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Energy Research and Development Division

FINAL PROJECT REPORT

Meeting Customer and Supply-side Market Needs with Electrical and Thermal Storage, Solar, Energy Efficiency and Integrated Load Management Systems

Gavin Newsom, Governor
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PREFACE

The California Energy Commission's Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation and bring ideas from the lab to the marketplace. The California Energy Commission and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The Energy Commission is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Meeting Customer and Supply-side Market Needs with Electrical and Thermal Storage, Solar, Energy Efficiency and Integrated Load Management Systems is the final report for the EPC-15-074 project conducted by Center for Sustainable Energy. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

The Center for Sustainable Energy (CSE) with subcontracted support from Olivine Inc., Tesla, Inc. (formerly Solar City, Inc.) Conectric Networks, LLC., and DNV-GL, led a multi-year technology demonstration pilot titled, "Meeting Customer and Supply-side Market Needs with Electrical and Thermal Storage, Solar, Energy Efficiency and Integrated Load Management Systems." The project consisted of two behind-the-meter energy storage and distributed energy resource (DER) technology portfolios that tested multiple-use applications with the aim of maximizing benefits for both the customer site hosts, electricity grid and the environment. Specifically, the project demonstrated how these applied technologies could decrease customer utility bills through a combination of "active" and passive efficiency measures and onsite solar photovoltaic generation-to-storage while also earning revenue by direct participation in the California wholesale energy and ancillary services markets — as proxy demand resources. Beyond providing day-ahead and real-time energy into the wholesale market, the project was among the first demonstrations of a resource behind-the-meter providing ancillary services via spinning reserves.

Keywords: *distributed energy resources, DER, wholesale market, energy and ancillary services, multiple-use-applications, energy storage, value stacking, transactive energy*

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EXECUTIVE SUMMARY

Introduction

As a global climate solutions leader, California is committed to decarbonizing its electricity supply by requiring generation to be at least 60% qualifying renewable energy by 2030 and 100% from carbon-free resources by 2045. Further, many local governments, community choice aggregators (CCAs) and businesses throughout the state are committed to even more aggressive time frames to achieve significant decarbonization targets.

Most renewable energy in California comes from solar photovoltaic (PV) and wind sources, with considerably greater penetration expected to come online in the next decade. Successful deployment of ancillary distributed energy resources (DERs), such as energy efficiency, demand management and battery energy storage, will facilitate this growth, but their success depends on market valuation mechanisms that can reliably monetize the services and benefits provided by these resources. Grid services and benefits are generally monetized in three ways:

- Contracted energy services
- Utility retail tariff pricing
- Wholesale market participation

Of these three, wholesale market participation is the newest and least-tried method for DER monetization. To date, only a handful of customer-sited (or behind-the-meter) DER technologies throughout California have successfully integrated as direct-to-wholesale market participants due to technical, institutional and regulatory barriers.

The purpose of this demonstration project, EPC-15-074, "Meeting Customer and Supply-side Market Needs with Electrical and Thermal Storage, Solar, Energy Efficiency and Integrated Load Management Systems," was to aggregate DERs located at multiple customer locations and bid them into the California Independent System Operator (CAISO) wholesale electricity and ancillary service markets with the goal of identifying solutions to overcoming the known barriers.

This report encapsulates the demonstrated use cases of two different types of DER resources that participated in the CAISO wholesale electricity market: Portfolio 1, consisting of battery energy storage systems tied to solar PV generation carports across five school sites, and Portfolio 2, an "internet-of-things" (IoT) system of smart electricity load sensors and controls in two hotel facilities. The project team's key findings and proposed solutions identify the key stakeholders and decision-makers, including DER industry vendors, consultants, utilities, state regulators and wholesale market operators, who are ultimately responsible for carrying out the necessary changes. Additionally, this report summarizes best practice strategies—based on demonstrated real-world experience—on how to prepare and use DERs in the wholesale electricity market, including innovative market participation models that have rarely been tried by the DER industry, such as ancillary services via spinning reserves and resource settlement via meter generation output (MGO).

