EPIC Final Report

Program	Electric Program Investment Charge (EPIC)
Administrator	San Diego Gas & Electric Company
Project Number	EPIC-3, Project 7, Module 1
Project Name	Demonstration of Multipurpose Mobile Battery
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Attribution

This comprehensive final report documents the work done in Electric Program Investment Charge (EPIC) 3, Project 7, Module 1. The project team that contributed to the project definition, execution, and reporting included the following individuals, listed alphabetically by last name:

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Executive Summary

Objective

The EPIC-3 Project 7 objective was to undertake a pre-commercial demonstration of a mobile battery energy storage system (MBESS) and examine the value proposition from deploying a mobile battery across multiple sites and use cases. With the MBESS functionally between a mobile diesel generator and a stationary battery energy storage system (BESS), this study sought to quantify the benefits of a flexible deployment of a MBESS to determine whether the benefits derived from a flexible range of services provided could justify the significant upfront costs associated with purchasing a MBESS.

Approach

EPIC-3 Project 7 was split into two modules (workstreams) involving two different MBESS units having different characteristics. This report documents the work in Module 1, which used the larger of the two MBESS units. The Module 2 work is documented in a separate report. For Module 1, SDG&E competitively procured a 362kW/1499kWh MBESS mounted on a gooseneck trailer with project funding. Sites with different use cases were considered and SDG&E entered negotiations with potential sites to ensure that the MBESS could be deployed for the intended use cases. Ultimately SDG&E selected two sites for MBESS deployment, Marine Group Boat Works, a Port of San Diego tenant, and the Cameron Corners Microgrid.

In parallel with site selection, SDG&E developed potential use cases and created the testing regimen for the MBESS. The testing regimens were designed to test the various use cases and quantify potential MBESS benefits. Each testing plan included a data collection plan to ensure that data collected was appropriate and sufficient to model test results and draw conclusions about the MBESS' ability to fulfil the intended use cases and quantify the benefits of the MBESS.

The MBESS was ultimately deployed at 3 different sites – an initial Commissioning and User Acceptance Test at SDG&E's Skills Training Facility, at Marine Group Boat Works and finally at Cameron Corners Microgrid.

The MBESS performed grid support services at Marine Group Boat Works connected in a grid paralleled fashion, ultimately performing a safety test, load smoothing, peak shaving, zero load, battery charging and discharging tests. At the Cameron Corners Microgrid, the MBESS performed resiliency functions, with the microgrid's existing infrastructure serving as an ideal testbed for MBESS deployment in similar situations around SDG&E territory. A load blackstart test was performed for downstream critical community loads. These loads included community facilities, a health clinic, telecommunications, fire station and gas station which SDG&E had previously undergrounded to provide increased public safety power shutoff (PSPS) resiliency. This test successfully demonstrated the load blackstart use case.

Key Findings

Testing the MBESS demonstrated the flexibility and value of a relocatable resource to SDG&E's distribution system, which was not possible from a single mobile diesel generator or a stationary BESS. The MBESS demonstrated the following benefits:

- Safety – The MBESS contributed to a safer worksite through development of customized deployment safety protocols and emergency stop functionality. It also proved to reduce runtime of more traditional diesel generators, decreasing the risk for a fuel spill and contributing to a quieter work environment and better air quality.
- Improved Reliability and Power Quality – The MBESS was able to demonstrate a successful load black start and coordinate the integration of other connected DERs to carry downstream loads for 24 hours. It also successfully shaved peak loads up to and exceeding its 362kW rating and load smoothed peaky customer loads down to a rate of change of 126 Watts/sec. When considering associated temperature decreases due to amperage reductions at the substation, the MBESS has the potential to increase grid infrastructure by 2.78 years, worth an estimated $170,389 over 10 years. The MBESS can also be used to offset planned grid upgrades, worth an estimated $141,618 per year.
- Improved Performance of the Utility Power System – Deployment of a 362kW MBESS was able to reduce circuit amperage, loading, and electrical losses by roughly 10%. Estimating a 362kW load reduction at 12kV, the resulting 30A reduction can yield a 6% decrease in total circuit loading.
- Lower GHG Emissions – Direct GHG reductions from a single MBESS reduce diesel generator fuel consumption by 303 gallons of diesel fuel, worth approximately $1,516. The same reduction in diesel fuel consumption eliminates the emissions of three metric tons of Carbon Dioxide Equivalent (CO_2e), worth about $72 in California's current Cap and Trade market. MBESS use could also allow customers to mitigate the temporary bill increases due to EV charging or ship-to-shore power, encouraging more indirect GHG emissions reductions.
- Lower Operating Costs and More Efficient Use of Customer Money – When compared to a diesel generator, the MBESS demonstrates $653,424 more in net benefits than a diesel generator rental over a 10 year period. When not actively deployed, a MBESS can also participate in the CAISO market, generating an estimated $14,660 in energy and regulation revenue.
- Economic Development – Should SDG&E choose to purchase or lease a fleet of MBESS to offset their entire power system 2021-2030 needs, it would generate a local market of over $11.4M in MBESS requiring sales, service, transportation and deployment support, creating local jobs.
- Disadvantaged Communities (DACs) – Deploying an MBESS in a DAC territory supports existing efforts to reduce GHGs, emitting no direct emissions itself and supporting other local and state efforts such as those associated with using shore power for ships when in dock and EV and forklift charging.
- Incremental Benefits of a Mobile Solution – Deployment of an MBESS is flexible and customizable to the specific application, able to easily rotate between events and grid support functions, where otherwise it would be cost prohibitive and/or infeasible to deploy a stationary battery. MBESS are also daisy-chainable, so multiple units can be deployed together to achieve higher total ratings, when needed.

Recommendations

The Mobile BESS tested in this EPIC project has a strong value proposition for deployment around SDG&E territory. Sized appropriately, it provides analogous function to a mobile generator which can black start loads after an outage, coordinate with other supporting generation sources, and carry loads until grid power can be restored. Because it is mobile, the MBESS can also provide grid support services which help demonstrate significant value over a diesel generator over the 10-year life of a MBESS. It is recommended that SDG&E continue to standardize deployment applications for a MBESS and commercially adopt and use these valuable assets in their service territory. A fleet of mobile batteries of different types, capacities and ratings should be considered. Both purchase and lease options for the mobile battery fleet should be considered.

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List of Acronyms

Acronym	Acronym Description
AB	Assembly Bill
BESS	Battery Energy Storage System
BtM	Behind the Meter
CAISO	California Independent System Operator
CARB	California Air Resources Board
CCM	Cameron Corners Microgrid
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CPUC	California Public Utilities Commission
CT	Current Transformer
DAC	Disadvantaged Community
DDOR	Distribution Deferral Opportunity Report
DER	Distributed Energy Resource
EMP	Energy Master Plan
EO	Executive Order
EPIC	Energy Program Investment Charge
E-Stop	Emergency Stop

Acronym	Acronym Description
FtM	In Front of the Meter
GHG	Greenhouse Gas
GNA	Grid Needs Assessment
HFTD	High Fire Threat District
HMI	Human Machine Interface
IOU	Investor-Owned Utility
LNBA	Locational Net Benefit Analysis
MBESS	Mobile Battery Energy Storage System
MGBW	Marine Group Boat Works
PCC	Point of Common Coupling
PQ	Power Quality
PV	Photovoltaic
PSPS	Public Safety Power Shutoff
PT	Potential Transformer
RFP	Request for Proposals
SB	Senate Bill
SCADA	Supervisory Control and Data Acquisition
SDG&E	San Diego Gas and Electric
SOE	State of Energization
UPS	Uninterruptable Power Supply

1.0 Introduction

The quantity of deployed Battery Energy Storage Systems (BESS) is quickly increasing in today's energy market due to the wide variety of potential use cases and rapidly declining costs. According to EIA, battery prices have fallen 72% between 2015 and 2019, a 27% decline per year[1]. BESS of all sizes can fulfil a host of applications, from supporting grid services such as peak shaving and load smoothing, to economic functions such as rate arbitrage and demand response to providing resilient backup power during a grid outage and others. To date, however, BESS installations, especially large-scale ones, have been predominately stationary, installed to support one site, group of sites, or distribution system area requiring the continual use of mobile diesel generators for mobile, flexible grid support. While stationary batteries allow the recipient site to potentially access the aforementioned functionality, there is the potential to increase the benefits of a BESS by making it mobile, increasing the utilization of a single asset by providing grid services and resiliency services, like a diesel generator would today. EPIC-3, Project 7 explored the stacked benefits of a Mobile Battery Energy Storage System (MBESS) and whether mobile application can increase a battery's potential to serve more functions and/or more customer use cases with a single unit, thereby increasing the value proposition for purchasing and using MBESS units.

2.0 Project Objectives

The objective of EPIC-3 Project 7 was to undertake a pre-commercial demonstration of a mobile battery system at multiple sites. The project was split into two modules (workstreams) involving two different MBESS units having different characteristics. This report documents the work in Module 1, which used the larger of the two MBESS units. The Module 2 work is documented in a separate report. For Module 1, SDG&E competitively procured a 362kW/1499kWh MBESS mounted on a gooseneck trailer with project funding. Sites with different use cases were considered and SDG&E entered negotiations with potential sites to ensure that the MBESS could be deployed for the intended use cases. Ultimately SDG&E selected two sites for MBESS deployment in Module 1: Marine Group Boat Works (MGBW), a Port of San Diego tenant, and the Cameron Corners Microgrid (CCM).

While the original intent was for a MBESS deployment at the cruise ship terminal at the Port of San Diego, a variety of factors made deployment at this site infeasible during the pre-commercial demonstration window. So, another site, with similar load trends, was chosen as one of two deployment sites. Ultimately, MBESS deployment was moved between the MGBW and CCM sites to demonstrate the stacked benefits of multiple use cases across various sites. At MGBW, the MBESS was connected in parallel to the grid to offset the highly variable loads associated with ship repair and cold-ironing ships (plugging ships in dry dock into shore power, rather than using diesel engines). At the CCM, the MBESS could support circuit resiliency and backup power during an extended duration outage such as a Public

[1] https://www.eia.gov/analysis/studies/electricity/batterystorage/

Safety Power Shutoff (PSPS). The objective was to evaluate the effectiveness of mobile batteries when rotated between applications and quantify the benefits associated with rotation of a MBESS through preferred applications.

3.0 Issues and Policies Addressed

This project was designed to support the state objective under Assembly Bill (AB) 628 to reduce wasteful, inefficient energy consumption, implement energy efficient improvements and use efficient low-emissions energy sources in the operations of its ports and harbors by supplementing current energy sources through use of battery energy storage. As mentioned above, the project created a platform for gathering new knowledge on stacked benefits from deploying a mobile battery across multiple strategic applications, including but not limited to scheduled charging and discharging, demand response, load smoothing, peak shaving, circuit loading reduction and islanding of grid loads prone to frequent outages.

Another goal of AB 628 is to promote economic development. Implementation of the mobile battery in front of the meter (FtM) aided in demand and energy cost reduction for SDG&E, complimenting the potential benefit through greater stability and decreased cost of energy services for businesses located downstream of the mobile battery deployment. In correlation to this project, maritime customers who consume shore power pass these costs along directly to their customers which in turn can impact the potential for business retention. Thus, this project poses a benefit to help minimize costs which are passed through to customers, allowing local businesses to achieve higher margins on the services they sell to their end customers.

Lessons learned from this project may lead to SD&GE deploying a fleet of mobile batteries. This will help strategic customers around its territory, specifically disadvantaged communities (DACs), reduce emissions of greenhouse gases (GHG) and other pollutants, and reduce periods of heavy localized electric power demand, which directly supports not only the District’s Climate Action Plan but also the California Air Resources Board (CARB) shore power regulation.

In addition, the project demonstration extended to the application of emergency backup power for an at-risk grid circuit in a High Fire Threat District (HFTD). HFTDs are in some of the most fire prone communities and, consequently, are even more prone to losing power during a Public Safety Power Shutoff (PSPS) event. Having mobile battery technology rapidly available to HFTDs would provide a significant level of resiliency to the affected communities.

4.0 Project Focus

Module 1 of this EPIC-funded project focused on pre-commercial demonstration of a mobile energy battery storage to evaluate potential use cases for the battery and to quantify the stacked benefits from a moveable asset. The knowledge gained in this demonstration is being used in the decision-making regarding investment in and deployment of a larger MBESS fleet around SDG&E’s territory. A fleet of MBESS would allow for flexibility in today’s dynamically changing energy landscape.

Once a MBESS was competitively procured from an equipment vendor, sites were selected to demonstrate various use cases of the battery. Existing site infrastructure and current distributed energy resource (DER) interconnection guidelines both determined what use cases could be tested at each site. The use cases then dictated development of test plans which were conducted to demonstrate MBESS functionality. Data was collected which supported the quantification of local use case benefits.

SDG&E worked with a consulting vendor to perform a pre-commercial demonstration of the MBESS's effectiveness in a variety of use cases, with the end goal of helping determine the value proposition of mobile batteries. The purpose was not to evaluate a specific vendor product, but to examine the value proposition for mobile batteries in general.

5.0 Project Scope Summary

5.1 High-Level Overview

While mobile batteries are becoming commercially available, the mobile utilization of the same asset at multiple locations with multiple use cases was new and needed to be demonstrated and thoroughly evaluated. In performing the procurement of mobile batteries for this project, SDG&E learned that a stable mobile battery industry did not yet exist, and vendors were challenged to provide products that met the project needs in a timely manner.

A primary issue for commercial and industrial businesses within the SDG&E service territory is low load usage with high peak demand for relatively short periods, which result in undesirable charges and low utilization of grid assets. Specifically, MGBW has a load profile with high peak demand and low load usage, resulting in a poor load factor and high demand charges. This type of load profile also requires that SDG&E provide significant circuit capacity, which is used only a small fraction of the time.

This project sought to demonstrate a new solution [i.e., MBESS] to assist MGBW and other locations in alleviating these problems. Whereas, pursuing a more traditional behind the meter (BtM) solution for load factor improvements has proven to be prohibitively expensive and infeasible to MGBW, the concept of placing a temporary FtM grid support asset on their property for little or no cost was amenable to site management as an alternative solution to their issues.

As an additional application, the MBESS was also deployed at the Cameron Corners community in Campo, CA. This site is located in a HFTD and is heavily susceptible to PSPS during adverse weather conditions. By connecting the MBESS to undergrounded downstream critical customer loads as part of a larger microgrid, SDG&E demonstrated a potential solution for backup power during emergency response situations such as wildfires and other calamities. In anticipation of extended power outages in the future, SDG&E may energize their Cameron Corners microgrid to provide residents with continued power for water and food supply, medical and health care, vehicle fuel pumping, electronic device charging, telecommunications and fire/emergency response. Enhancing the resiliency of these communities will attribute to the accessibility of resources for affected customers. Strategic deployment of a MBESS into

HFTDs will additionally reduce the need for fossil-fueled diesel generators and subsequent GHG emissions, especially if interconnected as part of a solar-powered microgrid.

6.0 Project Approach

The project plan included the following tasks, designed to set up the mobile battery tests, site selection, data collection model results and draw conclusions about the MBESS's ability to meet certain use cases and any additional stacked benefits associated with a mobile application.

Task 1 - Initiation of Project Plan

- Identification of stakeholders and formation of stakeholder steering committee
- Project kick-off, development of project plan and resource requirements, and formation of SDG&E internal project team

Task 2 - Development of Project Requirements

- Fact finding from literature or other programs

Task 3 - Development of Funding Plan and Site Hosting Requirements

- Baselining current situation and practice for application at two sites
    - MGBW
    - CCM
- Development of a Funding Plan

Task 4 - Site Selection and Arrangements

- Site Selection for grid paralleling use cases (MGBW)
- Site Selection for grid islanded use cases (Cameron Corners) in HFTD territory.

Task 5 - Preparation of RFP for Procuring Competitive Bids to Supply Mobile Battery

- Develop Requirements for the RFP
- RFP Release, Proposal Evaluation and Vendor Selection

Task 6 - Preparation of Use Cases and Test Plan

- Preparation of Use Case(s) for MGBW
- Preparation of Use Case(s) for the CCM

Task 7 - Development of Test Set-Up and Modelling Capability Support

- Set-up test parameters and measure results from the application of peak shaving, voltage regulation and end-use demand charge reduction for MGBW facility.
- Accurately prepare test parameters and gauge outcomes that result from the application of emergency backup power duration from a MBESS.

- Identify metrics to support collecting data to test the initial benefits estimate. Also, identify metrics to judge whether the selected body of use cases was adequate to make conclusive findings and recommendations in the final analysis.

