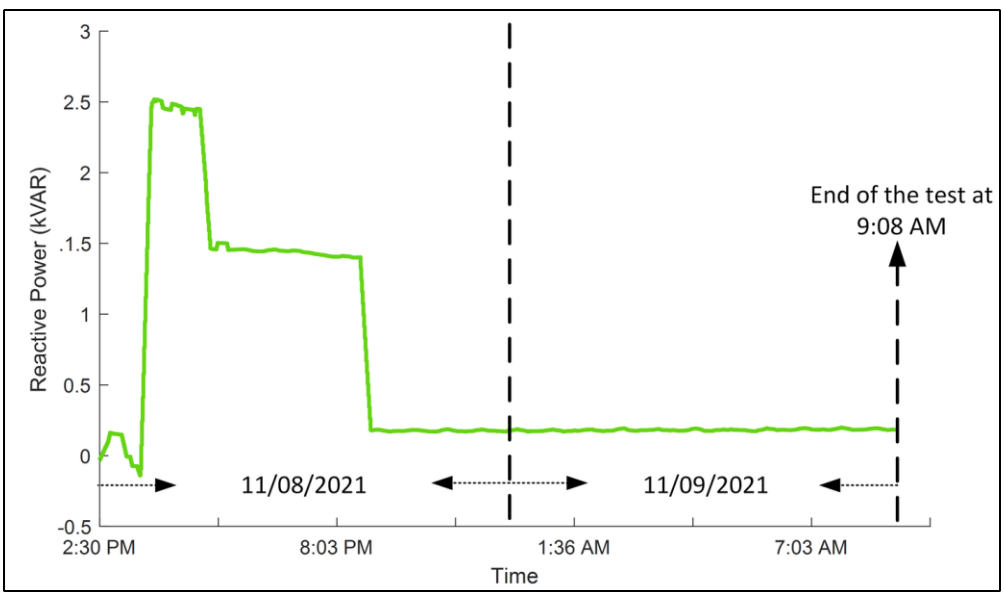

Figure 6-6. kVAr Supplied/Absorbed by MBESS at POI at CRC 2

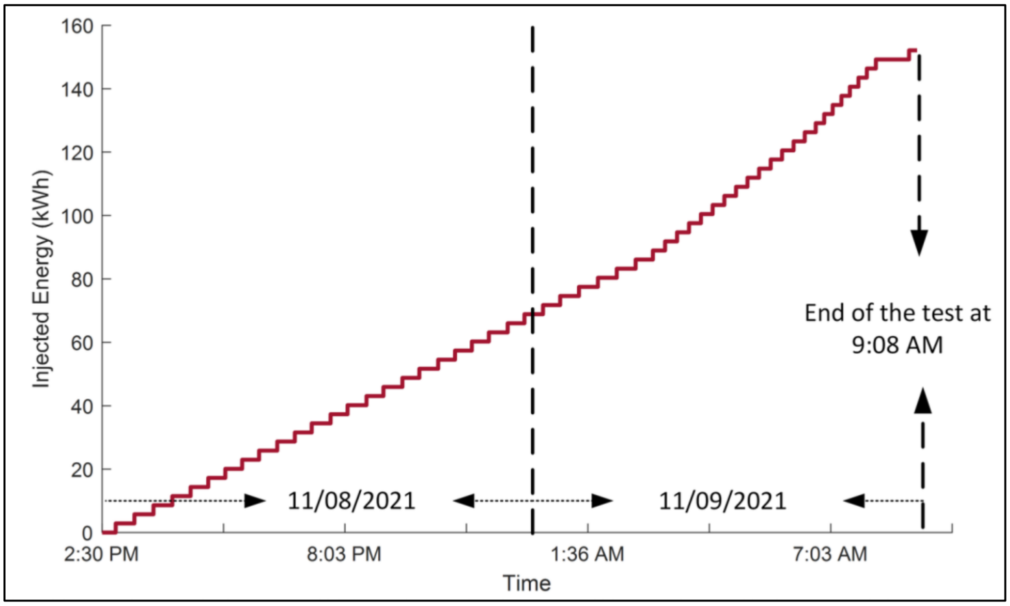

Figure 6-7. Cumulative Injected kWh at POI at CRC 2

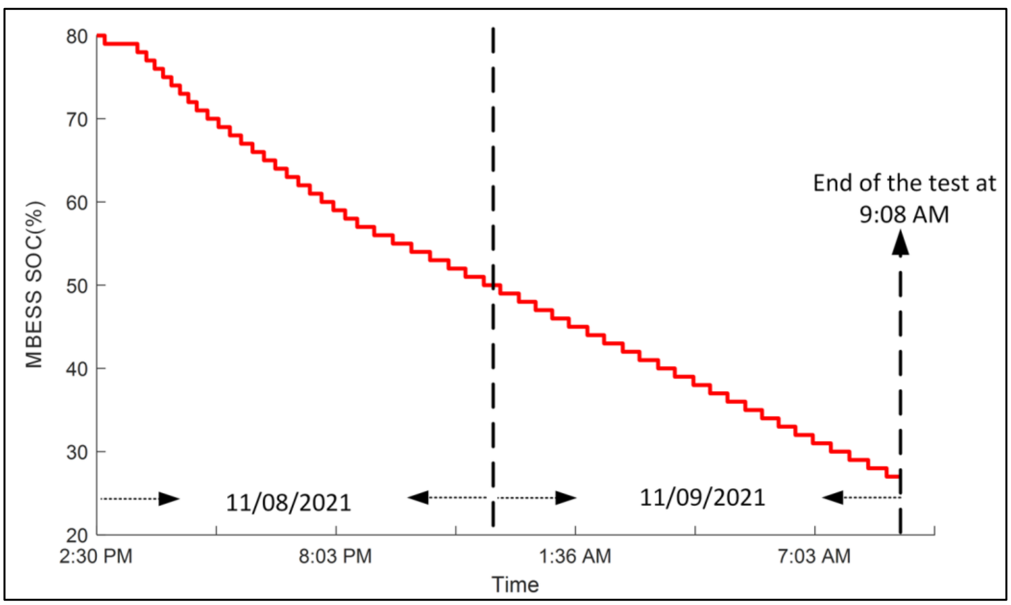

Figure 6-8. MBESS SOC during the Demonstration at CRC 2

6.2 Updated Benefits Analysis

During the demonstration, the MBESS was utilized for PSPS outage management at two different sites. The initial analysis assumed that the MBESS would be utilized for 3 outage events, up to 72 hours of duration, avoiding a total of 216 hours of PSPS outage throughout the year. Based on the field demonstration, the MBESS was utilized for 2 outages with a total duration of 43.96 hours. The MBESS successfully supplied load at CRC buildings during both outages.

It should be noted that the PSPS outage management demonstration performed at both CRCs was simulated and did not reflect the actual utilization for real PSPS events.

Table 6-4. compares initial benefit analysis target values for PSPS outage management with the results from the field. During field demonstration, the number of outages, duration of outages, and the average load deviated slightly from initial assumptions, which explains the difference in overall savings from PSPS outage management. It should be noted that similar saving results will be achieved with originally assumed target values for the number of outages, outage duration, and average load during the outage. Furthermore, successful supply of the load in islanding mode during CRC outages and the transportation of the MBESS from site to site with minimal efforts for interconnection are further proof validating the initial benefit analysis.

Section 7.2 suggests potential enhancements to the utility system by using MBESS commercially.

Table 6-4. Public Safety Power Shutoff Overview Comparison

Metric	Target	Field Results
Number of PSPS outages	3	2
Outage duration	72 hours	43.96 hours
Average load served during the outage	14.64 kW	6.85 kW
Total supported energy during the outage	3162 kWh	301.3 kWh
Saving on avoided cost of the outage	$ 28,458.00	$ 2,711.70

6.3 Commercialization Cost Estimates

Commercialization cost estimates the total cost required to establish the necessary infrastructure and dedicate resources to procure the required equipment, integrate the assets into existing infrastructure, operate and maintain the asset, and manage the overall asset utilization. The following items summarize different categories of commercialization costs each utility may be dealing with when integrating MBESS technology into their fleet. The order mainly follows the life cycle of technology within the utility environment:

- **Product Qualification and Standardization—Group Involved: Standards**
  Setting up an evaluation framework for qualifying the products based on the offered technology. The Standards team needs to prepare guidelines and documentation on deployment and utilizations. In addition, a standard interconnection box for the facilities of interest should be defined and installed.
- **Ownership and Inclusion in Utility Process—Group Involved: DER**
  Assigning the asset ownership to a certain department within utility (or creating a new department to lead the effort) and dedicating resources for scheduling and operation, contractor relationship, customer relationship (if applicable), and overall management of the process.
- **Procurement, Legal, and Permitting—Groups Involved: Engineering and Procurement**

Setting up the procurement process, including specification document development, standard request for proposal (RFP) document, defining business model strategies (purchase vs. lease) and financial setup, setting up warranty and after-sale service contracts, etc. In addition, permitting process should be developed for any required permits, including transportation, siting, etc.

- Integration to the Control Center—Group Involved: Distribution Operation
  The MBESS solution needs to be integrated into utility SCADA or another back-office enterprise platform by developing a standard method of communication, standardizing data requirements and data exchange for each location, developing screens for monitoring and control of MBESS, developing cybersecurity requirements, etc.
- Operation and Maintenance—Group Involved: Fleet Management
  Dedicating and training resources for the day-to-day operation of MBESS units and maintaining the units over the life cycle of the products. This includes routine inspection and testing of the units and performance tracking and data capture at the utility side, which is required for executing warranty and contractual obligations. Furthermore, developing a fleet management process is part of required responsibilities under the fleet management team (e.g., setting up the fleet space for storing/placing the units on utility premises while not in use and contracting transportation company for towing and relocating the units).
- Customer Outreach—Group Involved: Public Relations
  Additional effort should be directed towards communicating the message to the public and industry on technology concepts, value propositions, and differentiation from other technologies.

Table 6-5 summarizes a high-level cost estimate for the commercialization process, assuming a fleet of 10 MBESS is being set up. The labor is calculated based on the duration of activity in months (assuming 120 effective working hours per month for utility staff, with a rate of $100/hr).

Table 6-5. Sample Estimated Commercialization Cost Breakdown

Attribute	Labor Person-months	Expense	Total Estimate	Note
Product Qualification and Standardization	3	$20,000	$ 56,000.00	The expense of standard interconnection box at 10 sites
Ownership and Inclusion in Utility Process	4	$6,000	$ 54,000.00	The expense of offices for dedicated employees (3)
Procurement, Legal, and Permitting	2	-	$ 24,000.00	
Integration to the Control Center	2	-	$ 24,000.00	

Attribute	Labor Person-months	Expense	Total Estimate	Note
Operation and Maintenance	3	$15,000	$ 51,000.00	The expense of additional fleet space and contract fees
Customer Outreach	1	$6,000	$ 18,000.00	The expense of material preparation for public awareness
Capital cost of 10 units (120/240V, 100 kW, 1 MWh)	10	$450,000	$4,620,000	Average price
Total			$ 4,847,000.00	

7.0 Findings

The demonstrations at the two sites clearly showed the viability and value of utilizing a mobile energy storage system for supplying the community centers during a specific time that interruption (outage) is expected. The approach alleviates the need for maintaining a stationary backup generation source at a facility year-round. It also provides a proper alternative for polluting emergency diesel generators. Several aspects of the demonstrations are further emphasized in the findings.

- Connection of the MBESS to the terminal box at each site was performed very smoothly and quickly, with no power interruption for the facility. It did not require any specialized skill or tool. A regular customer can even make the connection by following the instructions.
- Using manual mode, MBESS was started very easily, following a few steps, by pressing the "start pushbutton" on the terminal box. The system status and operation could be checked frequently using a portable monitor (tablet) that provides access to unit HMI.
- There was almost no noise during the unit operation, which is a major advantage of using MBESS, especially at night in a very quiet neighborhood. The unit would have caused extremely troubling noises in the evening and at night with diesel generators.