Project Purpose

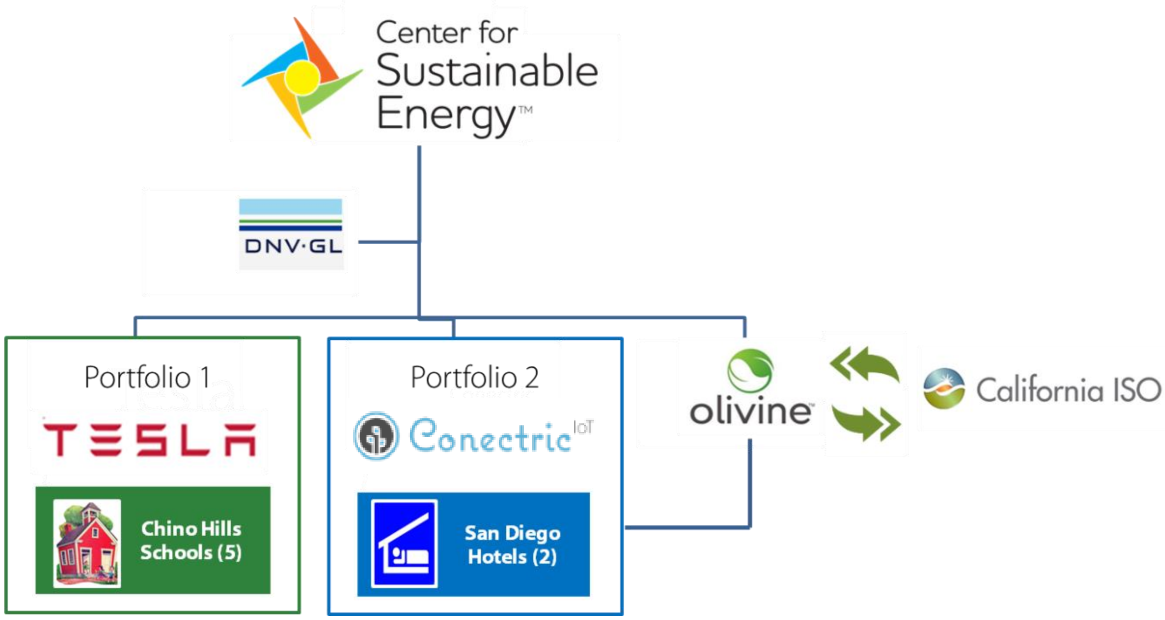
The purpose of this project was to develop and demonstrate multipurpose operational strategies for DERs, namely batteries and load controls behind the meter, to simultaneously reduce customer utility retail bill costs and gain revenue by participating in the CAISO wholesale electricity market as an "invisible intervention" or otherwise not disrupting or adding risk to interrupting the host customer's day-to-day core business and operations. It meant that the two sites were going to see a reduction in electric utility costs while continuing to operate, with the schools effectively delivering education (K-12) to students and the hotels providing comfortable overnight and other hospitality services to guests.

The two DER portfolios participated in the CAISO wholesale electricity and ancillary services markets under a market product construct known as proxy demand resources (PDR). Behind-the-meter DER participation in the CAISO wholesale market is a relatively new use case. To date, the entire process of preparing, registering, bidding and settling behind-the-meter DER participating as PDR in the market has almost entirely been done through existing demand response programs administered through the state's three major investor-owned utilities (IOUs). That has resulted in market participation processes and procedures only being understood by a narrow set of technically educated DER providers, regulators and customers. This situation resulted in a second key project goal to document the strategic set of replicable processes and procedures for PDR to successfully participate in the CAISO wholesale electricity market. As the results and lessons learned from this project are more widely disseminated, the project team hopes to see increased DER participation in the CAISO wholesale electricity market, which will provide co-benefits of further reducing DER and electricity costs for customers and ratepayers, improve the efficiency of the grid and allow for deeper decarbonization of the electricity grid.

Project Approach

The project team consisted of the Center for Sustainable Energy (CSE), serving as the project manager and interlocutor with the California Energy Commission on behalf of the project team; Olivine Inc., serving as the scheduling coordinator and demand response provider for the DER portfolios; Tesla Inc., managing a portfolio of aggregated battery storage systems at five different school sites (Portfolio 1); Conectric Networks (Conectric), managing a portfolio of networked sensors and load controls at two hotels (Portfolio 2); and DNV GL, providing measurement and evaluation of the project results. Figure ES-1 shows the general roles and construct of the project team. Additionally, the project team recruited and interacted with a technical advisory committee of industry, market and regulatory experts to obtain feedback during project implementation and to interact on lessons learned.

Figure ES-1: General Schematic of Roles and Resources for EPC-15-074



The project team conducted research by documenting each step of the project ranging from customer engagement; metering, telemetry and data requirements; and the market registration process to market participation and market simulation results.

Project Results

The project team achieved its primary goal of developing operational strategies to bid behind-the-meter battery and passive thermal storage technologies into the CAISO wholesale electricity market without compromising retail bill savings to customers or disrupting daily critical operations. They also found that the revenues gained as an active participant in the CAISO wholesale electricity market are eventually sustainable. And although no single strategy works for every customer—as each customers' needs, utility rate and electricity demand differ—the project team is confident that it has charted a clear pathway for behind-the-meter DER to prepare, bid and settle as a PDR in the CAISO wholesale electricity market.

Portfolio 1 tested the various CAISO market products it enrolled in as a PDR, specifically the day-ahead and real-time energy markets and ancillary services as spinning reserves. It also used the meter generator output (MGO) baseline settlement method to determine load reduction performance during market participation events. Though several market policy barriers were identified by the project team, the biggest takeaway from Portfolio 1 wholesale market participation was the PDR "no export rule" that does not allow counting grid exports from behind-the-meter DER. The project team suggests a relatively easy to implement partial fix to this barrier by allowing behind-the-meter DER to count grid exports participating as ancillary services such as spinning reserves.

As of today, despite having over one-third of the state's electricity provided by renewable generation sources such as solar PV and wind, the vast majority of ancillary services provided on the California electricity grid are from existing fossil-based, i.e., natural gas, power plants. DER can and should play a stronger role in providing cost-effective, zero carbon emissions-based ancillary services and such a PDR rule change would be major step in the right direction.