Task 8 - Execution of Demonstration

- Execution of the demonstration for the MGBW site
- Execution of the demonstration for the CCM site

Task 9 - Assimilation of Test Results

- Assimilate test data in preparation for analysis of demonstration results.
- Collect and process data from demonstration results
- Critically review, by each use case, how well the project objectives were obtained.

Task 10 - Analysis of Data and Test Results from Demonstration

- Analyze the data and other results from the demonstration to provide a basis to support development of key findings, conclusions, and recommendations for the project.
- Critically review all data to understand which use cases were successful in terms of providing cost-effective solutions for using mobile batteries and which were not successful. Determine the value proposition for each use case. Following the analysis, archive the data for future use.

Task 11 - Development of Conclusions and Recommendations

- Develop the key findings, conclusions, and recommendations for the project.
- Use the results of the data analysis task to update the initial benefits analysis and to formulate key findings, conclusions, and recommendations for the project.
- Confirm the success or failure of each use case that was demonstrated. Develop the value proposition for the individual use cases and the collective value proposition for all use cases in terms of stacked benefits.

Task 12 - Preparation and Implementation of Tech Transfer Program for both deployment sites

- Develop, prepare and implement a tech transfer plan
- Identify the process for transferring project results into practical use by SDG&E, as well as by other potential users.
- Indicate which tech transfer activities may have already taken place during the demonstration work, which will be done in the closing of the project, and which will need to be done by the stakeholders after the project ends.
- The tech transfer plan should be consistent with the recommendations made regarding which use cases should and should not be pursued commercially.

Task 13 - Perform Interim Project Reporting

- Perform required interim reporting activities on a regular basis, throughout the life of the project.

Task 14 - Development of Equipment Disposition Plan

- Define and implement a disposition plan for equipment and software used in the project

Task 15 - Preparation of the Comprehensive Final Report Capturing Description of the Work, Results, Conclusions, Accomplishments Relative to Metrics, Recommendations Regarding Commercial Adoption, and Tech Transfer Plan

- Complete a final report for the project, suitable for filing with CPUC and public release
- Consolidate all relevant project milestones, events, task outcomes, conclusions, and recommendations into a single, comprehensive final report.
- The report shall also include a good summary of the final benefits estimate and value proposition for the project.
- This report will be the primary and most complete tool for tech transfer of project results to prospective users.
- The report should be prepared as a draft for review by the stakeholders followed by a final version incorporating stakeholder feedback.

6.1 Baseline Studies/Fact Finding

6.1.1 Initial Benefit Estimate and Value Proposition

EPIC-3, Project 7 was initially targeted to help improve safety, advance power system infrastructure, and improve system operations for the customers' benefit. Implementation of a mobile battery can, therefore, provide benefits in the following areas specified in SDG&E's application to CPUC for approval of EPIC-3 investments.

1) **Improved Safety:** Public and employee safety are very high priorities for SDG&E. Each project, as a minimum, should comply with existing safety policies and not result in any safety violations or safety incidents. In certain cases, a project can minimize safety risk by either reducing probability of a safety incident, mitigating the severity of an incident, or enabling early detection that allows correction/prevention of unsafe situations.
2) **Improved Reliability and Power Quality:** Two goals of power system modernization are to improve the level of reliability and to optimize the quality of power as seen by the customer. Higher reliability means reducing the occurrences of outage and reducing the duration of outages when they do occur. Improved power quality means reducing the disturbances seen in the power itself, such as voltage variation, flicker, and harmonic content in the power waveform.
3) **Improved Performance of the Power System:** Improved system operations and performance (i.e., system electrical efficiency) will help reduce electrical losses in the system, such as reductions in resistive losses associated with current flow through the conductors and reductions in transformer electrical losses.
4) **Lower Greenhouse Gas Emissions:** Advanced infrastructure can help reduce electrical system losses, which in turn will reduce the need for electric generation. Less generation means reduced

greenhouse gas emissions (GHG). Additionally, infrastructure such as battery storage can store electricity from renewable or other low-emission sources and offset consumption during periods where higher-emission sources would be required, also reducing GHGs.

5) **Lower Operating Costs and More Efficient Use of Customer Monies**: Customers can see lower costs on their utility bill through peak demand reduction and shifting utility-delivered consumption to lower-cost time periods. Furthermore, reductions in peak load can defer or eliminate certain utility infrastructure investments and avoid electric procurement and generation costs, ultimately mitigating any potential rate increases.
6) **Economic Development:** A secure source of low-cost, high-quality, reliable electric power is essential to economic development and to retain and attract businesses in California. The purpose of EPIC funding is to support investments in research and development projects that benefit electric utility customers. The utility EPIC activities are limited by the EPIC ordering decisions to precommercial demonstrations of technologies and integration solutions that provide benefits to customers by promoting greater reliability, lower costs, increased safety, and other designated benefits.
7) **Ancillary Benefits:** Finally, EPIC-3 Project 7 will create new knowledge, lessons learned, and potential recommendations on the incremental benefits achieved and incremental costs incurred by rotating a mobile multipurpose battery into different applications and locations. Incremental benefits can include increased utilization of the asset, flexibility to assist with more than one use case, and ability to react to real-time situations more effectively. Incremental costs can include up-front equipment costs, up-front setup and administrative costs (such as for interconnection and/or certification), transportation costs, and ongoing operations and maintenance costs. The final evaluation will need to consider incremental cost-benefit analysis of the project to assess whether a mobile-multipurpose battery solution is cost effective and viable.

As part of pre-demonstration activities, SDG&E estimated the value proposition for deployment of a MBESS:

Value Propositions – SDG&E Customer Programs

SDG&E customer rebate and incentive programs are bound by constraints for permanent and/or stationary equipment. However, in alignment with SDG&E Customer Programs commitment to serve the needs of its disadvantaged community (DAC) customers as it pertains to air pollution reduction, this project demonstration contributes to air quality improvement for the Port District including MGBW, which is adjacent to some of SDG&E's most concentrated DAC areas. The MBESS would also contribute to cleaner air anywhere it offsets emissions from other energy sources.

Value Propositions – State Initiatives

Demonstration of the multipurpose mobile battery supports the state initiative to reduce the emission of GHG by providing augmentation for current emergency back-up solutions (i.e. diesel generators) through alternative energy solutions such as MBESS. Furthermore, assisting with the reduction of GHG emissions in the electricity sector at the lowest possible cost, supporting the Loading Order and contributing to goals related to low emission vehicles and transportation, economic development, and efficient use of ratepayer monies.

AB 628, signed into law by Governor Brown on October 11, 2013, authorizes the San Diego Unified Port District, in conjunction with San Diego Gas & Electric Company, to prepare an Energy Management Plan (EMP) to reduce air emissions and promote economic development in the District. In doing so, the State of California declared the following:

- That it seeks to “promote efficient use of low-cost, low-emissions energy sources in the operations of ports and harbors;”
- That ports offer a unique opportunity to “reduce vehicular emissions of GHG and criteria pollutants;”
- That it “encourages the development of new businesses and retention of existing business within port boundaries;”
- That “businesses located within port and harbor districts may benefit through greater stability in the cost of energy services;” and
- That investor-owned utilities, such as SDG&E, are in the “optimal position" to work with ports to provide energy-related service alternatives and programs.

AB 628 aligns with the State’s broader objective of combating climate change through GHG reductions and energy regulations.

- Governor Schwarzenegger, through Executive Order (EO) S-3-05 and Assembly Bill (AB) 32, required the State to reduce its GHG emissions by 80% below 1990 levels by 2050.
- Governor Brown further required, through EO B-30-15 and codified through Senate Bill (SB) 32, the State to reduce its GHG emissions by 40% below 1990 levels by 2030.
- The State went even further with SB 350, which required that energy efficiency be cumulatively doubled by 2030 and that 50% of electricity generated and sold must come from renewable energy resources by 2030.
- Governor Brown, through EO B-16-2012, also set a goal of having 1.5 million zero emission vehicles on the road by 2025.

California Air Resources Board Shore Power Regulation (CARB)– Section 93118.3 Airborne Toxic Control Measure for Auxiliary Diesel Engines Operated on Ocean-going Vessels At-Berth in a California Port

A cruise ship that visits a California Port five times or more in a calendar year fall under this regulation, and has requirements for 2014, 2017 and 2020.

2014 - At least 50% reduction of onboard auxiliary diesel engine power generation while docked at berth

2017 - At least 70% reduction of onboard auxiliary diesel engine power generation while docked at berth

2020 - At least 80% reduction of onboard auxiliary diesel engine power generation while docked at berth

Value Propositions – HFTD Emergency Support

SDG&E's tier 3 region consists of areas on the CPUC Fire-Threat Map where there is an extreme risk, including likelihood and potential impacts on people and property, from wildfires associated with overhead utility power lines or overhead utility power line facilities also supporting communication facilities. Tier 3 is distinguished from Tier 2 by having the highest likelihood of utility-associated fire initiation and growth that would impact people or property, and where the most restrictive utility regulations are necessary to reduce utility fire risk (taken from Sec 2.8. in TMC1320).

Demonstration of the multipurpose mobile battery may not only support State initiative to reduce GHG emission but also introduce a capability for enhancing wildfire mitigation resource resiliency, specifically in-line with Community Resource Center (CRC) back-up power solutions. This proposition has the potential to expand integration with renewable generation such as solar, creating a medium scale microgrid to carry larger load pockets within those communities during extended emergency power outages (8 hours or longer).

6.1.2 Initial Selection of Metrics

EPIC-3 Project 7,Module (1) initially identified the following benefit areas and metrics shown in Table 1, below.

Table 1: Initial Identification of MBESS Benefit Areas and Metrics

Benefit	Description	Criteria and Metrics	Desired Targets
Safety	This project is not expected to reduce any existing safety risk. However, this project should comply with existing safety policies and regulations, including transportation, fire, and electrical safety, and not result in safety violations or safety incidents. Additionally, elimination of diesel exhaust emissions providers cleaner air for all to breathe, improving community health.	• Confirm compliance with the following safety-related policies and regulations: • Transportation regulations • Fire safety codes • Electrical safety codes (Rule 21) • Utility interconnection • Local permitting requirements • Other safety-related requirements identified during the project • Investigate and report any safety incidents that occur during the installation, operation, or transportation of the mobile battery.	• The target is 100% compliant and zero injury incidents.
Improved Reliability and Power Quality	Higher reliability occurs by reducing the occurrence and the duration of outages and reducing incidents where	• Track number of hours that mobile battery is connected and available to perform value-added reliability services for equipment	• Successfully black start and power downstream

	power disturbances impact the site's operations. The mobile battery project can provide a level of protection against outages and power disturbances both by being online and available (i.e. as an insurance policy, like an uninterruptible power supply) and by actual mitigation of the impact of an outage or power disturbance (i.e. providing full or partial backup power during an outage and/or potentially avoiding equipment damage by allowing for a controlled shutdown.)	deemed critical or essential by the customer (i.e. customer would be willing to pay money for some sort of backup protection.) • Track the percentage of time that the battery, while connected, is available to perform reliability services. • Track number of events avoided or mitigated, type and duration of these events, and the operational benefit of avoiding or mitigating the event. • Where feasible, conduct tests to assess battery effectiveness at providing reliability services and track results of the tests.	customer loads demonstrating PSPS outage mitigation.
Improved Performance of the Power System	Improved system operations and performance (i.e., system electrical efficiency) will help reduce electrical losses in the system, such as reductions in resistive losses associated with current flow through the conductors and reductions in transformer electrical losses.	• Track the peak demand seen at the utility connection point without the battery and, based on battery discharge, project the peak demand that would have occurred without the battery. • Track the peak current seen at the utility without the battery and, based on battery discharge, project the peak current that would have occurred without the battery.	• Visible reduction in circuit loading and current when using MBESS
Lower Greenhouse Gas (GHG) Emissions	Battery storage can help reduce electrical system losses, which in turn will help reduce the need for electric generation, especially from fossil fueled "peaker" plants. Less generation means fewer GHGs. Additionally, infrastructure such as a battery can store electrically from renewable or other low-emission sources and offset	• Demonstrate the difference in CO2 emissions from grid power produced during high renewable times and low renewable times. • Identify GHG reductions that deployment of a MBESS can support	• Demonstrate GHG reduction from use of MBESS

	consumption during periods where higher-emission sources would be required, also reducing overall GHG emissions.		
Lower Operating Costs and More Efficient Use of Customer Monies	Customers can see lower costs on their utility bill through peak demand reduction and shifting utility-delivered consumption to lower-cost time periods. Furthermore, reductions in peak load can defer utility infrastructure investments, ultimately mitigating potential rate increases. The project can reduce customer bills through improvement of load factor and reduction of the peak load requirement as well as shifting load to lower cost time periods. Additionally, a reduction in peak load on constrained circuits can lead to deferral of certain capital expenses needed to upgrade distribution infrastructure (though these benefits and costs are very circuit specific).	• Track customer load profile at the utility connection point with the battery and, based on battery discharge, project the load profile that would have occurred without the battery. • Provide an annual bill estimate for both profiles to estimate customer bill savings. • Track the peak demand seen at the utility connection point with the battery and, based on battery discharge, project the peak demand that would have occurred without the battery. • Desired target: Reduce customer energy bill charges through MBESS deployment. Demonstrate circuit peak reduction to demonstrate MBESS use to facilitate grid capital infrastructure deferrals.	• Reduce customer energy bill charges through MBESS deployment. • Demonstrate circuit peak reduction to demonstrate MBESS use to facilitate grid capital infrastructure deferrals.
Economic Development	A secure source of low-cost, high-quality, reliable electric power is essential to economic development and to retain and attract businesses in California. Potential energy and cost savings from avoided procurement and generation costs, peak load reduction and customer bill savings can contribute to economic attractiveness.	• Reduce business cost with energy bill savings and increased reliability	• Visible customer energy cost savings through peak shaving and improved reliability for businesses in the HFTD / PSPS-prone areas.

Disadvantaged Communities (DACs)	The CPUC has encouraged EPIC program administrators to seek projects that benefit disadvantaged communities, including rethinking the location of clean energy technologies to benefit burdened communities. Furthermore, specific project benefits may have direct benefit to the local community (i.e. reduced source emissions when the source is physically located in the disadvantaged community, such as using a mobile battery instead of a diesel generator; GHG emission reductions due to electrical savings are attributed to the generation source, which may not be in the disadvantaged community).	• The project can operate in a disadvantaged community and show investment in these communities. The project may achieve GHG benefits that support state goals and may reduce emissions from sources located within the disadvantaged community.	• Demonstrate reduction in GHGs emitted by MGBW through deployment of a MBESS in their operations and reduction in generator runtime hours when MBESS is deployed for resiliency purposes.
Incremental Benefits of a Mobile Solution	A MBESS solution will accrue incremental and stacked benefits by being rotated through a variety of sites, minimizing MBESS idle time and providing a variety of benefits to multiple customers, including SDG&E. Incremental costs for a mobile battery solution include up-front equipment costs, up-front setup and administrative costs, transportation costs, and incremental operations and maintenance costs. The project can achieve incremental benefits in asset utilization and accrue incremental benefits. The incremental benefits can be compared to incremental	• Track the number of operating hours at the primary site and number of operating hours at the secondary site and report the increase in utilization associated with the mobile solution. • Estimate the cost benefit of the increased asset utilization. • Track the incremental benefits achieved with the mobile battery at secondary sites. • Track the incremental costs associated with a mobile battery. • Evaluate an incremental return on investment (ROI) by considering incremental benefits and incremental costs.	• Increased ROI of the MBESS by semi-permanent deployment in multiple locations.

	costs to determine a return on investment for the mobile solution.		

6.2 Description of Pre-Commercial Demonstration

6.2.1 Location

SDG&E initially planned to deploy the MBESS for Module 1 at the Port of San Diego Cruise Ship Terminal to demonstrate the above-mentioned benefits shown in Table 1. As a consequence of site negotiations, the Cruise Ship Terminal was determined to not be a viable test site within the timeframe of the EPIC-3 cycle. The SDG&E team then expanded the search to sites which allowed for originally intended use case testing as closely as possible. In the expanded search, SDG&E considered additional sites of the following type:

- Port / marine duty with varying site baseloads due to ships cold ironing while in port.
- Local higher educational institutions with variable site loads due to events
- Existing / in-progress community microgrid projects
- PSPS backup / support functions
- Substation and grid infrastructure construction support

Ultimately, two new sites were selected which allowed SDG&E to test various use cases as originally intended, MGBW and CCM, a site which provided a different set of use cases to expand the MBESS stacked benefits.