The unit operation and supplying the facility were successfully demonstrated in both sites for more than 12 hours of an outage with no need to stop or start the unit. With diesel engines, the unit may need to be stopped after 6–8 hours and restarted again to meet the hard duration limitation for emergency use of diesel genset (enforced by local jurisdictions in some places).

7.1 Findings Discussion

Several operating scenarios were investigated during the demonstration, and observations were made to improve the system's overall performance.

- The use of the tablet for user interface and operation monitoring was shown to be not a convenient way of accessing the HMI page. A stationary outdoor-rated HMI device installed at the same location as the pushbuttons on the terminal box should be investigated and applied for future units.
- The unit includes meters and power quality devices inside the container. It was also found that the main power meter is better installed on the unit's exterior and closer to the operation pushbuttons to provide immediate measurement as a way of feedback for the user on the level of power exchange with the facility.
- During a troubleshooting incident, the UPS power was utilized instead of the external auxiliary power source, which caused the depletion of UPS batteries. As a result, the power supply to all control and monitoring systems was disconnected, which led to the loss of access to the system. The instructions were added to the system operation manual to keep the system on external auxiliary power for any troubleshooting procedure.
- During system preparation for energization, the auxiliary power cable was connected incorrectly, which led to the burning of the auxiliary circuit contactor. The contactor was replaced to resolve the issue. The instructions were added to the system operation manual to provide additional instructions on the system preparation and setup.

7.2 Updated Value Proposition

The MBESS demonstration was categorized originally within the EPIC framework category of Customer-Focused Services. The major value propositions for mobile battery solutions are:

1. **Enhanced Reliability and Resiliency:** The most important value proposition of MBESS, which perfectly aligns with the EPIC framework, is outage management for utility customers, which enhances the system's reliability and resiliency. It could be achieved through microgrid applications incorporated into the MBESS controller.

    1.1. **Observations from Demonstration:** MBESS successfully demonstrated the customer supply use case during outage:

    - During islanded application, the MBESS maintains the voltage and frequency of the island and supplies the load up to its rated value.
    - The demonstration was performed for load supply during the outage. Based on the energy capacity of each unit and the customer load profile, the supply duration varies.

2. **Mobility:** One of the main value propositions of the MBESS is the ability to be self-sustained and transported to different locations and quickly be redeployed at a new location. The mobility feature will enhance the value of energy storage systems and leverage geographic versatility benefits.

    2.1. **Observations from Demonstration:** The MBESS successfully demonstrated the mobility aspects:

- The system's design was considered for all the integration components, including isolation transformer and plug-and-play Cam-Lok connection box, which facilitated easy connection to the customer/utility system.
- The overall redeployment and reconnection time at a new facility was less than five minutes.

Currently, the definition of a mobile storage solution is perceived differently across the industry and solution providers. Some of the proposed solutions as mobile storage are rather transportable (meaning that the stationary version can be transported from one location to another). However, such solutions do not offer some features, including:

- Integrated solution with interconnections assets incorporated.
- Plug-and-play terminal connection for fast redeployment at the site.
- 24/7 onboard monitoring and control platform.

It is important to consider these issues in the commercial adoption of MBESS.

3. **Grid Support Functionalities:** One of the areas that the MBESS offers value is the ability to support the grid for services such as power quality improvement (by voltage support) or demand reduction. This is important since the MBESS can stack applications throughout the year and during seasons without expecting outages. It can be utilized for grid support services per utility need.

   3.1. **Observations from Demonstration:** MBESS successfully demonstrated:
   - Grid-connected performance for parallel operation with the grid (charge/discharge).
   - Transfer between different modes of operation.
   - Specific applications such as load management and voltage support.

4. **Situational Awareness:** As a new asset in the utility portfolio, situational awareness over the area of integration becomes another value proposition. The MBESS provides a unique angle to enhancing situational awareness in that it will be deployed to different locations in the system for brief periods. It is expected to enhance integration into distribution system operations and the system operator and, thus, provide greater visibility in the vicinity of the grid to which the MBESS is connected by supplying information such as real and reactive power flow, voltage, frequency, and other key performance indices. The design of the MBESS monitoring and control system will include provisions for data acquisition that create additional value.