Portfolio 2 was unable to register and participate in the CAISO market due to customer engagement challenges that were in part related to the procedural complexity involved in the initial market registration procedures. The hotel's facilities energy manager had been mired in a set of circumstances that seem to represent the most common circumstance for professionals in his role—he had too many other competing priorities taking up his time and attention, including commissioning a new hotel facility and attending to several other equipment and operational emergencies across the scores of hotel sites under his management. He simply did not have the available bandwidth to process the full scope of the project and complete the critical steps on his part, e.g., signing customer utility data release authorization and demand response provider agreement forms needed in order to prepare the two hotel facilities for wholesale market participation. In response to hitting this project implementation barrier, the project team instead modeled the two hotel facilities' demand response potential based on Conectric's IoT energy data and analytics collected through facility diagnostics screening. The project team found that relatively simple and non-operationally intrusive strategies such as precooling chiller water and building envelope at both hotel facilities several hours in advance of a potential market demand-spiking heat wave could yield a compelling financial benefit approaching tens of thousands of dollars in electric utility bill savings. In addition, the project team found that the two hotel facilities qualified for and could yield significantly more electric utility bill savings by enrolling and actively participating in the Capacity Bidding Program (CBP) offered through their IOU, San Diego Gas & Electric (SDG&E).

Technology/Knowledge Transfer/Market Adoption

The project team engaged in multiple knowledge transfer activities throughout the term of the project. Several members participated in numerous regulatory proceedings at the California Public Utilities Commission (CPUC) and CAISO discussion forums, both of which have significant direct impacts on the ability of behind-the-meter resources to participate in the CAISO wholesale electricity markets. The regulatory and market policy-shaping forums included the following.

- ***Demand Response (R.13-09-011):*** Several members of the project team participated in the Supply-Side Working Group (SSWG) created under this proceeding. The SSWG sent a final report of specific regulatory and market policy barriers with suggested solutions to the CPUC in late 2019, several of which were informed by learnings and challenges of this demonstration pilot.

- ***Self-Generation Incentive Program (R.12-11-055):*** The project team filed several sets of comments to the CPUC providing recommendations, lessons learned and best practices on wholesale market participation as developed through this project. As a result, energy storage systems incentivized by SGIP were found eligible to participate in demand response opportunities and California’s wholesale market.

- ***Energy Storage (R.15-03-011):*** Created under this proceeding, the Storage Multiple-Use Applications (MUA) for Energy Storage Working Group deliberated from February to August 2018 and included several individuals from the project team as contributing parties. In particular, Portfolio 1 was cited on several occasions as a real-life use case among the few behind-the-meter storage resources participating in the CAISO wholesale market as a MUA DER.

- ***CAISO Energy Storage and Distributed Energy Resources (ESDER) Initiative*:** This initiative has scoped numerous changes to market rules and procedures for PDR with the intention of expanding behind-the-meter DER participation in the wholesale market. A number of lessons learned from this project could directly inform future iterations of the ESDER initiative.

Additionally, team members spoke about the project at several technical forums and related industry conferences, informing interested stakeholders on the project’s progress. Team members also wrote articles for publication on company websites and in third-party journals about the project and lessons learned. Through these multiple avenues, the team has been able to broadly share the project concept and results.

Benefits to California

The project delivered an improved understanding of the benefits of and barriers to expanding demand response (DR) participation in California. Specific benefits include:

- Increased understanding of options and best practices for supply-side DR to integrate and operate in CAISO wholesale markets. The improved understanding can potentially lower technical, institutional and regulatory barriers for wholesale integration.
- Increased understanding of the economics for supply-side DR to participate in CAISO markets with the benefit of developing strategies that maximize value to customers and the grid.
- Facilitated development of new value streams for DERs that help these technologies become more cost-effective for customers.

- Increased understanding of options and best practices for behind-the-meter storage to participate in the wholesale market. The improved understanding can serve to lower technical, institutional and regulatory barriers for wholesale integration.
- Increased understanding of the avoided costs and benefits of large-scale supply-side DR deployment. This may influence policymakers, regulators and CAISO to effectively leverage the benefits of DR to plan for the grid and design wholesale market rules.
- Increased understanding of the effects of large-scale behind-the-meter storage deployment, which may influence policymakers and regulators on grid planning and policy setting.

CHAPTER 1: Introduction

When the STEEL project was first proposed to the CEC in 2015, the status of DER integration as supply-side DR in California wholesale markets was practically non-existent. Over the last five years, California has taken steps to encourage the participation of DERs in DR programs and mechanisms, such as the CPUC's Demand Response Auction Mechanism (DRAM) pilots and wholesale market integration of the three major investor-owned utilities (IOUs) longstanding load-shed DR programs. However, a lack of developed projects in conjunction with inadequate wholesale market rules and regulatory barriers continue to limit the deployment of non-DRAM and non-IOU program supply-side DR. Therefore, DR continues to play a limited role in addressing supply-side problems in California, e.g., the addressing the Duck Curve. This demonstration project illuminated and clarified the remaining gaps in the understanding of best practices for operationalizing DERs in California that can respond to price signals that balance supply and demand in wholesale markets.