6.2.1.1 Marine Group Boat Works

MGBW is a full-service marine vessel hauling, refitting, repair and construction facility in Chula Vista, CA. MGBW embraces the importance of preserving the environment and has a longstanding track record of green initiatives which allow them to stay on the forefront of conservation for both their community and industry. These initiatives include:

- installation of a curbed stormwater drain which captures and monitors stormwater discharge to be clear of hazardous materials
- adherence to Port of San Diego regulations and guidelines for removing vessels from the bay before major maintenance and repair work is completed
- installation of solar PV at their National City location
- Use of electric vehicles and electric forklifts for local errands and boat yard work

MGBW staff were excited to engage with SDG&E on this demonstration project and were extremely accommodating to the test team, providing space to deploy equipment, tenant coordination and outage notification and information on historical electrical usage and boat services performed.

From an electrical infrastructure and loading perspective, this site proved to be an ideal test site to deploy the MBESS and test its grid paralleling functions. The site receives their main SDG&E service in the middle of the boat yard, with a dedicated 12kV/480V stepdown transformer. From there, the service feeds two main meters, one for main facility operations and the other for shore power and construction power. There is another 240V/120V transformer and meter fed from the main service entrance, but the load on that meter is minimal.

Daily construction activities such as welding, grinding, cutting, pumping, and lifting as well as “cold ironing” (plugging in ships when in port) provide an electricity usage profile which is highly variable – with high demand peaks during normal work hours of 7:30am – 4:00pm and a highly variable baseload depending upon the number of ships plugged in and work being performed.

The MBESS was ultimately connected to the 480V side of the site transformer and functioned in front (FtM) of the existing site meters due to contracting and liability issues and performed its functions on behalf of SDG&E’s existing grid. While the customer’s existing bills remained the same with this configuration, potential behind the meter (BtM) savings were also simulated and presented to the customer as to the potential monetary benefits of installing a MBESS behind their existing meters.

6.2.1.2 Cameron Corners Microgrid

As part of its ongoing efforts to reduce wildfire risk and the impact of Public Safety Power Shutoffs (PSPS) during adverse weather conditions, SDG&E is undergrounding critical customers to reduce susceptibility to high winds, installing infrastructure to facilitate the connection of alternate generation and, in some cases, installing full microgrids. CCM is a prime example of all the above activities and a perfect testbed for interconnecting a MBESS, supporting generators and carrying critical downstream loads in a simulated PSPS. The full CCM consists of solar photo-voltaic (PV) panels and permanent energy storage, allowing several key community facilities, including a school, library, health clinic, telecommunications hub, fire station and gas station to remain powered during a PSPS. However, for this test it served as an available, managed site with which to test MBESS connection and is typical of the kind of infrastructure upgrades around SDG&E service territory which would allow for quick connection of backup generation sources.

MBESS testing at CCM focused on demonstrating the blackstart and islanding capabilities of the demonstration unit, not only bringing up downstream load after an outage, but also the unit’s ability to function in coordination with diesel generators that are more typically used to provide temporary power to a grid circuit after an outage.

6.2.2 Use Cases

To effectively demonstrate the stacked benefits of this MBESS, grid-paralleling and islanded mode use cases were executed as part of this project. Table 2 describes all the original use cases demonstrated as part of this EPIC demonstration project.

Table 2: Initial MBESS Use Cases

Use Case	Grid Paralleling / Islanding	Description
Safety	Both	MBESS is able to completely shut down after engaging the emergency stop (E-Stop) button. This function promotes overall site safety. MBESS operation is also significantly quieter and cleaner than operation of equivalent diesel generators, allowing for clearer communication and air to breathe.
Load Factor Correction	Paralleling	Sites with poor load factor, high demand peaks and relatively low baseload can benefit from strategic reduction of momentary high demand peaks, thereby improving load factor and strain on the grid.
Load Smoothing	Paralleling	The MBESS will control the rate of change of customer loads reducing strain on grid infrastructure.
Demand Peak Shaving	Paralleling	The MBESS will place a cap on site peak loads, reducing overall demand required from the utility. Peak shaving can be deployed to remove momentary spikes in demand or limit demand to a preset level during strategic times (e.g. TOU peak periods)
Demand Response	Paralleling	Discharging the MBESS to the grid can mimic traditional demand response programs, without interrupting the customer's operations. Pre-set amounts of capacity can automatically be dispatched on strategic circuits during peak congestion times.
Deferral of utility infrastructure investments	Paralleling	Strategic MBESS deployment can add temporary capacity to load constrained circuits while more permanent infrastructure upgrades are planned and constructed. Similarly, MBESS deployment can be strategically deployed to eliminate the need for circuit infrastructure upgrades, if driven by specific load peaks.
Load Blackstart	Islanded	When attached to a downstream load, the MBESS can blackstart loads of appropriate size without the need of additional generating resources.

6.2.3 Equipment Requirements

The equipment used in this EPIC demonstration project supported use of a large MBESS, a 362kW / 1499kWh lithium-ion battery securely mounted to a trailer. Table 3 outlines the equipment requirements for the MBESS deployment as part of this EPIC demonstration.

Table 3: MBESS Equipment Requirements

Equipment	Requirements
MBESS	Battery: • 362kW/1499kWh Capacity • UL 1642 Compliant Lithium Ion Cells • Closed-loop onboard thermal management system • NEMA 3R / IP66 Enclosure Inverter: • 86A Max Continuous Output Current • 860-960V DC Input Voltage Range • 360-555V AC Output Voltage Range • 60Hz • 3 phase, 3-Wire Site Controller • Modbus TCP/DNP3/Rest API Trailer • 48’ Aluminum Gooseneck Trailer • (3) Emergency Stop Buttons • 600V / 800A NEMA 3R AC Disconnect and Generator Tap Box • Grounding Loop
Site Meter	Meter – provides reference voltage and current to MBESS, and is necessary for grid-paralleling functions • Pre-approved meter from MBESS manufacturer • Ethernet Port for communication with site controller
Transformer	A Transformer will be needed if the MBESS is connected to any other voltage than 480V 3phase. For this project, a

Equipment	Requirements
	12kV/480V 3 phase Delta/Wye Grounded Transformer was used to connect the MBESS to the grid at 12kV.
Potential Transformers (PTs)	While the MBESS Site meter needed reference voltage from 3 phases and ground, the meter was able to handle 480V, so no PTs were needed. Reference voltage at 480V was fed through a 20A breaker directly to the ports on the back of the meter.
Current Transformers (CTs)	The MBESS site meter required a CT around each power phase. CTs used had a 1000:5 turndown ratio, which kept current reference in line with Site Meter specifications.
I-Line Panels	1200A rated I-Line panels with camlocks were necessary during this test deployment to split the 480V power coming from the low side of the transformer to the MBESS camlocks via a 600A breaker, to provide reference voltage for the site meter (20A breaker) and to power a 30A Mill Panel (30A breaker) for site power.
Mill Panel	A 30A Mill Panel was used to step down 480V 3 phase power to single phase 120 to provide power to the site meter, computers, printers, etc.
Controller	A gateway was used as a controller in order to send commands to the battery and change modes of operation.

6.2.4 Software Requirements

The MBESS came equipped with its own interface software, providing both local access and web-based limited control but needed a gateway in order to have full programming control over the battery. This software was also capable of over-the-air updates, and depending upon desired functionality, new modes of operating, such as microgrid control, could be remotely unlocked as needed.

6.2.5 Supporting SDG&E Infrastructure and Data Requirements

The MBESS in this EPIC project was connected in both grid-paralleled and islanded modes, so SDG&E meter and SCADA data was crucial in validating proper operation of the unit.

When grid-paralleled at MGBW, the MBESS was connected in front of the existing site meters, so site meter data was obtained to verify loads seen by the site meter and MBESS. Additionally, substation circuit loading data was obtained to observe any visible drops from MBESS deployment.

When deployed at the CCM, the MBESS setup was connected to the existing infrastructure already in place, including terminators, Trayer switches and transformers. Through operating positions of the Trayer switch, downstream loads were able to be disconnected from the larger grid and switched over to demonstrate the black start capabilities of the MBESS.

6.2.6 Customer Acceptance Testing

Upon delivery of the MBESS unit, SDG&E performed a thorough, multi-day acceptance test of the equipment received at its Skills Training Facility located in San Diego, CA. This equipment was set up as shown in the following one-line diagram, including a grounding transformer and load bank to provide necessary MBESS grounding and simulate loads on the battery, respectively:

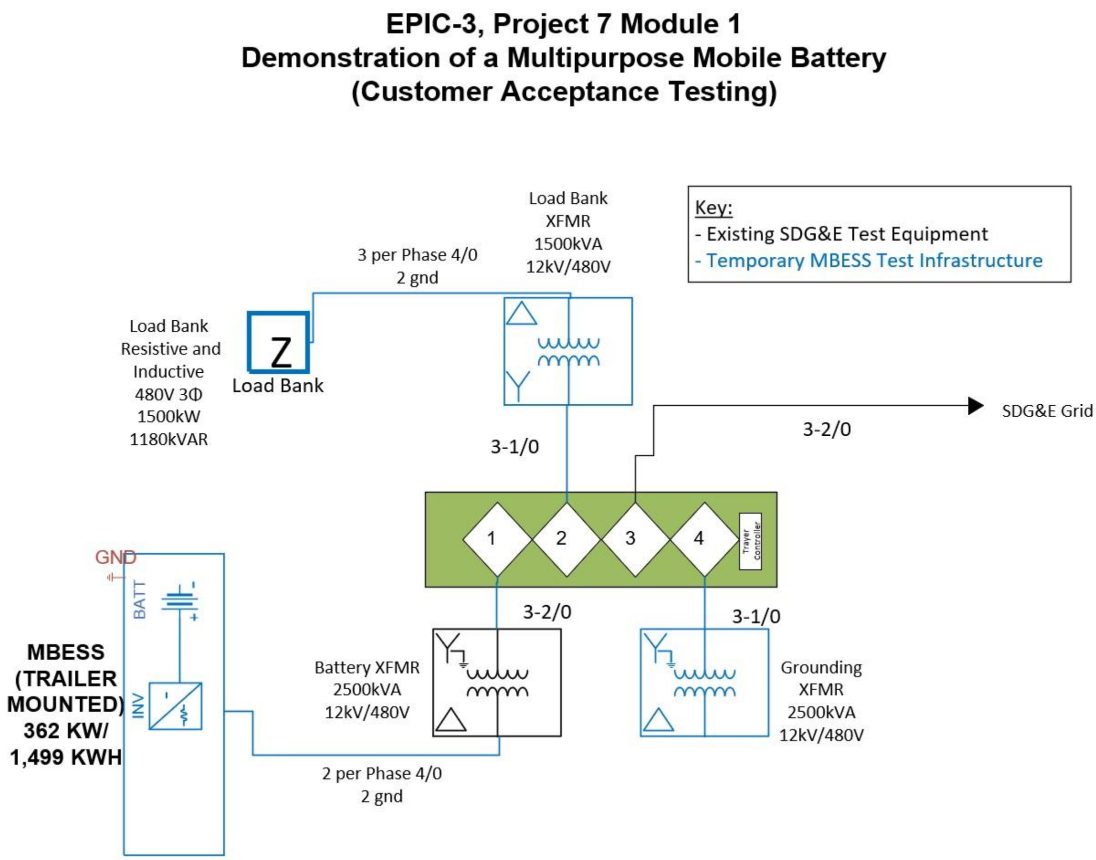

Figure 1: MBESS Customer Acceptance Testing One Line Diagram

The MBESS unit was then taken through the Customer Acceptance tests listed in Table 4.

Table 4: MBESS Customer Acceptance Test Results

Test No.	Test	Expected Results	Pass/Fail
1.	Anti-islanding Mode – Standby	Inverter trips offline when grid power not detected	Pass
2.	Anti-islanding Mode – Parallel – Charging	System will not island and PCS will disconnect per IEEE 1547 AC Breakers open	Pass
3.	Anti-islanding Mode – Parallel – Discharging	System will not island and PCS will disconnect per IEEE 1547	Pass
4.	Parallel Mode – Local	Verify MBESS runs with parallel mode enabled	Pass
5.	Parallel Mode Constant Real Power – Local – Charging	Verify MBESS runs with parallel mode enabled	Pass
6.	Parallel Mode – Constant Reactive Power – Local	Verify MBESS runs with parallel mode enabled	Pass
7.	Parallel Mode – Four Quadrant Test	Verify MBESS reacts in all quadrants to specific setpoints	Pass
8.	Parallel Mode – Target State of Energization (SOE) Charge – Local	Target SOE Mode Enabled PCS to charge at -362kW to target SOE	Pass
9.	Parallel Mode – Target SOE Discharge – Local	PCS to discharge at 362 kW to Target SOE	Pass
10.	Island Mode – Blackstart Enabled	First set of tests: Load bank at 300kW, 200kW, 100kW, 0kW, 200kW Second set: 181kW @ PF=0.5, 363kW @ PF = 0.84, 543kW @ PF = 0.77	Pass
11.	Emergency Stop (E-Stop)	Verified all E-stops operate as intended	Pass

Test No.	Test	Expected Results	Pass/Fail
12.	Uninterruptible Power Supply (UPS)	Verified UPS operates as intended after loss of power	Pass
13.	Human Machine Interface (HMI) Customer Login and Command Operation	Ensured successful customer login and command operation	Pass

Tests which required a site meter for voltage and current reference were unable to be performed at this time, as a manufacturer's approved site meter was unavailable at the initial check out.

6.2.7 Test System Design

Various testing systems were used to support the MBESS deployment and confirm data gathered by the Site Controller.

To provide site meter measurements to the MBESS site controller, a power quality and revenue meter (PQ meter) was installed as part of this test. Current transformers (CTs) were connected around each of the three phase 480V lugs in the site transformer (Figure 2) to monitor net grid-facing current between the MGBW loads and MBESS charge/discharge. Leads on each of the three 480V phases and ground were also fed into the PQ meter to provide reference voltage for the MBESS and site controller. The PQ meter was then connected to the MBESS site controller via an ethernet cable.

Figure 2: MBESS Connection to MGBW Transformer

As a double check on voltage, current and other power quality parameters seen by the site meter, SDG&E connected a portable PQ Meter to the same transformer voltage lugs and placed the CTs around the same cables to confirm current flow in and out of the system. The entire test setup can be seen in Figure 3.

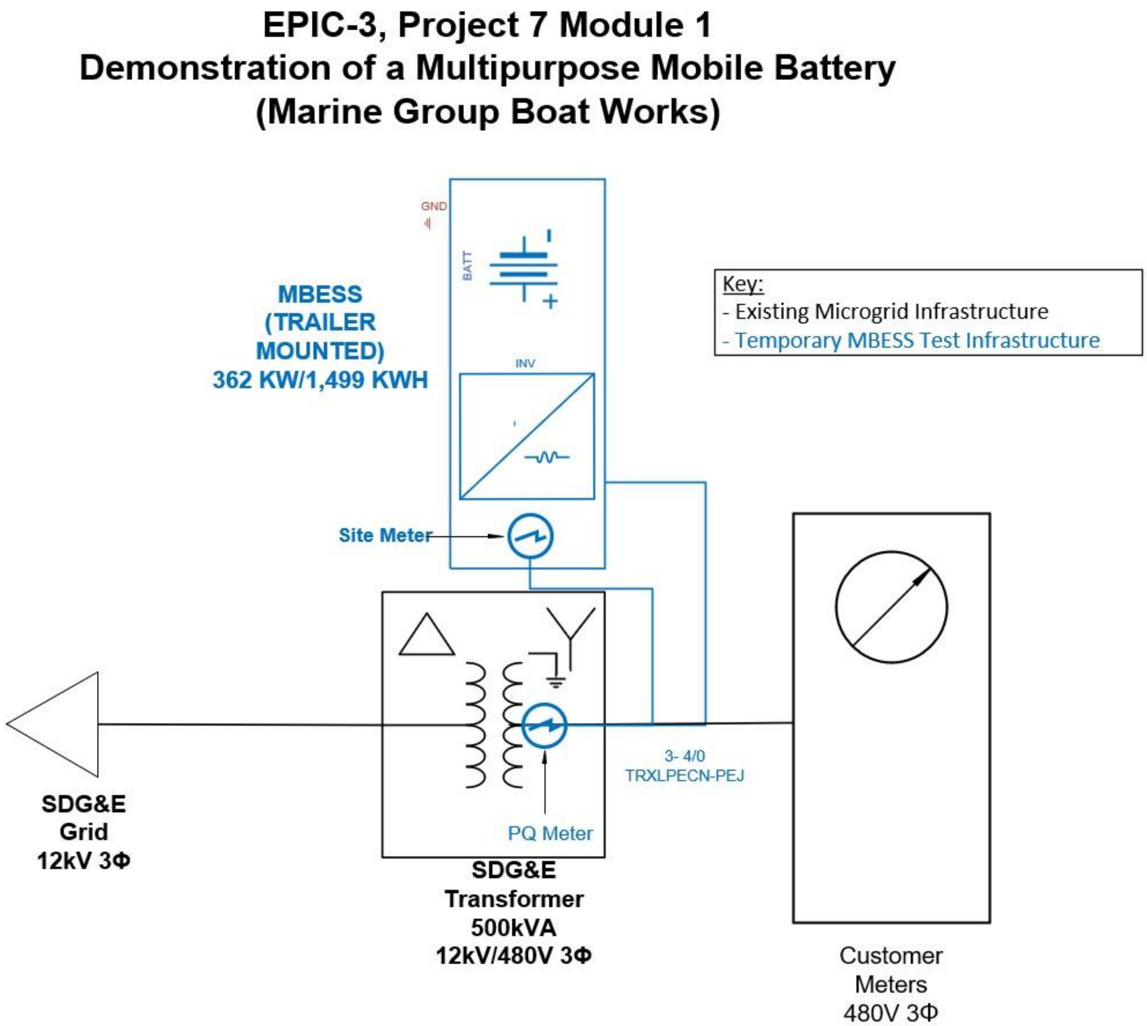

Figure 3: Marine Group Boat Works One Line Diagram

SDG&E customer site data was also obtained for the testing week to verify the loads seen by both the Site Meter/Controller and the PQ meter.