   4.1. **Observations from Demonstration:** MBESS successfully demonstrated:
   - System metering at different points.
   - Extensive data logging from different sources of data (battery cells and BMS, power conversion system, inter-tie relay, condition monitoring devices, etc.).
   - System remote access and monitoring.

5. **Societal Benefits:** The MBESS provides a wide range of hard-to-quantify benefits such as reducing GHG emissions, improving public utility image, and knowledge gain for utilities through technology evaluation and implementation. The mobility features of MBESS facilitate charging from different locations and then relocating and supplying the customer load as needed. For instance, co-locating MBESS with a solar site makes it a carbon-free generation source that can significantly lower the amount of GHG compared to traditional portable diesel generators.

8.0 Conclusions

This EPIC project successfully demonstrated the viability of utilizing mobile energy storage solutions for supporting customers during outage events in remote and rural areas of the service territory. The MBESS was able to supply CRC load for an extended time (over 24 hours) at each demonstration site. The MBESS also completed 155 miles of transportation on highways and rural roads when relocating among the three sites.

The new battery technologies based on LFP enable the safe and reliable transportation of the batteries when fully charged and integrated into the power conversion systems. The key concern with safely transporting fully charged battery cells was a limiting factor in developing mobile solutions. The project showed that mobility could be achieved with proper use of the technology and adequate design to incorporate sensors and monitoring and the technical capability for enabling the solutions.

The viability of several use cases for the MBESS was fully evaluated during SAT. The outage management use case was also extensively verified in two real-world MBESS deployment sites, with adequate data gathering to facilitate a detailed performance analysis and benefits assessment.

9.0 Tech Transfer Plan

9.1 Project Result Dissemination

The results of this module of EPIC-3, Project 7, will be published and made available to the general public in this comprehensive final project report, which will be posted on SDG&E's public website and filed with CPUC. This report is the main record of what was demonstrated and learned in the project and is the primary tech transfer tool. The project's results and findings may also be submitted for consideration by industry conference organizers.

Several meetings were held throughout the project design and testing stages involving the stakeholders and subject matter experts from various SDG&E departments. The focus of the meetings was to describe the project progress and obtain feedback or suggestions on various aspects of the use cases and test system development. A shortlist of key meetings is provided below:

- Meeting on the review of the baseline analysis for the use cases and benefit evaluation, during which the methodology for the use case analysis and baseline estimate was presented. The recommendations from various teams were gathered and incorporated in the baseline analysis results.

- Meeting for FAT and SAT setup development to ensure the proposed test setups are comprehensive enough to facilitate various test cases and operating scenarios that would help evaluate the MBESS features and performance.
- Remote witnessing of the FAT and review of the performance.
- An in-person meeting at ITF during the SAT for performing the tests and discussing the results.
- Working session at ITF for knowledge transfer and user training of the operation modes and utilization of the MBESS.

The engagement of these key SDG&E stakeholder groups in these activities supports their ability to engage in commercial adoption processes after the EPIC project ends. Key internal stakeholders to be engaged in post-EPIC activities are:

- Distribution planning
- Advanced technology
- Distribution operations
- Protection and automation
- Information techology
- Customer programs

9.2 Transition for Commercial Use

Presently, the utility industry has a significant interest in learning about MBESS applications and utilization experience. Utility systems are exposed to various natural disasters, and they are looking for mobile solutions that can be reliably deployed in the field to support customers during outage recovery time, yet are environmentally friendly, safer, and less polluting (noise- and emission-wise) in comparison to the conventional diesel generator approaches. SDG&E, based on the results of this EPIC project, has gained firsthand experience with the performance and logistical aspects of the MBESS. The benefit analysis outcome can support business case development for a fleet of MBESS.