The primary objective of the STEEL project was to assess and test how aggregations of DERs could respond to current, planned, and potential wholesale and utility price signals. Operational objectives included the deployment and dispatch of state-of-the-art DER technologies, metering and telemetry, operational strategies, and economic modeling and analysis. Specific objectives of the project included:

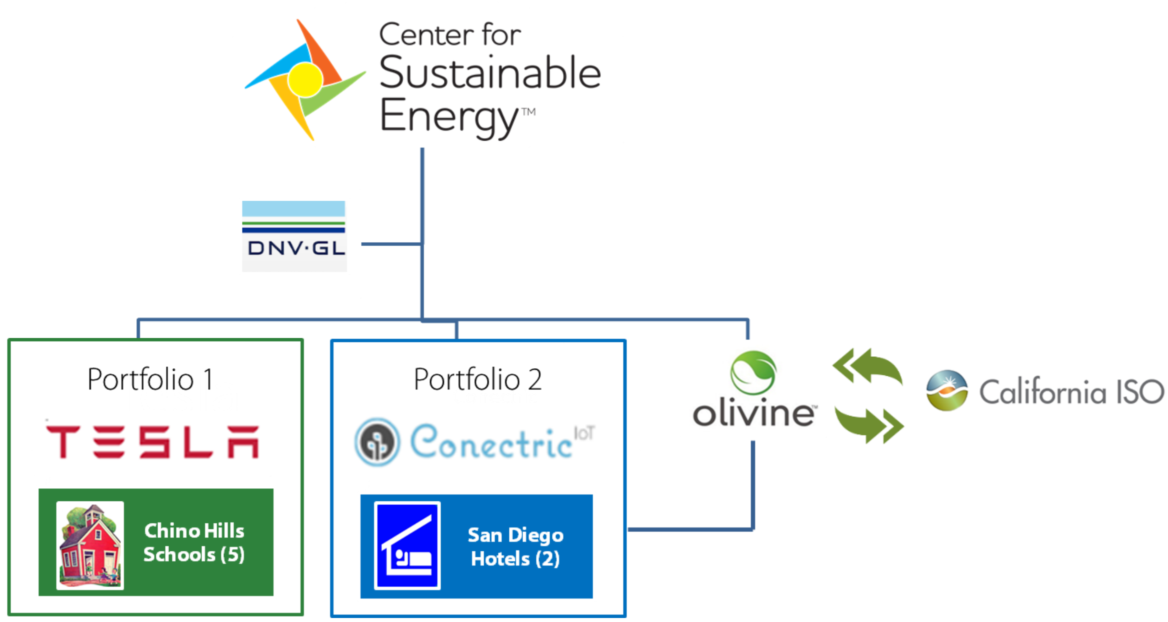
- Test and evaluate market operations in CAISO markets
    - Submit economic bids, receive market awards and coordinate outages by interacting with CAISO grid operations systems
    - Meter and financially settle market awards
- Test and evaluate CAISO's proposed baseline methodologies for performance evaluation and settlements in day ahead (DA) market
    - Including metered generation output (MGO) and retail baseline adjustments
- Test and evaluate CAISO's export adjustment rules for financial settlements of PDRs
    - Develop operational strategies to maximize customer and system value under CPUC-approved retail and CAISO wholesale tariff structures
- Develop operational strategies to co-optimize between retail and wholesale services including marginal and opportunity costs of limited energy storage resources
- Develop operational strategies to manage uncertainty of limited energy storage resources based on customer capabilities to manage demand and wholesale participation requirements

- Install and test communication equipment capable of responding to simulated or actual price signals
- Evaluate resource responsiveness to price signals through real-time market operations and simulated transactive price signals
- Evaluate ancillary service market potential by simulating contingent and non-contingent events
- Facilitate the creation of new markets for DERs, allowing these technologies to become self-sustainable without incentives
- Examine current and proposed future utility tariffs and rates and identify how these rates encourage or discourage efficient uses of DER technologies.

Project Overview

Project STEEL is made up of two portfolios of distributed energy resource (DER) aggregations designed to participate in the CAISO energy and ancillary services markets while still providing retail bill management for customers. Portfolio 1 uses behind-the-meter (BTM) battery storage while Portfolio 2 uses real-time occupancy, load sensors and controls to shift onsite load. Over a two-year period, the project team installed and prepared DER technologies, necessary metering and telemetry, conducted analysis of technical and economic potential of wholesale market participation, and ultimately tested the DERs into the CAISO markets. Figure 1 provides a general overview of the roles of each partner in the project.

Figure 1: General Schematic of Roles and Resources for EPC-15-074



Portfolio 1

Portfolio 1, managed by Tesla, Inc. (who subsumed original partner developer Solar City, Inc. in 2017), consists of five schools aggregated as a single source and located in Chino Hills, CA. The schools are all served by Southern California Edison (SCE).Each site uses battery storage to discharge electricity to the onsite load and reduce electrical demand from the grid to reduce retail bills and to participate in the wholesale market. Each battery can discharge at its rated capacity for up to two hours and is based on the powertrain architecture and components of Tesla's electric vehicles, with optimizations in design and cell chemistry for grid-connected stationary energy storage applications. The batteries were designed to optimally cycle between twenty to eighty percent charging capacity at least one to two times per day.