Substation circuit loading data (one second intervals) was also used to verify the MBESS's impact on circuit loading.

At Cameron Corners, PQ meters as well as data gathered from the MBESS site controller were used to verify operation of the MBESS, associated generators and site loads. Substation data (one-minute intervals) were used to verify the MBESS's impact on circuit loading. The entire system setup for the MBESS deployment at CCM can be seen in Figure 4.

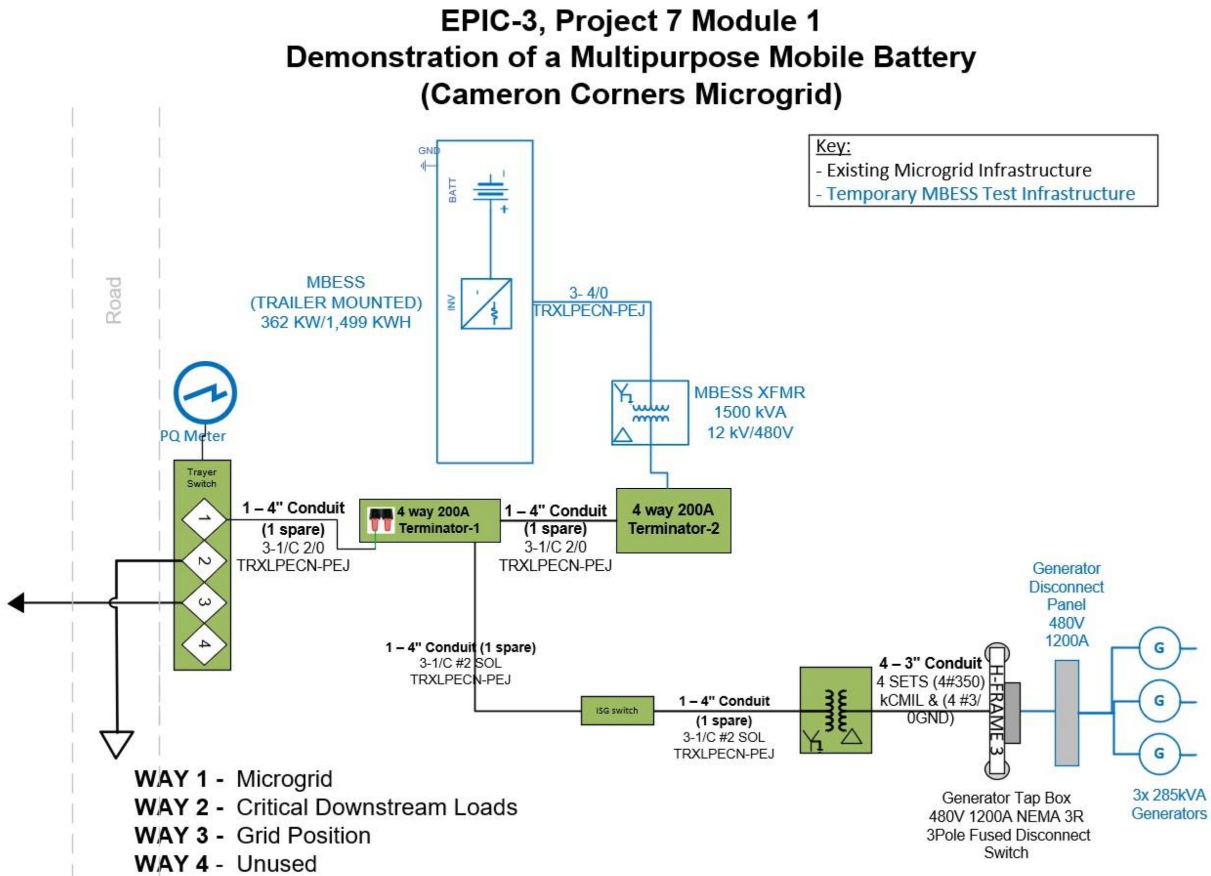

Figure 4: Cameron Corners Microgrid One Line Diagram

6.2.8 Updated Metrics

After selecting the MBESS site and deploying the equipment, the following changes listed in Table 5 were made to the updated metrics and benefits for the project to more accurately capture potential benefits from the MBESS deployment.

Table 5: Updated MBESS Metrics and Benefits

Benefit	Description	Criteria and Metrics	Desired Targets
Safety	Use of a MBESS instead of traditional mobile diesel generators can improve job site safety by reducing the risk, however unlikely, of a fuel spill and by	• Decrease the potential for a diesel fuel spill through use of a MBESS rather than traditional diesel generators	• Demonstrate that a MBESS can perform the function of a diesel generator so on-site fuel storage can be reduced

Benefit	Description	Criteria and Metrics	Desired Targets
	decreasing ambient noise allowing for clearer job site communication.	• Calculate reduction in job site noise pollution by using a MBESS instead of diesel generators	• Calculate a meaningful decrease in job site noise pollution
Improved Reliability and Power Quality	Currently diesel generators provide an adequate solution for SDG&E when providing grid support during emergencies. However, because of their emissions, they are limited to emergency functions only. A MBESS can provide emergency backup, supporting reliability, but also can support broader grid reliability through peak shaving, load smoothing, voltage and frequency regulation, and by prolonging life of grid equipment.	• Ensure that MBESS can act as a backup power source, capable of black starting downstream loads like a diesel generator. • Demonstrate peak shaving and load smoothing abilities • Calculate increase on grid infrastructure lifespan based on circuit amperage reductions and corresponding equipment temperature reductions • Calculate dollar value of grid equipment lifespan increases • Calculate dollar value of grid / circuit upgrades deferrals	• Successfully black start and power downstream customer loads demonstrating PSPS outage mitigation. • Show peak load shaving capabilities and load smoothing thresholds • Grid equipment lifespan extensions are real and meaningful • Value calculations for lifespan increases and grid infrastructure upgrade deferrals demonstrates value to SDG&E
Improved Performance of the Power System	Improved system operations and performance (i.e., system electrical efficiency) will help reduce electrical losses in the system, such as reductions in resistive losses associated with current flow through the conductors and reductions in transformer electrical losses.	• Calculate the peak current reduction for the MBESS deployment • Determine the percentage of reduction the MBESS is of a full circuit loading	• Visible reduction in circuit loading and current when using MBESS
Lower Greenhouse	Using a MBESS instead of diesel generators will provide reductions in	• Calculate the diesel fuel savings (gallons	• Show a reduction in diesel fuel

Benefit	Description	Criteria and Metrics	Desired Targets
Gas (GHG) Emissions	localized emissions at sites needing grid resiliency.	and cost) associated with a switch to MBESS • Convert diesel savings to yearly metric tons of CO_2e • Calculate CO_2e reduction value on California's Cap and Trade market.	consumption for grid resiliency support. • Determine value of emissions reductions on California's Cap and Trade market.
Lower Operating Costs and More Efficient Use of Customer Monies	Using a MBESS to support grid upgrade deferrals provides real value to SDG&E, money that would otherwise be spent on infrastructure upgrades. Because of the mobile nature of a MBESS, strategic deployment based on SDG&E's grid needs assessment can push out capital upgrades, which would save or defer use of ratepayer dollars. This value can be calculated and can be factored into the lifecycle cost of a MBESS for SDG&E. Ideally, it could make MBESS a more financially advantageous investment for SDG&E to meet its grid resiliency needs than the more traditional diesel generators.	• Calculate the 10 year lifecycle cost of a MBESS purchase vs. a diesel generator rental model, currently employed by SDG&E. Include upfront costs of the MBESS purchase, ongoing and yearly costs and potential revenue streams from other MBESS functions such as grid upgrade deferrals and CAISO market functions.	• Demonstrate a greater ROI for a MBESS vs. a diesel generator • Demonstrate positive value from partial participation in CAISO market functions.
Economic Development	Should SDG&E choose to procure additional MBESS to support grid resiliency and grid infrastructure upgrade deferrals, this will generate a local market for these units. Not only will it draw awareness to such a product and its flexibility, but also it will attract jobs associated with the supply, setup, operation and maintenance of the MBESS	• Calculate the number of MBESS needed to fully defer SDG&E's planned grid upgrades between 2021-2030. • Calculate the value of local market investment required to procure MBESS for	• Generate a significant local market investment in MBESS technology

Benefit	Description	Criteria and Metrics	Desired Targets
		grid upgrade deferrals.	
Disadvantaged Communities (DACs)	The CPUC has encouraged EPIC program administrators to seek projects that benefit disadvantaged communities, including rethinking the location of clean energy technologies to benefit burdened communities. Furthermore, specific project benefits may have direct benefit to the local community (i.e. reduced source emissions when the source is physically located in the disadvantaged community, such as using a mobile battery instead of a diesel generator; GHG emission reductions due to electrical savings are attributed to the generation source, which may not be in the disadvantaged community).	• The project can operate in a disadvantaged community and show investment in these communities. The project may achieve GHG benefits that support state goals and may reduce emissions from sources located within the disadvantaged community.	• Demonstrate SDG&E's increased ability to support GHG reductions in DACs through deployment of a MBESS in their operations and reduction in generator runtime hours when MBESS is deployed for resiliency purposes.
Incremental Benefits of a Mobile Solution	When compared to the traditional resiliency solution (a diesel generator), a MBESS solution will accrue incremental and stacked benefits by being relocated to a variety of sites and perform a variety of functions, minimizing MBESS idle time and providing a variety of benefits to SDG&E. ROI and long-term benefits have been quantified in the other benefit areas above.	• Demonstrate increased flexibility in MBESS deployment vs. traditional diesel generators • Evaluate additional potential value generation opportunities for a MBESS vs. traditional diesel generators • Identify any additional benefits associated with using a MBESS over Diesel generators.	• Increased flexibility of deployment • Additional functionality successfully demonstrated by a MBESS • Quantify any additional benefits

6.2.9 Site Acceptance Testing

At MGBW and Cameron Corners MBESS deployments, the system was connected to the existing site switchgear per site interconnection schematics and energized. Readings from test, including the site meter, PQ meter and MBESS site controller were all compared to ensure metering was correctly installed and accurately calibrated.

6.2.10 Test System Integration

The MBESS project was a stand-alone operation at the MGBW site, providing all cabling, switchgear, protection and connectivity for a successful deployment and demonstration. However, at Cameron Corners, the demonstration was able to leverage permanently installed microgrid site infrastructure to connect and power downstream loads. As part of its ongoing efforts to reduce wildfire risk and the impact of PSPS during adverse weather conditions, SDG&E is undergrounding critical customers to reduce susceptibility to high winds, installing infrastructure to facilitate the connection of alternate generation and, in some cases, installing full microgrids. The Cameron Corners Microgrid site is a prime example of all the above activities and a perfect testbed for interconnecting a MBESS, supporting generators and carrying critical downstream loads in a simulated PSPS. This kind of arrangement is typical of the infrastructure upgrades found around SDG&E territory which would allow for quick interconnection of backup generation sources.

6.2.11 Execution of Demonstrations

Table 6 lists pertinent details regarding the execution of the demonstration.

Table 6: MBESS Demonstration Test Activities

Day	Details
MGBW Day 1	• Safety Tailgate • MBESS transported from original commissioning spot to MGBW • MBESS energized and main 480V AC breaker closed to energize communications • Site meter communications with site controller established • Additional test equipment delivered to the site (I-Line & Mill Panels, Cables) • Rotation check performed on the site transformer to prepare for interconnection wiring work on day 2
MGBW Day 2	• Safety Tailgate held to prepare for outage and transformer interconnection • Wiring of power cables, I-Line, Mill Panels, MBESS, CTs and reference voltage leads all set up • Outage Taken • CTs hung on transformer leads, extension plates installed to allow for MBESS interconnection. • Customer power restored • Battery taken out of storage mode, and energized

Day	Details
	• Battery charged in preparation for testing
MGBW Day 3	• Safety Tailgate • System connections set up to allow communication and control of battery • Site meter and power quality meter readings compared • Set up first test: load smoothing. • Testing not performed, as current CTs were installed backwards and provided negative readings. • Battery discharge tests performed; results observed. • System deenergized in preparation for CT polarity to be fixed. • Customer outage taken to swap CT leads • Customer power restored • Site meter readings taken to confirm proper current and power signals
MGBW Day 4	• Safety Tailgate • Battery charged to 80% SOE for days testing • Preparation for days testing. • Battery load smoothing tests performed • Battery peak shaving test performed • Battery zero load test performed • E-Stop Test Performed
MGBW Day 5-8	• Safety Tailgate • Battery charging performed to not set a new site peak. • Site tear down • Customer outage to remove test equipment from site transformer • Power Restored • MBESS and test equipment moved from MGBW to Cameron Corners
CCM Day 1	• Safety Tailgate • MBESS, test equipment, mobile transformer, generators delivered to Cameron Corners and set up in place
CCM Day 2	• Safety Tailgate • MBESS shoefly interconnected (not using permanent microgrid infrastructure) with generators to perform microgrid controller programming and testing
CCM Day 3	• Safety Tailgate • Microgrid controller programming completed

Day	Details
	• Test equipment interconnected into permanent SDG&E microgrid infrastructure behind open Trayer switch (no customer load interconnection)
CCM Day 4	• Safety Tailgate • Behind open Trayer switch, cold load pickup test performed with load bank to pre-test picking up real customer load. • Blackstart sequences of operation and protection settings finalized • Microgrid protection settings programmed into system protection devices for microgrid position of Trayer switch
CCM Day 5	• Safety Tailgate • Grid position on Trayer switch opened, downstream outage taken • Microgrid energized and MBESS issued blackstart command with generators in standby • Downstream loads closed in to be picked up by MBESS. • When battery reached minimum SOE, microgrid controller commanded generators online to carry load while battery charged. When desired SOE reached, MBESS took control of downstream loads again and generators ramped down. • Process continued for 24 hours
CCM Day 6	• Safety Tailgate • Generators and MBESS commanded off • Trayer microgrid position opened causing downstream outage • Trayer grid position is closed, and downstream loads are re-energized. • Test teardown.

6.2.12 Use Case Execution

Table 7 illustrates the execution details performed by the MBESS for each of the use cases.

Table 7: MBESS Use Case Test Results Summary

Use Case	Execution Details
Safety	E-Stop test completed in both grid-parallel and islanding modes
Load Factor Correction	Load factor re-calculated with customer interval data and site meter data while load smoothing, peak shaving and zero load tests were performed.

Use Case	Execution Details
Load Smoothing	Load smoothing tests performed as standalone – smoothing natural customer load, and at prescribed peak levels.
Demand Peak Shaving	Peak shaving tests performed as intended, both at pre-set levels and “zero-load” levels.
Demand Response	MBESS discharge at prescribed levels up to 362kW performed as intended.
Deferral of utility infrastructure investments	Substation test data pulled for duration of peak shaving and load smoothing tests.
Load Blackstart	Downstream loads successfully black started with Mobile Battery

6.2.13 Data Acquisition

In order to determine the performance of the MBESS during use case execution, the data shown in Table 8 was collected.