10.0 Recommendations

Based on the successful pre-commercial demonstration of the technology and use cases, it is recommended that SDG&E commercially adopt MBESS into their operations. SDG&E would need to designate which business units should be involved in the commercialization process and appoint one business unit to lead. It is suggested that initially, the DER group take the lead to identify applications and coordinate the use of MBESS across SDG&E service territory commercially. The next natural step would be to develop a commercialization plan.

SDG&E needs to form an operation and maintenance (O&M) plan to store MBESS units while not operating at sites. This plan shall address the need for space to park/store these MBESS units, define the requirement for accessing auxiliary power during the park/store time, and the operational procedures for regular charge/discharge of the units while in storage to avoid damage to the batteries.

A fleet of MBESS of different types, capacities, and ratings should be considered. Both purchase and lease options for the MBESS fleet should be considered. The value proposition observed in this Module 2 of EPIC-3 Project 7 and the companion work of Module 1 indicates significant benefits can be derived from the use of MBESS. However, the number of applications addressed in both modules was limited by time and funding in the EPIC project. Additional applications (operating procedures and use cases) need to be investigated during the early stages of commercialization.

Some issues to be considered are:

- The use cases demonstrated in the project were limited to the outage management scenarios due to the configuration at the CRC sites. It is recommended to perform additional testing and evaluation at other potential customer sites to collect and analyze grid supporting use cases such as Volt-VAR or peak shaving. Although those use cases have been verified in the laboratory environment, the real-world deployment and assessment will bring additional knowledge gains, data, and operational learning to refine the value proposition of MBESS solution.
- The MBESS used for this project provides a single-phase output. However, the system can support both single-phase and three-phase applications if they are included in the project's functional specifications. It is recommended that future projects incorporate both types of single-phase and three-phase outputs to support residential and commercial facilities. The multiple output type will increase the coverage and utilization cases for the system.
- Integration to the dispatch center and remote control or observability were not part of the EPIC project. However, remote dispatch and monitoring will be key aspects of the field operation. They should be tested when the mobile solution gains enough traction to acquire multiple units and build a fleet of MBESS.
- Depending on the number of relocations expected, a combined truck-trailer approach may become more beneficial and convenient than a flatbed trailer in support of multiple use cases and utility applications. This can be a modification applied in future systems.

An MBESS can be equipped with electric vehicle chargers for the additional benefit of supporting customers during outage scenarios. A hybrid MBESS with an onboard charger will significantly improve the business case and come at a low incremental cost

11.0 References

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2. https://www.sandiego.edu/law/documents/centers/epic/1Electric%20Emissions%20Factor%20Method_061716.pdf
3. https://www.eia.gov/tools/faqs/faq.php?id=74&t=11
4. https://www.icecalculator.com/home

12.0 Appendix A – Standards and Guidelines

#	Name	Definition
1	ANSI	American National Standards Institute
2	ANSI C37/IEEE	Surges withstand capabilities, whenever applicable
3	ANSI C57/IEEE	Transformer Standards, whenever applicable
4	ANSI Z535	Product Safety Signs and Labels
5	ANSI/IEEE C2	National Electric Safety Code
6	Cal/OSHA	California Occupational Safety and Health Administration
7	CFC	California Fire Code
8	Electric Tariff Rule 21	Generating Facility Interconnections
9	IEEE 1547	IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
10	IEEE 1881	Standard Glossary of Stationary Battery Terminology
11	IEEE 519	IEEE Recommended Practices and Requirements for harmonic Control in Electrical Power Systems
12	NEC	National Electric Code
13	NEMA	National Electrical Manufacturers Association
14	NESC	National Electric Safety Code
15	NFPA 704	Standard System for the Identification of the Hazards of Materials for Emergency Response
16	NFPA 855	Standard for the Installation of Stationary Energy Storage Systems *Applicable in the event of adoption by contract execution
17	UL 1642/IEC 62133	Applicable sections related to battery cell safety, where applicable
18	UL 1741	Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
19	UL 1778	Underwriters Laboratory's Standard for Uninterruptible Power Systems (UPS) for up to 600V AC
20	UL 9540/9540A	Standard for Energy Storage Systems and Equipment

#	Name	Definition
21	42 United States Code (U.S.C.)	Noise Control Act of 1972