In addition to energy storage, each school also has onsite solar photovoltaics (PV). Table 1 shows a size breakdown of each school site battery and solar PV resources in the portfolio. While the solar PV is used to reduce onsite load, since it is a non-dispatchable resource, it is not used to control and reduce load when bidding into the wholesale market.

Table 1: List of Tesla Battery and Solar PV Resources Across Five School Sites for Portfolio 1

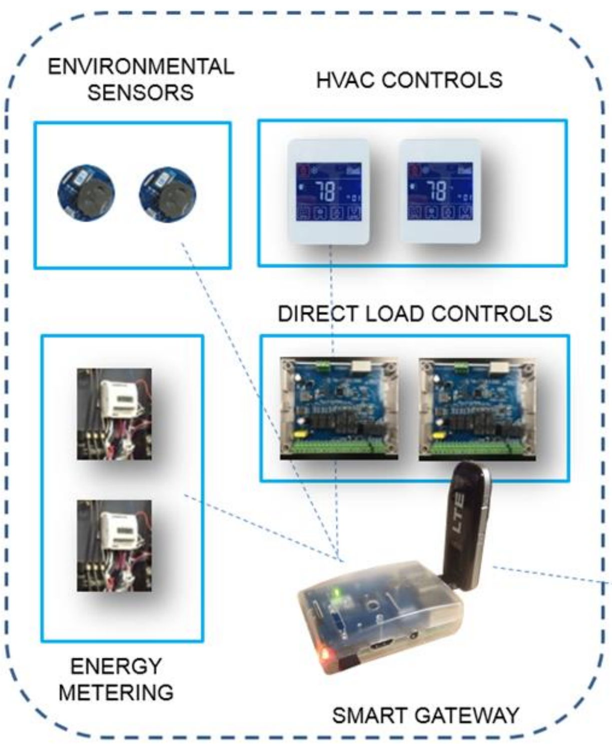
Site Name	Battery Resource	Solar PV Carports
Chino Hills High School	250 kW/475 kWh	1,078 kW
Chino High School	250 kW/475 kWh	707 kW
Don Lugo High School	250 kW/475 kWh	904 kW
Ruben Ayala High School	250 kW/475 kWh	1,116 kW
Walnut Ave Elementary School	100 kW/190 kWh	168 kW
Portfolio 1 Total	**1,100 kW/2,090 kWh**	**3,973 kW**

Portfolio 2

Portfolio 2, managed by Conectric, consists of two medium-large hotels in San Diego County that are aggregated together as a single PDR resource. The PDR resources have a maximum load reduction capacity of 160 kW – 215 kW for 4-6 hours (640kWh – 1,300kWh). The amount and duration of load reduction changes depending on several factors, including season, weather, and time of day.

Portfolio 2 deployed a suite of sensors, software, and controls to reduce and shift load as needed (see Figure 2). Through the software, sensors, and data analytics, each hotel site could continuously monitor business and occupant energy needs and actively reduce unnecessary energy-consuming loads. The load control software can manage tens of thousands of micro-loads based on actual requirements for energy to operate the building per its business requirements and occupancy comfort. Each controllable load is considered "available" or "un-available" inventory based on real-time sensor data. Extensive testing and calibration of the software and sensors' data was necessary to maintain a dynamic, optimal balance of maintaining building occupants' comfort, running important business operations, and providing load reduction at moments when wholesale electricity market prices are high.

Figure 2: General Schematic of Conectric's Sensors, Meters and Load Control Devices Communicating Data within a Dedicated Wireless Network



Wholesale Market Bidding

Olivine led the wholesale market preparatory, integration (registration), bidding and settlement activities for both portfolios with the CAISO.

Costs and Benefits Analyses

DNV-GL completed the project cost benefit analysis (CBA) for the Portfolios, as well as a future hypothetical CBA of gigawatt-level behind-the-meter storage integrated into CAISO wholesale market. Behind-the-meter storage can potentially provide peak energy, renewables firming, and ancillary services—frequency regulation and reserves for CAISO.

Project Innovations

While DERs have participated in the CAISO market since 2014, the STEEL project is innovative in several different areas. Specifically, the DER portfolios are participating directly in CAISO markets while bypassing traditional utility demand response programs, the portfolios are leveraging the meter generator output (MGO) baseline methodology, and Portfolio 1 is providing and simulating different types of ancillary services. These are described in greater detail below.

Direct CAISO participation of behind the meter resources

The STEEL project portfolios participate directly in the CAISO energy and ancillary services markets without going through a utility supply-side demand response or pilot program, such as the Supply-Side Pilot or Demand Response Auction Mechanism. To date, most DER portfolios have participated in the market through utility programs rather than directly into the market. These programs typically call the events or define parameters on how/when resources can participate in the market. Participating directly into the CAISO markets gives the resources more flexibility to bid into the markets when desired according to onsite needs and conditions.

However, participating directly into the CAISO markets does not provide a capacity payment, as many utility supply-side demand response programs and pilots do, so the flexibility of direct market participation must be weighed with potential economic loss of not receiving a capacity payment.