Table 8: MBESS Test Data Captured

Data Source	Processing Tool(s)	Data Frequency	Data Collected
PQ Meter	Microsoft Excel	1 Sample / Sec	Voltage (V), Current (A), Real Power (kW), Apparent Power (kVA), Reactive Power (kVAR), Frequency (Hz)
MBESS Site Controller	Microsoft Excel Manufacturer Web Interface	Variable Sample Rate	Battery Real Power (kW), Battery Reactive Power (kVAR), Load Real Power (kW), Battery Energy Remaining (kWh), Battery SOE (%), Target Real Power (kW), Target Reactive Power (kVAR), Frequency (Hz), Battery Export Energy (kWh), Battery Import Energy (kWh)
Customer Meter Data	Microsoft Excel	1 Sample / 15 minutes	Customer 15 min Load Data (kWh)

Data Source	Processing Tool(s)	Data Frequency	Data Collected
Substation Loading Data	Microsoft Excel	1 Sample / second	Substation Loading Data Every Second(A)

6.3 Data Analysis

Data from the equipment listed in section 6.2 above was collected and analyzed as shown in Table 9. Results of the analysis are shown in Section 7, below.

Table 9: MBESS Test Data Analysis

Test	Use Cases Supported	Data Used	Test Description
E-Stop	Safety	Battery Discharge Power (W)	Battery discharge power was monitored before and after depressing E-Stop button on MBESS trailer.
Load Smoothing	Load Smoothing	Grid Facing Load (W)	Target Site Load Rate of Change Set in MBESS controller. Grid facing load monitored before and after MBESS placed into Load Smoothing Mode. Rate of change of grid facing load calculated to assess impact of load smoothing
Peak Shaving	Demand Peak Shaving	Grid Facing Load (W)	Target Grid Facing Load set in MBESS controller. Grid facing load monitored before and after MBESS placed into Peak Shaving mode. Grid facing load monitored for compliance to set targets.
Zero Load	Demand Peak Shaving	Grid Facing Load (W)	Target Grid Facing Load set to zero in MBESS controller. Grid facing load monitored before and after MBESS placed into Peak Shaving mode. Grid facing load monitored for compliance to zero net grid facing load.
Battery Charging / Discharging	Demand Response GHG reduction	Grid Facing Load (W)	Battery charge or discharge commands sent at prescribed kW levels. Grid facing load monitored to ensure commensurate load changes are seen.

Test	Use Cases Supported	Data Used	Test Description
Black Start	Load Blackstart	Battery Power (W), Generator Power (W)	Downstream loads closed into battery placed in islanding/grid forming mode. Battery microgrid controller monitored grid frequency and injected current to maintain frequency using mobile generators if load exceeded battery capabilities. Microgrid controller also monitored MBESS SOE to switch to charge mode when minimum SOE reached. Once maximum SOE reached, generators shut off and MBESS continues to carry load as available. Repeat as necessary for 24 hours.

7.0 Project Results

MBESS testing results indicate that functional performance was successful in all benefit areas. Table 10 summarizes the results of each test.

Table 10: MBESS Project Test Results Summary

Test	Use Cases Supported	Pass/Fail	Notes
E-Stop	Safety	Pass	Battery Power drops to zero when E-Stop button depressed.
Load Smoothing	Load Smoothing	Pass	Average site load rate of change post-load smoothing was 52-72% smoother than with no load control. Also, load rate of change control was between 33% (when constrained to 166 W/s) and 152% (when constrained to 50 W/s) of set targets.
Peak Shaving	Demand Peak Shaving Load Factor Correction	Pass	Grid facing load capped at prescribed 200kW target with maximum 1.4% deviation of load target.

Test	Use Cases Supported	Pass/Fail	Notes
Zero Load	Demand Peak Shaving	Pass	Grid facing load capped at prescribed 0kW target with maximum 3000W (~1% of overall load) deviation from load target.
Battery Charging / Discharging	Demand Response GHG reduction	Pass	Battery charges or discharges at prescribed levels, adding to or subtracting from the net site load in the commensurate amount.
Black Start	Load Blackstart	Pass	Battery successfully black started downstream customer loads, microgrid controller successfully started generator spinning reserves to meet increased site loads and handed off control to generators when needing to switch to charging mode.

7.1 Results Discussion

7.1.1 Safety Use Case

A successful E-Stop test (illustrated in Figure 5) contributed to demonstration of a safety benefit when using a MBESS. The project complied with existing safety policies and regulations, including transportation, and did not contribute to any safety incidents. Should a safety issue arise stemming from use of the MBESS, it can be shut down instantaneously.

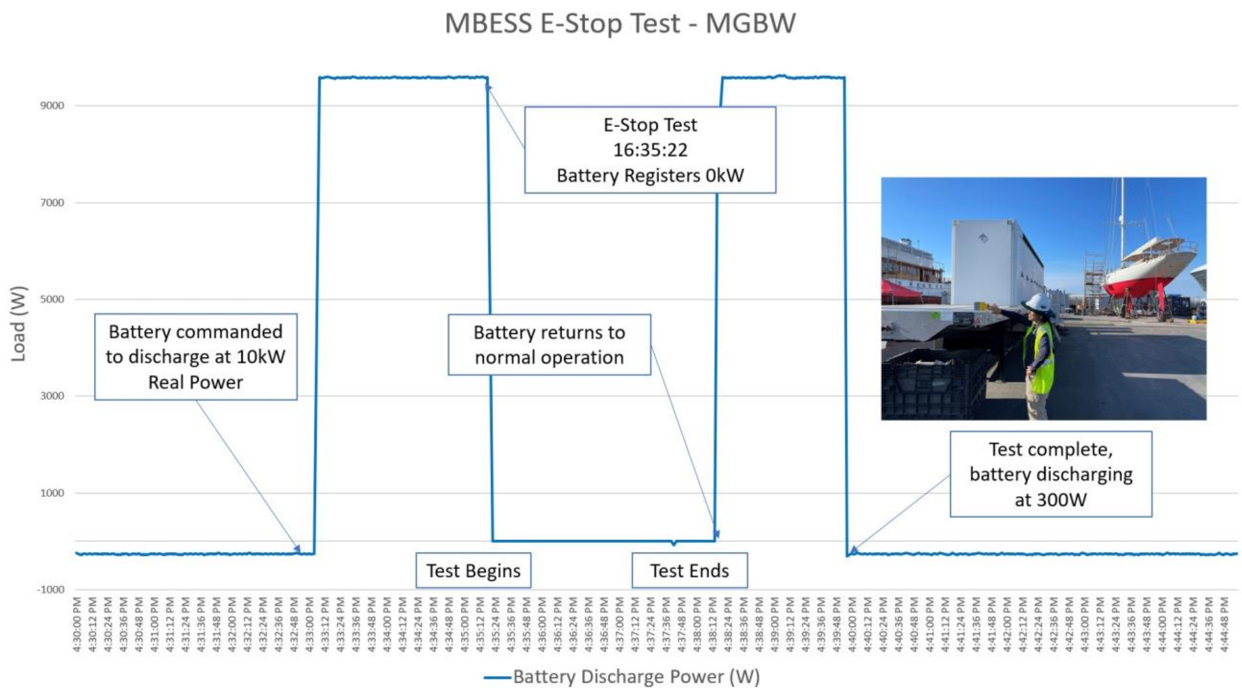

Figure 5: MBESS E-Stop Test Graph

At CCM, when the downstream loads were being carried by the MBESS, it was noticeably quieter than with the generators running, even at idle. Communication and site awareness were increased when operating on MBESS alone.

7.1.2 Load Factor Correction

With the MBESS's ability to peak shave and load smooth, the MBESS can successfully correct a load factor, very close to 1. As seen in figure 6, in the 200kW load smoothing and peak shaving test, the MBESS was able to hold an average peak load of 202,712W, which is 1.4% above the 200,000W target. Using MGBW's hourly meter data obtained during the testing week, the site's native load factor was 76% for that week, well above their historical 20-60% load factor calculated from monthly utility data. In either scenario, the MBESS's ability to correct load factor to 98.6% is a significant improvement for a site with high peak loads and low usage. Deploying a MBESS at customers such as MGBW would benefit SDG&E's FtM distribution infrastructure by providing more consistent loading at the substation level.

7.1.3 Load Smoothing

When connected in parallel to the grid in a FtM configuration, the MBESS can smooth out peaks in loads and control the ramp rates of customer loads as seen by the grid. A specific load smoothing test (Figure 6) was run with the MBESS at MGBW with two different rate of changes specified 166W/s and 50W/s. In comparison to customer load rate of change before the load smoothing test at an average of 462W/s, the MBESS was able to reduce load changes to an average of 220W/s and 50W/s, respectively. This demonstrates an achievable 54-89% in grid-facing load rate of change.

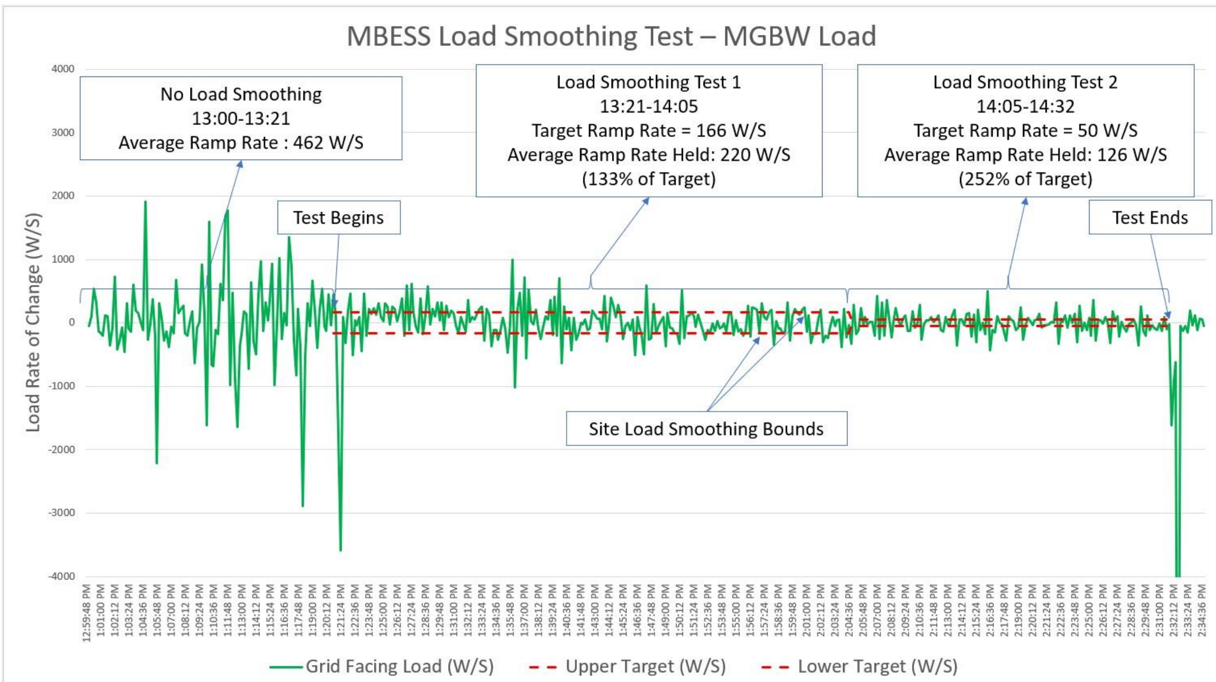

Figure 6: MBESS Load Smoothing Test - MGBW

Similarly, a reduction in ramp rate for grid-facing amps can also be seen during the load smoothing test. Pre-load smoothing test, the average rate of change for grid facing amps was 0.871 amps/sec. However, after implementing the two load smoothing tests, the rate of current change seen at the MGBW transformer dropped by 20% and 12%, respectively, in comparison to the baseline. This data can be seen in Figure 7.

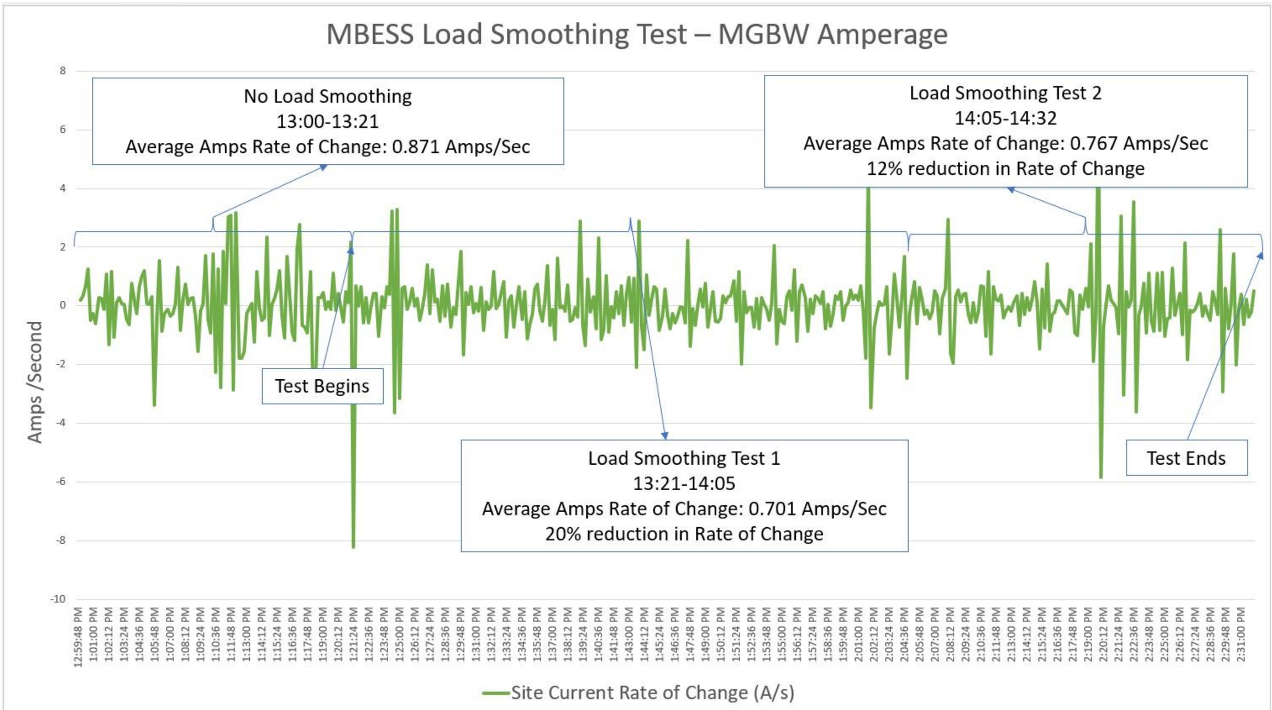

Figure 7: MBESS Load Smoothing Test - MGBW

7.1.4 Demand Peak Shaving

Two demand peak shaving tests were conducted with the MBESS while connected in parallel to the grid at MGBW. The first set a maximum output for the site at 200 kW and the second test set target site load at zero kW, effectively eliminating the load of MGBW from the circuit.

In the 200kW peak shaving test, the MBESS was able to maintain the grid-facing site load within 1.4% of the target, give two different ramp rate parameters, 0 W/s and 5 W/s. You can see this performance in the graph in Figure 8 comparing the site's actual load to the grid facing load.

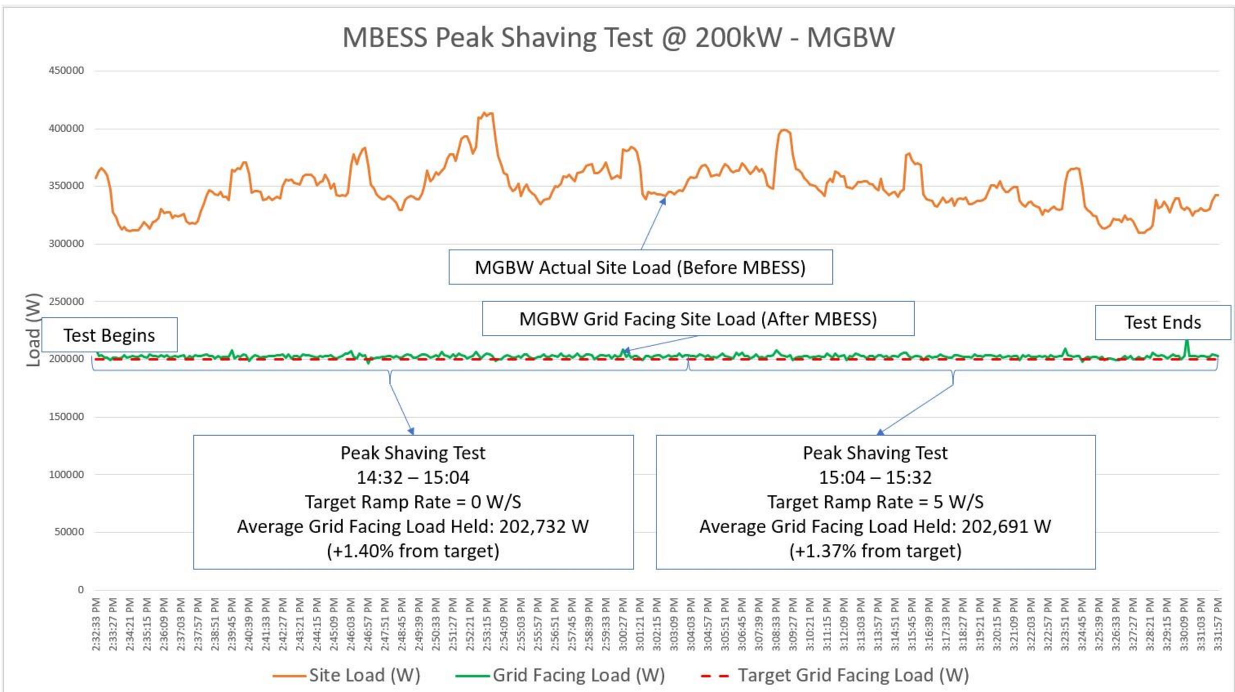

Figure 8: MBESS Peak Shaving Test @ 200kW - MGBW

Similar performance was demonstrated during the zero load test, the ultimate peak shaving, which effectively eliminated the MGBW's load from the corresponding circuit. Through this period, the MBESS was able to maintain a grid facing site load of 3,841W, or approximately 1% of the site's gross load of over 300kW. You can see the performance of this test in Figure 9, whereby grid facing load is all but eliminated. Of note, there are a few peaks in this test where the site load changed too rapidly for the battery discharge to effectively respond, resulting in a few minor peaks in the grid facing load. However, overall performance of the MBESS in this test met expectations.