MGO

The meter generator output (MGO) methodology calculates demand response performance by relying on a sub-meter that directly measures the contribution (energy delivered) by the registered generation device (i.e. batteries storage systems) located behind the whole-premises revenue meter. The CAISO tariff currently allows only batteries to use the MGO methodology. MGO was approved by the CAISO Board of Governors in February 2016 as part of the Energy Storage and Distributed Energy Resources (ESDER) Phase 1 Initiative and was subsequently incorporated into the CAISO tariff in November 2016. However, since then the MGO method has not been widely used by industry as utility demand response programs use whole premises meter baselines rather than MGO. Thus, this project provides an opportunity to demonstrate MGO and share lessons learned.

Portfolio 1 leveraged the MGO method by directly submetering the batteries at each site and comparing market results to the whole premises meter method. Portfolio 2 is also directly metering controllable loads, but the CAISO does not allow these types of DERs to use the MGO methodology. Thus, Portfolio 2 uses the whole premises 10-in-10 baseline methodology and can compare load reduction estimations to actual measured load reduction from the loads.

Ancillary Services

Portfolio 1 participated in the ancillary services market by providing spinning reserves. Most DERs have typically provided energy in either the day-ahead or real-time energy markets but have not provided ancillary services. This project seeks to test DERs' ability to provide spinning reserves and potentially spinning reserves coupled with MGO.

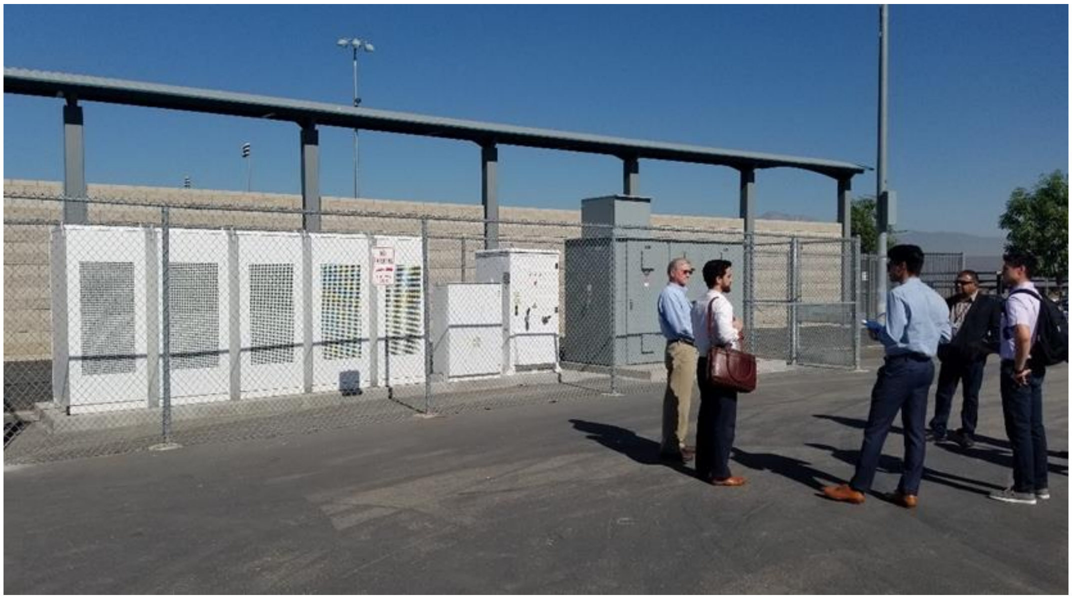
CHAPTER 2: Project Approach

This section describes the project team's approach to engage with customers, including the rules and requirements for Proxy Demand Resources market integration, metering, and telemetry; technologies required to develop a price responsive DER portfolio; and the operational strategies of each portfolio.

Customer Acquisition and Engagement

Customer engagement was essential to completing the required testing of the project. During each phase of the project, the project team worked with customers to understand their needs and to operationalize the project. Ultimately, customers decide whether to allow their sites and technologies to participate in the market, and customer approval is essential for behind-the-meter projects to succeed.

Project partners Tesla and Conectric mapped out several months during the early phases of the project to communicate and set expectations with their respective customers to prepare for project implementation. Conversations with customers were expected to include obtaining necessary customer approvals, i.e., internal management approvals, understanding the technologies and possible behavior or facility management changes, establishing vendor-customer agreements to access and share customer utility meter data, and finally, once participating in the wholesale market, how to disburse wholesale market revenues.



Members of the project team meet with Chino Hills Unified School District staff in front of a bank of Tesla commercial battery units at Chino Hills High School

Credit: Jonathan Hart, CSE

Customer Benefits Equation

With the introduction of potential new revenues from each portfolios' direct participation in the wholesale market, the equation for maximizing customer benefits becomes more complex. This situation is not unlike when a customer or DER vendor must determine if enrolling in a utility DER program will yield a beneficial outcome. Customer benefits are typically based on return on investment (ROI) savings by reducing energy use and/or demand charges as dictated by the specific terms of the utility provider's retail tariff that is then billed to the customer on a monthly basis. For the schools and hotel customers in this project, their retail utility tariff consisted of monthly non-coincident peak demand charges and time-of-use energy rate periods (typically three to four hourly periods per day) with the highest cost energy assessed in the late afternoon and evening hours (e.g., 5 to 9 PM).