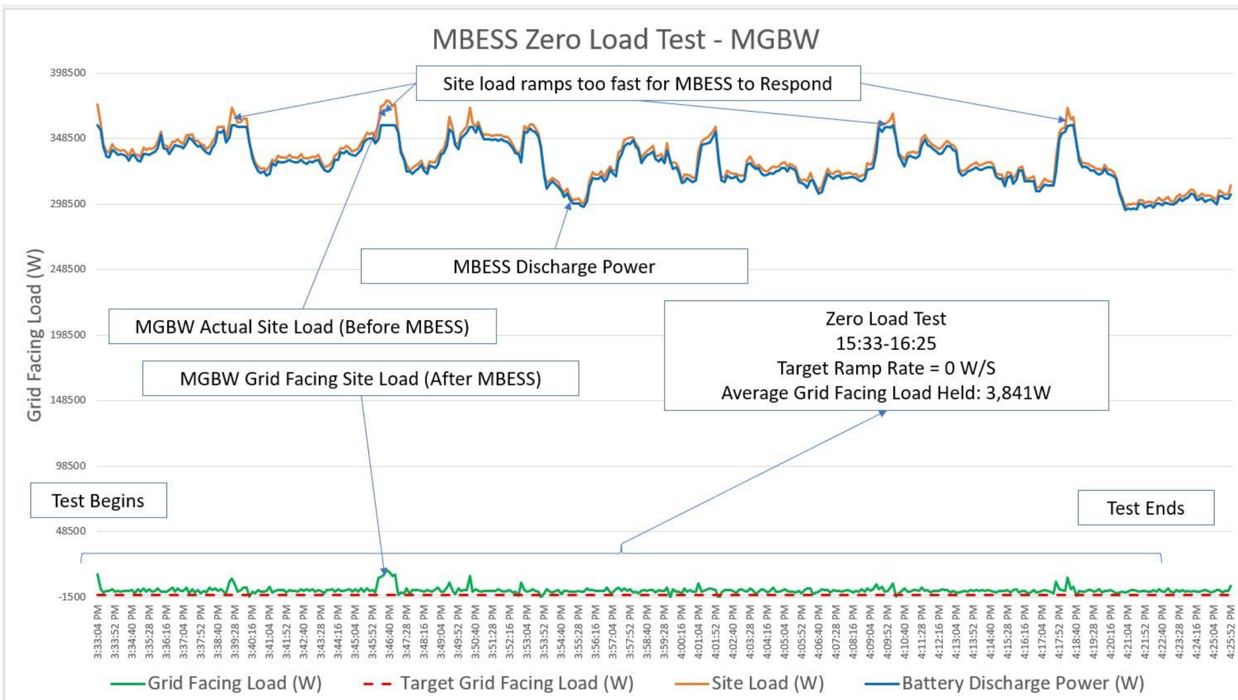

Figure 9: MBESS Zero Load Test - MGBW

To understand the impact on the corresponding substation, amperage and loading data was taken and analyzed prior to and during the time period of the peak shaving tests. Loading and Amperage reductions were seen during both tests with the biggest impacts seen during the zero-load test – a 11% drop in maximum circuit amperage and a 10% reduction in MW seen on the circuit. Figure 10 shows this graphically, plotting both the circuit current (in amps) and circuit loading (in MW).

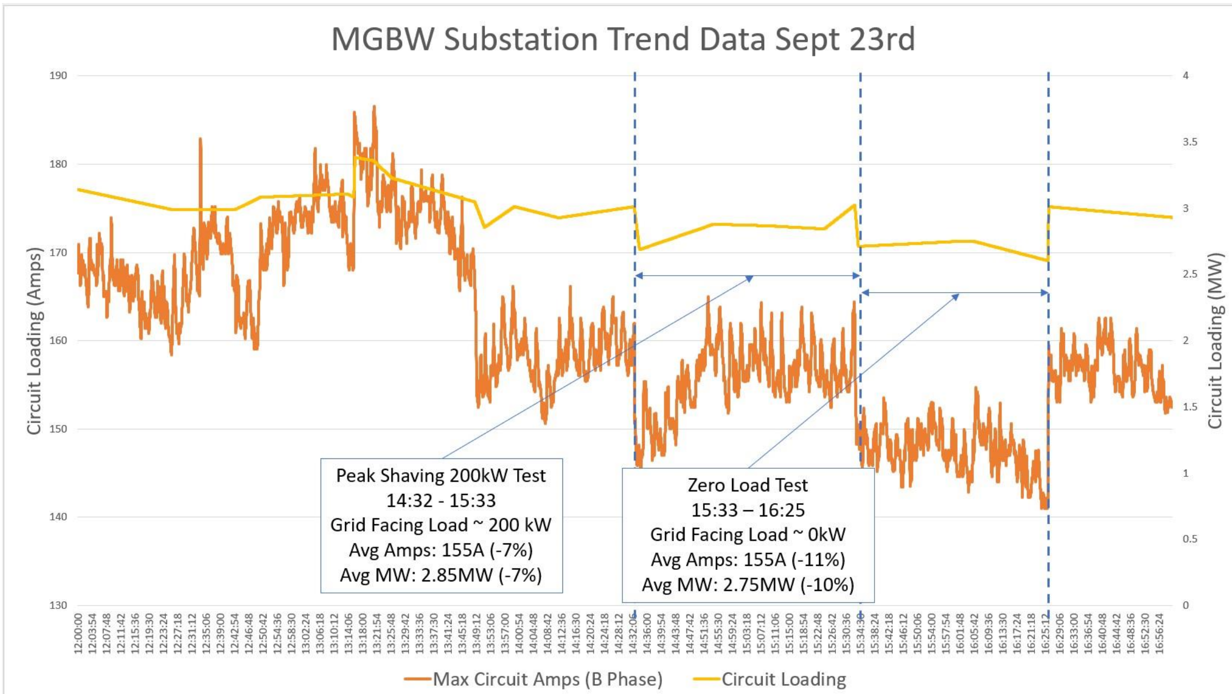

Figure 10: MGBW Substation Trend Data

Reductions in circuit loading were also seen during the Cameron Corners blackstart & island test. To discount any potential contributions from solar PV on the circuit, averages were taken of calculated for circuit current and loading from 6pm- 7am. On average, islanding the Cameron Corners customers reduced circuit current by 5.57 Amps at 12kV or a 10.7% reduction. Circuit loading reductions were commensurate, averaging 0.88MW less on the islanded day, or a reduction of 8.9%. Circuit conditions are shown in the graph in Figure 11.

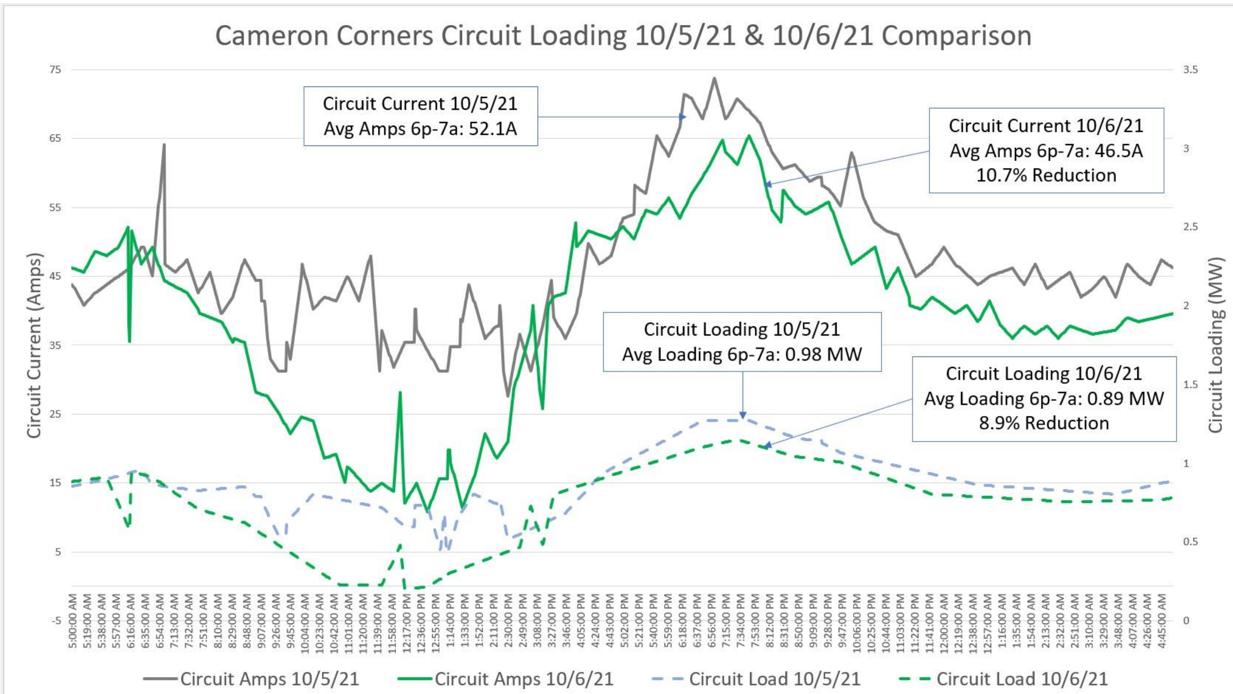

Figure 11: Cameron Corners Circuit Loading Two-Day Comparison

Through the peak shaving and zero load testing, the MBESS demonstrated its ability to participate in the demand response market. Not only is the battery able to reduce and cap site load to a preset level, it is also able to eliminate a site's load from the corresponding circuit. Additionally, as seen in the test in Figure 12, the MBESS can discharge a pre-set amount to the grid, even beyond the site load if needed.

7.1.5 Demand Response

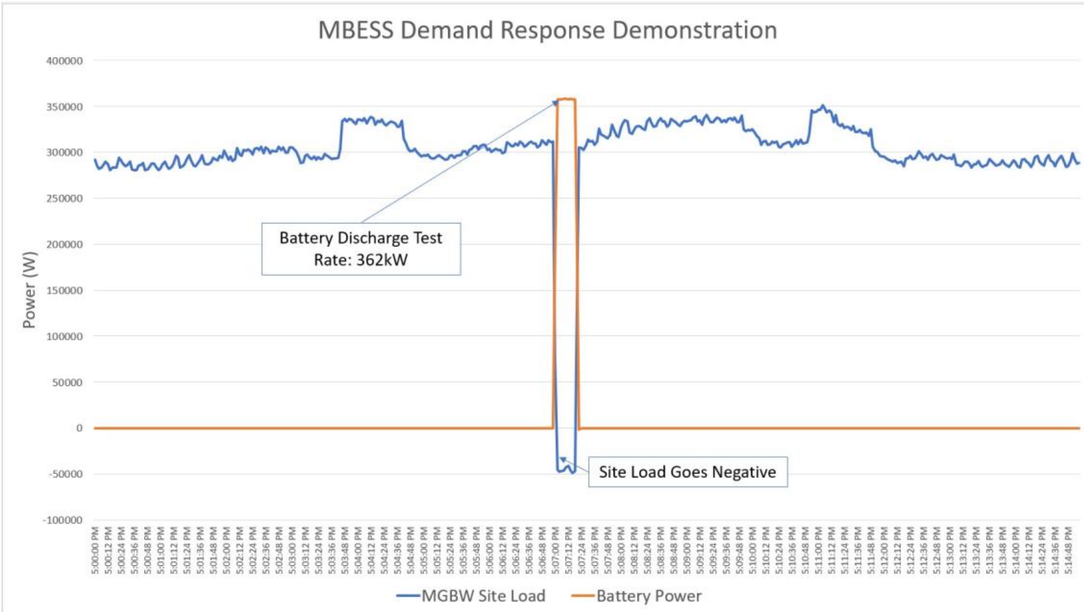

Figure 12: MBESS Demand Response Demonstration

7.1.6 Deferral of Utility Infrastructure Investments

From the testing performed with the MBESS at both MGBW and Cameron Corners, deferral of utility infrastructure investments is possible. From the Zero Load Test, the MBESS reduced circuit loading by any preset amount, up to the maximum discharge capacity of the battery, reducing circuit amps by 10% and circuit loading by 11% in the particular case of the test. The observed circuit loading reduction data observed is in line with the 12kV circuit current reduction a 362kW can provide, approximately 30 Amps. Assuming a 12kV circuit is designed for 500A maximum loading, this is a maximum circuit current reduction of 6%.

Also contributing to the increased life of grid infrastructure, from the Load Smoothing Test, the MBESS was able to smooth out the rate of change of circuit load by 52% and 72% when compared to the original circuit rate of change.

The MBESS blackstart and islanding performance at Cameron Corners demonstrated a key deferral of utility infrastructure investments. In a scenario similar to that at Cameron Corners, SDG&E could prioritize undergrounding of key community loads in PSPS-prone locations, and power them during PSPS season with a MBESS, while a full community resiliency plan is put in place. The mobility of the MBESS allows SDG&E to deploy significantly sooner, as they would with a mobile generator, and carry critical community loads with a zero-emission temporary solution.

7.1.7 Load Blackstart

The MBESS deployment test at Cameron Corners focused on proving the Blackstart use case. Traditionally, synchronous generators (e.g. diesel generators) have been used to black start downstream loads and inverter based generators (e.g. BESS) have struggled to handle black starts due to high inrush current from certain inductive loads. Working with the MBESS manufacturer, the SDG&E team not only successfully black started downstream loads at Cameron Corners, but also autonomously handed off control of grid-forming operations to diesel generators connected in parallel when the battery was completed.

Two methods of black starting downstream loads at Cameron Corners were tested during the MBESS demonstration. The first method, which mirrored SDG&E's existing procedures for black starting loads using synchronous generators, energized the MBESS in island mode before closing in downstream loads via a Trayer switch. The second method, which was recommended by the battery manufacturer, closed in the deenergized downstream loads to the MBESS and then issued the blackstart command, allowing the MBESS to ramp up current until voltage and frequency setpoints were able to be met.

In both cases of black start, the cold load pickup and soft start configurations, the MBESS successfully black started downstream loads of 63kW and 76kW, respectively, within 2 seconds of the load close-in / blackstart command. Test results can be seen in Figure 13. While these load pickups were less than the 300kW rated maximum black start capacity of the MBESS, initial acceptance testing revealed that the MBESS was capable of a load blackstart higher than its rated capacity.