The energy and demand charge dynamics of the schools and hotels utility tariffs meant that DER investments such as 'passive' energy efficiency and load shifting away from the evening peak energy rate hours would yield customer benefits by way of monthly bill savings. With the advent of participation in the wholesale market and potential market revenues to be gained, the utility retail tariff was no longer the single determining 'baseline' for the customers and vendors to base their DER investment and operational strategies upon.

Operational Strategies

The team found it is possible to develop operational strategies for DERs that allow for wholesale market participation without compromising retail bill savings to customers. However, there is no single strategy that works for every customer as each customers' needs, utility rate, and electricity demand differ.

Portfolio 1

Portfolio 1 participated balanced wholesale revenue opportunity with the opportunity cost of foregoing some of the potential benefits of retail bill management. During hours where the site had an opportunity to reduce load below its baseline, the system algorithm calculated whether market participation would be financially prudent to either participate or not at a certain load for a given period of time and at various bid prices (per CAISO market bidding rules). When it was economically attractive to participate, load reduction was implemented through behind-the-meter dispatch of the battery.

The strategy for Portfolio 1 relied on several data streams, some of which have a variety of forecasting techniques. Tesla had experience forecasting customer load, solar PV output, and optimizing the dispatch of the battery given a specific rate/tariff. This functionality was a core part of the commercial and industrial (C&I) storage offering for many years. The new objective determines how wholesale participation is coordinated with this existing functionality.

The following data points were used to inform Portfolio 1's bidding strategy:

- Retail Tariff Information
- Net Load Forecasts of host sites
- Wholesale Price Information

Once bids are submitted and market awards are received, Tesla uploads those economic price signals into the local optimization engine connected to the battery's controller. Under perfect 24-hour foresight when the day-ahead forecasted load and market price match up with actual conditions, the battery will dispatch at each scheduled hour in the day-ahead market and obtain a market award settlement in the exact amount as planned. However, as the day-ahead forecasts will inevitably be imperfect, the battery optimization will tailor the battery dispatch from its day-ahead program and use real-time (15-minute interval) market information to create an optimized real-time energy market bid. In sum, the optimization solves for battery dispatch in the day-ahead and real-time wholesale energy market based on the retail tariff, and forecasts of net load, potential market award, and imbalance charges (i.e. market penalty).

Tesla receives 15-minute metering and telemetry data from a variety of system assets, which include gross customer site load, PV generation, and battery state of charge, among other signals. This data can be used to benchmark the performance of a given strategy or forecasting technique in comparison to the ex-post review of perfect performance under the known net load and day-ahead prices.

Portfolio 2

Portfolio 2 anticipated following a "price taker" strategy, meaning the resource did not have a set price that wholesale markets must reach to submit a bid. Rather, the portfolio planned to submit bids at times that are most technically feasible for the resource and accept the wholesale market price during those intervals (so long as the market allows).

Portfolio 2 developed three primary methods[1] to strategically manage site loads when participating in the wholesale market:

1) **Load Shift** by primarily using passive thermal energy storage.
2) **Load Shed** when peak-demand economic conditions merit additional reductions
3) **Load Shimmy** which will be simulated through fast response motor control coupled with precise sub-metering and telemetry capabilities.

Portfolio 2 required the following data points to inform its load reduction strategies:

- Pricing Information
  - Retail rates
  - Wholesale market prices
- Load Analysis
  - The load rating of the circuit or load being controlled
  - Actual load on the circuit
  - Available controllable loads
- Building Characteristics
  - Thermal characteristics of the buildings, such as quality of building envelope
  - Efficiency and power input of the mechanical systems, such as HVAC equipment
  - Heating and cooling capacity
- Environmental Factors
  - Indoor and outdoor environmental factors are considered, such as temperature and humidity
- Building Use Profile

[1] The demand response terminology that was established in the *2025 California Demand Response Potential Study* (2017) by Lawrence Berkeley National Laboratory that was adopted into the record of the Demand Response Proceeding at the California Public Utilities Commission (Rulemaking 13-09-011) and available online at: http://www.cpuc.ca.gov/General.aspx?id=10622.

- Physical human occupancy and utility of rooms
- Usage patterns of different zones in the hotel
- Unoccupied zone inventory

Members of the project team meet with the facilities engineer to scope the rooftop chiller at the Hilton Garden Inn Old Town San Diego

Credit: Pierre Bull, CSE

To collect the necessary data points, Conectric designed a networking optimizer that could accept input and output from up to 50,000 sensors within its network of equipment controls. Sensor data included near-real-time collection of temperature, humidity, occupancy, door positioning, window position (in the case of movable windows/envelope), and electrical circuit energy. Additionally, the optimizer controled loads independently through direct load control (signaling relays), thermostat control of individual HVAC zones (fan coils and ventilation), and existing building automation.

Data from sensors is transported to the cloud and stored in an elastic cloud server for analysis (see Figure 3). Conectric is impartial to the cloud server or storage but used the Google Cloud Platform for this project. The energy and sensor data were analyzed using an Open Source statistical software package called R, which correlates sensor events with weather and energy consumption to identify what circuits were optimized or sub-optimized and could be controlled to produce the load-shaping delivery.