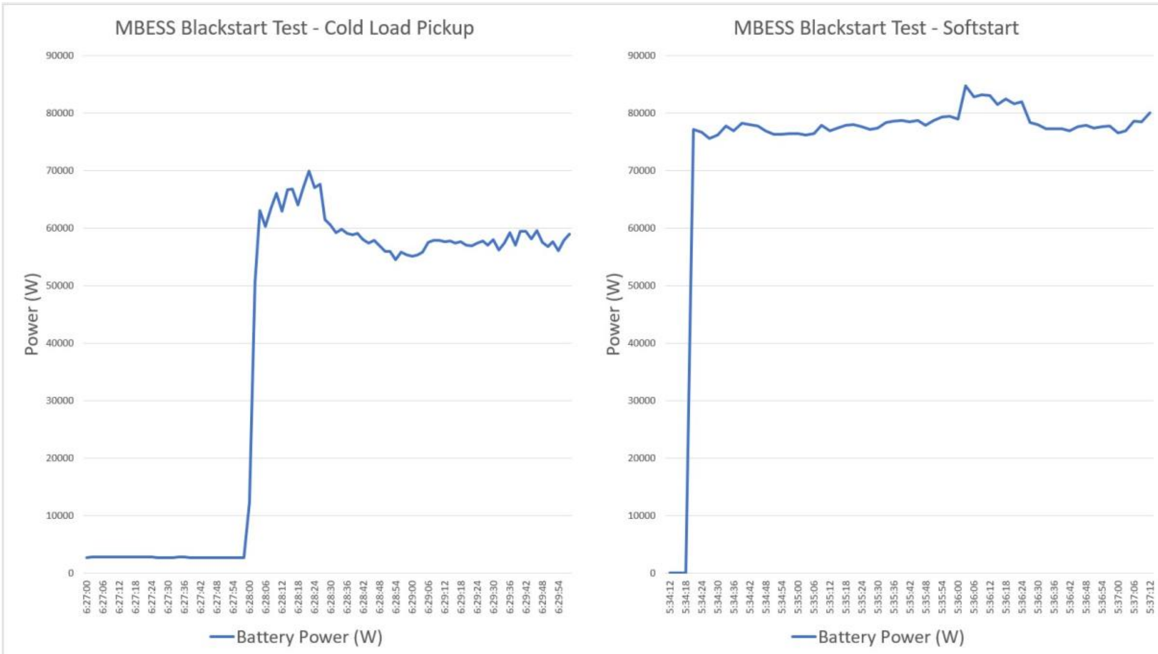

Figure 13: MBESS Blackstart Test Charts

The other important MBESS software which was tested during the 24 hour black start/island test was the microgrid control software which allowed seamless and automated control of the grid-forming duty to be handed off between the MBESS and paralleled diesel generators. After the MBESS's microgrid controller successfully black started the downstream loads, the microgrid ran on battery alone until it reached its minimum (SOE) of 25%. Upon seeing this minimum SOE was reached, the microgrid controller started the diesel generators and used them to carry the downstream loads and charge the battery back up to a target SOE of 90%. Upon reaching the desired SOE, the microgrid controller shut down the generators and proceeded to run the downstream loads on battery only until depleted down to the minimum prescribed SOE.

The microgrid controller also monitored the downstream load on the feeder and was programmed to start a generator as spinning reserve should the downstream load come within 50kW of the rated islanding capacity of the MBESS. This was tested with a load bank (Figure 14) during pretesting but the load on the feeder never exceeded the capacity of the MBESS, so it was never tested with real load.

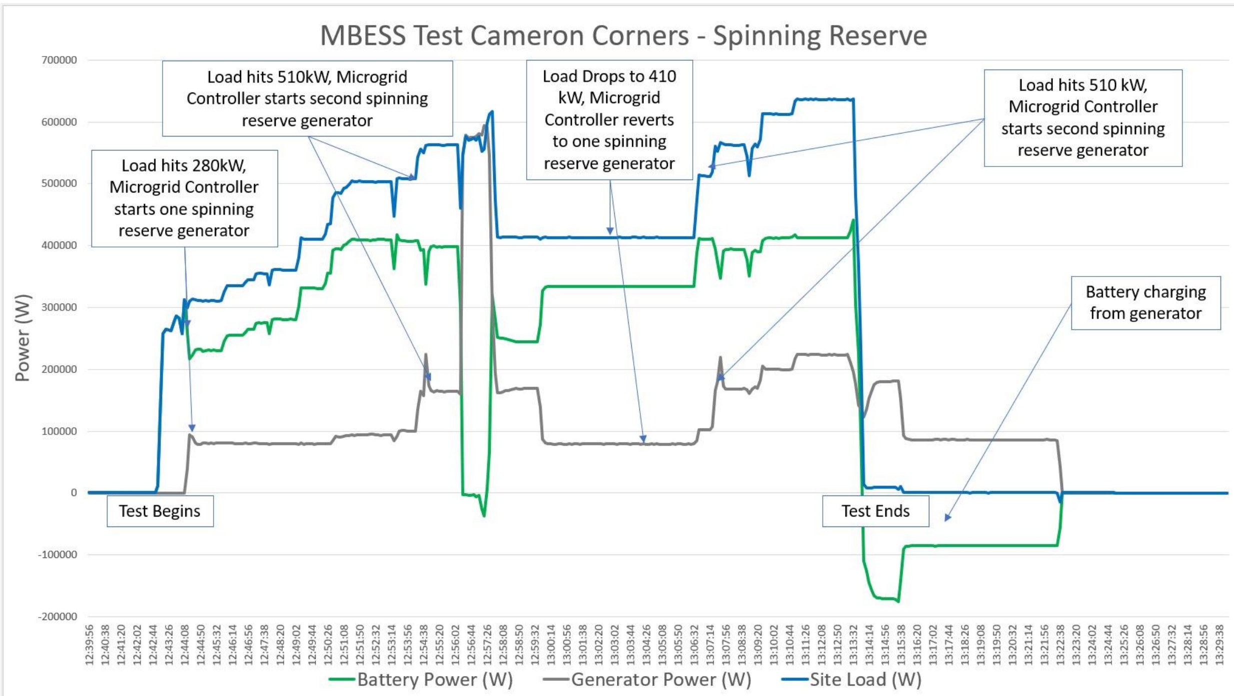

Figure 14: MBESS Test Cameron Corners - Spinning Reserve

7.2 Updated Benefits Analysis

A comprehensive benefits analysis is presented below in Table 11, based on the test results and additional analysis performed.

Table 11: MBESS Updated Benefits Analysis

Benefit Category	***Metric***	***Quantification***	***Comment/Source***
Safety	Chance of Fuel Spill vs. Diesel Generator	Decreased	MBESS contains no liquid fuel
	Noise Pollution Reduction	24	dB when compared to a diesel generator
Improved Reliability and Power Quality	Demonstrated Downstream Load Blackstart	Successful	Loads can be cold closed into an energized MBESS or ramped up slowly
	Ability to Peak Shave (Less than or equal to)	400 or 362	kW Peak shaving capacity, momentary or steady state.
	Ability to Load Smooth, minimum	126	W/s rate of change, as observed in the testing
	Increased Lifespan of Grid Equipment	2.78	Years (assumes 6% decrease in temp, correlated to circuit loading and MBESS utilization)
	Value of Lifespan Increase for Grid Equipment	$170,389	Based on average LBNA cost from SDG&E DDOR report
	Annual Grid Upgrade Deferral Benefits	$141,618	Based on SDG&E 2020 GNA/DDOR Report
Improved Performance of the Power System	Decrease in Circuit Current	30	Amps (362kW @ 12kV)
	Decrease in Circuit Current as % of Total Circuit Loading	6%	Assume Circuits are "Fully Loaded" at 500A at 12kV
Lower GHG Emissions	Annual Diesel Fuel Savings	303	Gallons of Diesel Fuel saved when using a MBESS instead of a diesel generator
	Annual Diesel Fuel Cost Savings	$1,516.30	
	Annual Diesel Fuel GHG Emissions Reduction	3	$MTCO_2e$

Benefit Category	***Metric***	***Quantification***	***Comment/Source***
	Annual Diesel Fuel GHG Emissions Reduction Value	$72.14	Using August 2021 carbon pricing from California Cap and Trade market
Lower Operating Costs and More Efficient Use of Customer Money	10 Year Lifecycle Net Benefit of 362kW MBESS vs. 285kW Diesel Generator Rental	$653,424	Includes upfront purchase cost, yearly cost to deploy and revenue generation potential
	Market Function Value (30% Participation)	$14,660	Based on 2020 CAISO Annual Report on Market Issues and Performance
Economic Development	Create a Local Market for Purchase of MBESS to offset 2021-2030 Grid Improvements	$11,438,320	Create a Local Market for Purchase of MBESS to offset 2021-2030 Grid Improvements
Disadvantaged Communities	Ability for SDG&E to support clean air in DACs	Increased	MBESS creates no direct CO_2 and particulate emissions unlike diesel generators and can also offset temporary load increases due to electrification such as EV charging and ship 2 shore charging.
Incremental Benefits of a Mobile Solution	Flexibility of deployment scenario	Increased	A single resource can provide backup power analogous to a diesel generator or can help defer grid upgrades or participate in the CAISO market.
	Additional revenue generation benefits over diesel generators	Grid Support, Market Functions, Grid Upgrade Deferrals	A MBESS can peak shave and load smooth, can provide voltage and frequency regulation and can be strategically deployed as needed to defer permanent grid upgrades needed from a few events.
	Increased Limit on Permissible Site Operation	Unlimited	Diesel Generators are Limited to 900 hrs/site

7.2.1 Safety

Because a MBESS uses no diesel fuel, it naturally decreases the chance of a fuel spill from a backup generation source. Actual data on fuel spills was not available from the rental agency, but any chance to decrease a diesel fuel spill is a positive thing.

One other safety benefit discovered during testing was how quiet the MBESS was vs. diesel generators, allowing for clearer communication amongst team members, improving overall site safety. Comparing average noise levels for 285kW diesel generators and a MBESS resulted in a 24dB reduction, which was enough to comfortably carry out a conversation with colleagues at normal volume levels.

7.2.2 Improved Reliability and Power Quality

Much has been said in this report about the MBESS' ability to successfully blackstart downstream circuit loads, to peak shave up to 400kW and load smooth down to 126W/s, however additional benefits for improved grid reliability were discovered during the testing.

As MBESS deployment on a grid circuit is roughly able to reduce amperage at the substation as referenced by up to 30A (362kW @ 12kV), there is an associated temperature reduction. According to grid infrastructure equipment manufacture Siemens[2], this decrease in temperature can be correlated to an increase in grid infrastructure lifespan. Assuming that the design temperature of the substation duct bank is 92^{o}C, a 6% reduction (30A reduction on a 500A "fully loaded" circuit) in temperature would lead to a 46% increase in equipment life. There is significant value associated with increased grid equipment life, and the average circuit Locational Net Benefit Analysis (LNBA) value circuit upgrade cost from SDG&E's 2020 Distribution Deferral Opportunity Report[3](DDOR) can provide a reasonable proxy to estimate value. Given values obtained from these publicly available filings, a 362kW MBESS would generate approximately $170,389 in value for increased lifespan of grid infrastructure over its 10-year life.

The MBESS itself also has value providing a dispatchable 362kW to help defer grid upgrades. According to SDG&E's addendum to their 2020 DDOR[4], SDG&E has set aside funding in a pilot program to help defer two specific grid upgrades, allowing for the calculation of value for a strategically deployed MBESS. Given pilot budgets and grid upgrade deferral needs in 2025, a 362kW MBESS would have a strategic value of approximately $141,618.

7.2.3 Improved performance of the Power System

A 362kW MBESS interconnected to a 12kV grid circuit can provide roughly 30A of current reduction. With full circuit loading approximated at 500A, before a circuit is considered full, and in need of an upgrade, this is a 6% reduction. Circuit capacity can be further reduced by interconnecting multiple MBESS on the same circuit.

7.2.4 Lower GHG emissions

Using SDG&E's 285kW generator deployment data for 2021 as a proxy for understanding GHG emissions from a "typical" diesel generator used to provide resiliency, there were small, but quantifiable benefits. First, if a MBESS were used in place of a diesel generator, there would be a diesel fuel consumption reduction, generating cost savings and GHG emissions reductions. Based on 2020 data, an average

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[2] https://new.siemens.com/us/en/products/energy/product-support/t-d-guardian-articles/electrical-equipment-lifespan-watt-in-the-world-.html
[3] https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M411/K212/411212341.PDF
[4] https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M402/K372/402372351.PDF

285kW diesel generator rented by SDG&E consumed 303 gallons of diesel fuel over the course of a year. At roughly $5.00/gallon of fuel, this is approximately $1,516 in fuel savings. By not burning diesel fuel, and using EPA standard emissions equivalence factors[5], that would result in a reduction of three metric tons of CO2 equivalent (MCO_2e) per generator per year. On the recent California Cap and Trade market, August 2021, those carbon credits would be worth approximately $72.14.

7.2.5 Lower Operating Costs and More Efficient Use of Customer Money

Despite a MBESS higher upfront cost than a rented diesel generator (which is effectively zero, when a third party owns, operates and maintains SDG&E's fleet of mobile diesel generators), the MBESS can generate revenue and/or create value in the ways described above in this section. Through the 10-year estimated life of a MBESS, using it for grid resiliency, circuit upgrade deferrals, to prolong the life of grid infrastructure and capturing the value of GHG emissions reductions, it is estimated to provide $653,424 in net benefits over rented diesel generators. Over a 10-year period, using a MBESS instead of a diesel generator more efficiently uses customer money to provide the same services.

As a subset of these overall costs, the MBESS can continue to provide value when not directly involved in SDG&E's day-to-day operations by participating in the wholesale power market. According to the 2020 Annual Report on Market Issues and Performance[6] published by CAISO, a battery in the San Diego/Imperial Valley Local Capacity Area can see Energy and Regulation market revenues of $134.99/kw-year. Allowing for the fact that SDG&E MBESS would target grid and resiliency support as its primary function, a conservative 30% participation in the CAISO market was assumed to yield a value of $14,660/year for a 362kW MBESS. Participation in energy market services also allows SDG&E to more efficiently provide the same services thereby using customer money in a more responsible way.

7.2.6 Economic Development

Using data found in SDG&E's 2021-2030 publicly available Grid Needs Assessment[7], it was possible to estimate how many 362kW MBESS would be needed to support grid infrastructure needs over the next 10 years. Assuming SDG&E were to choose this way to proceed, almost $11.5 million dollars would be spent procuring MBESS units, creating a local market of jobs pertaining to the delivery, setup, operation, teardown, and transportation of MBESS units. Other entities, such as commercial fleet customers and equipment rental agencies would see the MBESS in operation and conceivably explore additional units of their own.

7.2.7 Disadvantaged Communities

Unlike diesel generator, a MBESS creates no direct CO_2 emissions or particulate emissions like diesel generators, any resiliency deployments in a DAC would be in line with state and local efforts to reduce

[5] https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_apr2021.pdf
[6] http://www.caiso.com/Documents/Presentation-2020-Annual-Report-on-Market-Issues-and-Performance-Aug-12-2021.pdf
[7] https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M411/K212/411212341.PDF

direct emissions in DACs. Deployment of an MBESS to specifically serve the needs of DAC customers as it pertains to air pollution reduction is in direct alignment with the original value proposition. Not only is a grid-charged MBESS a zero local emissions solution for grid support, but also the MBESS's ability to offset vehicle electrification load promotes electrification of other types of vehicles such as ships, electric vehicles and off-road vehicles, reducing localized pollution often experienced in DAC communities.

7.2.8 Incremental Benefits of a Mobile Solution

With the successful test of the MBESS as part of this EPIC funded project, SDG&E has a new, flexible tool at its disposal to provide reliable, cost-effective power to the communities served. With a single resource, resiliency services can be offered on-demand as the MBESS functions in an analogous manner to the more traditional diesel generator. When not needed in that capacity, the MBESS can be easily relocated to provide grid support and capacity to help defer grid upgrades and save SDG&E and their customers money. Finally, when no services are needed, the MBESS can be used to bid into the CAISO market and provide value to SDG&E and its customers by participating in the energy and regulation markets.

Over the 10-year life of a MBESS, significantly more revenue generation and/or value is demonstrated that the analogous diesel generator which, due to emissions restrictions, cannot provide more than emergency grid resiliency support. Also due to emissions restrictions, diesel generators are limited to roughly 900 hours/site before they must be swapped out. MBESS have no such restrictions and can remain in place as long as necessary, saving on relocation costs and allowing for them to serve medium term functions as well as short term ones.

7.3 Commercialization Cost Estimates

Cost estimates for commercialization of MBESS are presented in Table12.

Table 12: Commercialization Cost Estimates

Component		Estimated Cost	Notes
Hardware			
	MBESS	$640,000	Includes a 362kW/1499kWh MBESS mounted on a lowboy trailer, controls and monitoring software
Interconnection Equipment (for Trailer)			
	Step Up Transformer	$10,000	3-phase, 500 kVA, 12kV/480V Delta-Wye grounded
	DER Trayer Switch	$125,000	12 kV primary connections only
	Inline Disconnect	$5,000	Service level disconnect panel with NEC rated visual circuit breakers
Site Meter			

Component		Estimated Cost	Notes
	Power Quality and Revenue Meter (includes addons)	$6,400	Site specific meter required to measure respective site loads to get a true load reading at the PCC
	Current Transformers	$400	3-phase CTs to step down current to a safe level for site meter
	Potential Transformers	$400	Site specific 3-phase PTs to step down voltage to a safe level for site meter
Total Upfront Costs		**$787,200**	
Ongoing Costs (Per Deployment)			
	Site Preparation	$2,500	Existing infrastructure upgrades (e.g., transformers, switches, etc.)
	Permitting	$2,000	Estimated based on Port of SD discussions
	Labor	$2,240	Estimated 8 hrs Electrician @ $150/hr + 8 hrs Tech @ $130/hr
	Transportation Costs	$1,500	Per site. Includes delivery and removal
Total Per Site Costs		**$8,240**	

8.0 Findings

The project demonstrated the flexibility of an MBESS and value of a relocatable battery resource to SDG&E's power system operations and customer services, which is not possible from either existing diesel generators or a permanent stationary battery resource. The MBESS effectively performed all functions demonstrated in either a grid support or grid forming capacity. A refined value proposition for commercial use of MBESS's was developed.

8.1 Findings Discussion

Findings from this MBESS demonstration project show the flexibility of such a resource and the variety of stacked benefits that can be attributed to a single asset. Table 13 provides a list of utility applications for a MBESS resource.

Table 13: Potential MBESS Applications

Interconnection	Application	Notes
Grid Parallel, FtM	Grid Support Services – Peak Shaving, Load Smoothing, Demand Response,	Utility places a MBESS in a strategic location to provide grid

Interconnection	Application	Notes
	Infrastructure Deferral, UPS for critical load support	support to alleviate temporary capacity issues or defer grid upgrades.
Island, FtM	Utility infrastructure construction, PSPS/outage support, microgrid testing/commissioning	Instead of rolling a diesel generator, use a MBESS in its place.

An MBESS connected in parallel with the grid, in front of the meter, demonstrated significant benefit to provide grid support services, such as peak shaving, load smoothing, and demand response, reducing wear on grid infrastructure, prolonging equipment life and deferring grid upgrades. The mobile nature of this resource allows the battery to be deployed to support intermittent and temporary load increases when needed and deployed elsewhere when not. Intermittent loads which would be optimally served by a MBESS would include cruise ship docking, sporting events, entertainment events or other discrete or seasonal events which set new circuit loading peaks to serve specific events.

The MBESS in this project also successfully provided resiliency to the grid, much like a mobile (diesel) generator would, powering downstream loads when the grid was not available. It was able to blackstart certain loads up to (and slightly beyond) the rated capacity of the battery and coordinate grid-forming operations when connected in parallel to traditional generation sources. The microgrid controller's ability to control grid-forming operations demonstrates its ability to coordinate various different generation sources, including renewables, ultimately leading towards a fully resilient and carbon-free microgrid.

When not in use for these functions, the MBESS can be relocated to a strategic location to perform energy and regulation market functions on the CAISO market, generating revenue for the MBESS owner. Further study will ultimately be needed to understand the permissibility of this function for different owners, including SDG&E.

8.2 Updated Value Proposition

With the test results and successful demonstration of use cases above, SDG&E was able to create an estimated value proposition comparing the net benefit of a MBESS vs. a traditional diesel generator over the 10-year useful life of a MBESS. Currently, SDG&E acquires diesel generators to provide grid resiliency through a rental model, significantly simplifying the procurement, maintenance and management of these devices. While this may ultimately prove a viable model for MBESS use, it is not available today, so 10-year costs of a 362kW purchased MBESS were compared to rental costs of a 285kW diesel generator, a roughly equivalent piece of equipment. MBESS costs were attributed based on commercialization costs estimated above in Table 12 of this report. Rental costs for 285kW diesel generators were based on 2021 rental cost data from SDG&E's DER group. As seen in Table 14 below which shows the upfront, yearly and revenue potential costs for a 362kW MBESS and a 285kW diesel generator, the purchased MBESS has much higher upfront costs than the rented diesel generator, but also is able to generate significant revenue and value for SDG&E, whereas the diesel generator is solely a sunk cost.

Table 14: Cost Comparison of 362kW MBESS Purchase vs. 285kW Diesel Generator Rental

362kW MBESS (Purchase Model)		**285kW Diesel Generator (Rental Model)**	
Item Description	**Cost**	**Item Description**	**Cost**
Mobile Battery Energy Storage System (MBESS)	$640,000	Diesel Generator	$0
MBESS Accessories	$147,200	Diesel Generator Accessories	$0
Total Upfront	**$787,200**	**Total Upfront**	**$0**
Site Preparation Costs	$9,583	Site Preparation Costs	$9,583
Mobilization Cost	$22,003	Rental Installation Cost (Per Generator Per Year)	$7,078
Charging Cost	$2,043	Fueling Cost (Per Generator Per Year)	$1,516
Maintenance Cost (including repair and service)	$500	Maintenance Cost to SDG&E (Rental)	$0
Total Yearly Costs Per MBESS	**$34,129**	**Total Yearly Costs Per Generator**	**$18,178**
Circuit Upgrade Deferral Revenue (DDOR)	$141,618		
GHG Emissions Reduction Value	$72		
Market Function Value	$14,660		
Equipment Upgrade Deferral Value	$17,039		
Total Yearly Revenue Generation Potential	**$173,388**	**Total Yearly Revenue Generation Potential**	**$0**

Over the 10-year life of the MBESS, the cumulative net benefit cashflow can be seen in Figure 15, comparing a purchased 362kW MBESS and a rented 285kW diesel generator.

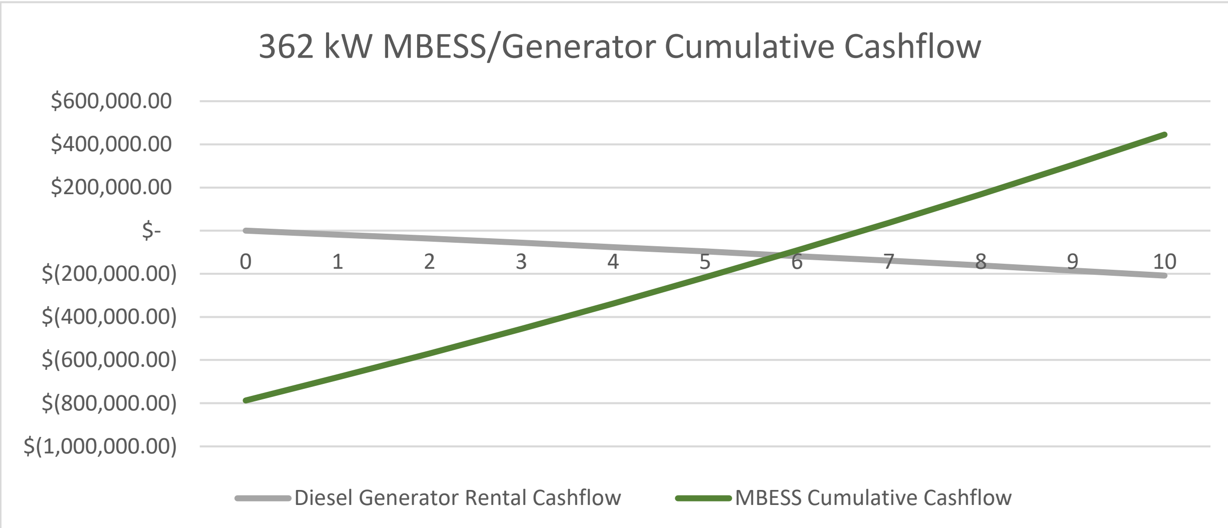

Figure 15: 362 kW MBESS / Generator Cumulative Cashflow

In 10 years, a MBESS, deployed through multiple resiliency, grid services, grid upgrade deferral and market functions has the potential to generate over $650,000 of net benefit over continuing to rent diesel generators.

A MBESS deployment is also aligned with state initiatives which seek to curb GHG emissions while supporting the loading order, promoting zero emission vehicles and stimulating economic development. Beyond the state initiatives outlined earlier in this report, a MBESS can offset the load increases due to vehicle electrification as stated in CARB’s EO N-79-20 mandate, which seeks to have 100% of new passenger vehicles in the state electrified by 2035, 100% of medium and heavy-duty vehicles electrified by 2045, 100% of drayage trucks electrified by 2035 and 100% of off-road equipment electrified by 2035. A MBESS and connected charging stations can be moved to support strategic vehicle charging wherever a new concentration of vehicles appears.

MBESS testing in the EPIC-funded pre-commercial demonstration revealed several additional use cases and values for further exploration which would serve to only increase the value of a MBESS beyond what was estimated above. These include:

- Frequency Regulation - A MBESS which is powering downstream loads can potentially improve frequency regulation by more closely matching power generation with downstream loads. Data observed from the Mobile Battery in grid forming mode showed that downstream load frequency was maintained between 59.93 and 60.04 Hz during islanded operation. A MBESS could also support larger grid frequency regulation by temporarily islanding key sections of the grid with voltage sag until a more permanent solution can be found. Frequency regulation is also a key component to unlocking value in the wholesale energy market.

- Volt/VAR Regulation - Introduction of a MBESS into an in FtM grid-paralleled application can help correct site power factor and align real and apparent power delivered.
- Scheduled Charging and Discharging - Software associated with the MBESS can look at grid carbon content, predicted load, solar PV production and determine optimal times to charge and discharge the battery to maximize greenhouse gas reductions from the MBESS and other distributed energy resource deployments. Scheduled charging can also be used to avoid charging the battery from the grid during circuit peak loading times.
- Uninterruptable Power Supply – Much like critical facilities have backup generation on-site with automatic transfer switches ensuring seamless power during an outage, the MBESS equipped with the proper software and site controls can handle the automated switching of grid-fed loads to backup-fed loads.

9.0 Conclusions

The MBESS successfully performed all the desired functions that were demonstrated, including FtM grid support functions and blackstart/islanding functions, as described in detail above. Once configured and interconnected, the battery performed according to expectations, or exceeded expectations, in every test. There is every expectation that the battery would continue to perform at expectations in future similar applications, as long as the loads that it serves are within the operating capacity of the battery.

A challenge experienced with the MBESS deployment was that varying setups were required for different battery applications and different grid conditions at each point of interconnection. This included voltage conditions, interconnection methods, metering options and required hardware. Because this was a pre-commercial demonstration project, each battery application was custom tailored to the task at hand with extra metering required to verify battery operation outside of the onboard site controller and management software. Beyond the extra testing equipment required, configuration and control of various MBESS parameters through DNP3 protocol required considerable effort to program the battery to perform the intended functions properly.

The MBESS tested in this EPIC project has a high potential value proposition when all potential uses of the battery are considered including resiliency services, circuit upgrade deferrals, GHG emissions reductions, market function participation and equipment upgrade deferral value.

Sized appropriately and deployed in a coordinated fashion, the MBESS provides analogous functionality to a mobile diesel generator which can black start loads after an outage, coordinate with other supporting generation sources and carry loads until grid power can be restored. However, the key to unlocking the value of a MBESS is in its use when not acting as a mobile generation source.

Based on 2021 SDG&E generator deployment data, the average 285kW generator was deployed for just over 30 hours, providing critical backup generation for the grid, but leaving ample time throughout the year to support other grid and customer needs. Taking these other functions into account, the MBESS shows the most value to SDG&E by supporting circuit upgrade deferrals, which are targeted and timebound grid needs, perfectly aligned with the flexibility of a (fleet of) MBESS. In summary, a single 362kW MBESS is able to generate over $650,000 in additional benefit. While the upfront cost is high, the reward for coordinated and strategic deployment can be great and should be explored further as SDG&E expands its interest in MBESS technology.

Beyond its economic value, the MBESS would also deliver significant societal benefits. It addresses the State's and SDG&E's GHG reduction and DAC goals, it furthers carbon reduction agendas, electrification efforts, and it generates significant economic potential surrounding the procurement, sales, service and deployment of a fleet of MBESS, all in an emissions free and quiet way. Customers, such as MGBW, seeing public use of battery storage, become curious themselves and want to investigate the role batteries may play in helping them to reduce their own operational costs.

A MBESS can be specifically deployed in DAC communities to reduce or eliminate increases in GHG emissions from ships, trucks or other vehicles which would more traditionally idle their internal combustion engines while stationary.

By scheduling charging of an MBESS during clean energy resource availability when the utility power system is powered by a significant amount of renewable resources, an MBESS can store excess clean energy and deploy it during times when the power system relies more on fossil fuel for power generation.

10.0 Tech Transfer Plan

10.1 Project Results 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 will also be submitted for consideration by organizers of public and industry conferences.

10.2 Transition for Commercial Use

A few key next steps surfaced as part of the learnings from this MBESS pre-commercial demonstration which will assist the transition of such a technology transfer to commercial use.

All relevant components needed to support a MBESS should configured and placed on the same trailer, including relevant disconnects, back feed protection, site meters, and transformers. A single trailer can then be rolled into place and more efficiently connected to a variety of different interconnection voltages and configurations. Once the trailer configuration is complete, a standard list of interconnection types should be developed to determine MBESS deployment applicability with the trailer.

With an all-in-one trailer configuration, this MBESS should also be tested in a behind the meter application for any customer who experiences temporary load increases such as a local university which has to deal with the increased electrical loads associated with a concert or graduation. Key learnings from this process should then inform the product deployment agreement, liability sharing and fee structure of a potential future deployment.

An MBESS should also be further tested to charge from on-site solar PV to further reduce the GHG impacts of its deployment and to test the cyclical charge/discharge associated with a solar PV fed battery.

Before commercialization, it is recommended that SDG&E look at their current interconnection regulations to more easily accommodate a mobile battery deployment in the future. Permissible use cases need to be further defined, as do the MBESS parameters to allow for expedited unit deployment a host site.

It is also recommended for SDG&E to establish procedures for treating an MBESS as a capital asset, much like they do transformers or other infrastructure equipment, defining product lifecycles, capitalization, and other key parameters before funding a fleet of MBESS units out of their general rate case. Internal SDG&E processes need to be built pertaining especially to standards and operating parameters to standardize procurement and deployment of these assets.

Finally, SDG&E should consider where a fleet of MBESS's is stationed when not deployed to maximize revenue or utility benefit. A fleet of undeployed and strategically located MBESS's could be charged from excess solar PV during the day to return 100% renewable power to the grid after sunset and the same fleet could also have the capacity to perform market functions, buying and selling power as the power market fluctuates.

11.0 Recommendations

Use of a MBESS in the following use cases will yield significant benefits to SDG&E as discussed in Section 8 above. Table 15 outlines the use cases and reasons for deploying a fleet of MBESS.

Table 15: MBESS Use Case Recommendations

Use Case	Recommended?	Why?
Safety	Yes	MBESS projects contribute to overall site safety with adequate E-stop capabilities, lack of tailpipe emissions, noise and auto-phasing capabilities when closing into downstream loads.
Load Factor Correction	Yes	A MBESS can shave high peak loads and improve a customer's load factor. More predictable and level power consumption benefits the the utility infrastructure.

Use Case	Recommended?	Why?
Load Smoothing	Yes	Smoother load changes benefits the lifespan of the utility infrastructure.
Demand Peak Shaving	Yes	A MBESS can eliminate peaky demands benefiting the lifespan and necessity to upgrade utility infrastructure.
Demand Response	Yes	MBESS can be dispatched to provide circuit capacity on demand.
Deferral of utility infrastructure investments	Yes	MBESS technology can be strategically deployed to alleviate the costly need for circuit upgrades due to infrequent circuit capacity issues. Or they can be temporarily deployed to provide capacity while circuit upgrades are planned and constructed.
Load Blackstart	Yes	A MBESS can successfully black start downstream customer loads. It can also act as the primary grid-forming microgrid controller operating in conjunction with other generation sources. When a MBESS is used in conjunction with diesel generators, it can significantly reduce the runtime of those generators.

It is recommended that SDG&E pursue commercial adoption of MBESS. It is recommended that SDG&E continue to refine and standardize system hardware, demonstrate other deployment scenarios, and adapt existing utility processes to allow for mobile energy sources. In the immediate future, additional sites and use cases should be demonstrated with the residual funds in the EPIC project to enhance the base of experience and better understand which applications have the greatest commercial value proposition. It is recommended that SDG&E's DER group lead the commercial adoption process. This group already manages SDG&E's mobile generator program. SDG&E's DER group should also coordinate with those internal resources responsible for grid planning to further discuss the potential for a fleet of MBESS to alleviate or eliminate the future needs for circuit upgrades. Given the fledgling nature of a MBESS supply industry, commercial adoption should consider both purchase and rental options for MBESS in the long term, similar to what is now done with mobile generators.