Optimized control strategies were implemented via pre-defined algorithms which signal a change of state for the direct load control, the thermostat control or other identified controllable loads.

Implementation of PDR in the Wholesale Market

To participate in the wholesale market each portfolio needed to register into the CAISO under the Proxy Demand Resource (PDR) participation model. The following section describes in greater detail, the market actor roles, requirements and steps taken by the project team to prepare the two portfolios for participation in the wholesale market. We first discuss the basic market rules and parameters of PDR at the CAISO. Then we describe the functional roles of each market actor and how each is involved in the steps necessary to prepare a PDR portfolio for bidding in the CAISO wholesale market. Each major step: pre-market, market bidding and post-market, are described in detail. In the pre-market phase discussion, we provide additional details on the price-responsive technologies, i.e., on-site metering and telemetry equipment, as well as market testing requirements needed for PDR.

Essential Market Eligibility Requirements

In order to participate as a PDR in CAISO's energy markets, several essential requirements must be met, as described below.

- *Geographic*: The customer locations that make up a PDR must entirely reside within a single Sub-Load Aggregation Point (Sub-LAP). Portfolio 1 in Chino Hills and Portfolio 2 in San Diego were both located within their respective Sub-LAP geographic boundaries.
- *Minimum Capacity Test*: All PDR participating in the Day-Ahead and Real-Time Energy markets must be able to demonstrate during resource market testing that they can achieve a minimum 100 kW curtailment for at least one hour. (This was the test for Portfolio 2.) If the PDR is to provide additional ancillary services, as was the case for Portfolio 1, the minimum portfolio aggregate threshold is 500kW.[2]
- *Notification Response*: Depending on the market in which it is participating, a PDR must be able to respond notification and follow instructions as directed by its market bid.
    - *Day-Ahead (DA) Market:* Notification arrives one day in advance (typically between 1:00 – 4:00 PM) and resource must prepare to respond during the hour(s) as directed by the market bid.
    - *Real-Time (RT) Market*: Resource must be able to respond to a 2.5-minute

[2] Noting that PDR may bid energy and ancillary service resources at the CAISO in increments less than 100 and 500 kW, respectively. Also note that the minimum threshold capacity amount does not need to be achievable in all hours.

notification and change resource output in as little as 5-minute increments at a time.
    - *Spinning Reserves*: Must be able to respond within 1 minute of receiving an energy dispatch instruction, reach rated capacity within 10 minutes of a dispatch instruction and maintain rated capacity for at least 30 minutes.[3]
- *Metering*: Service Accounts must have hourly metering for day-ahead only resources and at minimum 15-minute metering for any real-time market enabled resources.

Wholesale Market Actor Roles

There are several different functional organizations necessary to enroll customers, create a resource aggregation, and operate a PDR in CAISO markets. The market roles are described below.

Utility Distribution Company (UDC)

The Utility Distribution Company is the entity that owns and operates the distribution system for the delivery of energy to end-use customers. Demand Response resources participating in CAISO markets are currently all in the territory of one of the three large IOUs in California: PG&E, SCE, or SDG&E. All locations in the Tesla portfolio are under SCE territory. Utilities are responsible for data authorization and validating that there are no dual enrollment conflicts.

Load Serving Entity (LSE)

The Load Serving Entity is defined as the entity that serves end-use customers and has authority and obligations pursuant to state or local law and regulation to sell electric energy to end-use customers within the appropriate balancing area. In California, LSEs were often the same entity as the UDC, but the expansion of Community Choice Aggregators (CCAs) has resulted in more diversity in energy suppliers. CCAs are increasingly developing their own Demand Response programs, but also may play a role in validating customer eligibility for third-party Demand Response.

Retail Demand Response Provider (Retail DRP)

The retail Demand Response Provider directly engages with customers, and if applicable, controls customer load or devices. Retail DRPs must complete CPUC

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[3] Resources providing Spinning Reserves have additional requirements to be able to provide Frequency Response in the event of a frequency disturbance on the grid. (Though PDR cannot yet officially participate in Frequency Regulation at CAISO.) This response will not be in response to a market dispatch instruction, rather the battery management system will need to be synced up to grid frequency (likely via a smart inverter) in order to respond appropriately. Specific requirements for a PDR resource providing Spinning Reserves are as follows:

- Resource must be able to drop load within 1 second if system frequency is below 59.92 Hz
- Resource must be able to ramp up to 10% of rated capacity within 8 seconds

requirements and adhere to data privacy standards. In this project, Tesla is the retail DRP and operator of the on-site batteries.

Wholesale Demand Response Provider (Wholesale DRP)

The wholesale DRP or CAISO DRP is the entity tasked with managing market registration and operation of Demand Response Resources. Even though the DRP is the actual market participant, the only direct involvement with the CAISO the DRP has is in the registration process. Otherwise, most market activity is facilitated through the Scheduling Coordinator. The DRP is required to sign an agreement with CAISO and agree to abide by applicable market rules. The DRP is also required to submit attestation and methodology on performance calculation for the Demand Response resource.

Scheduling Coordinator (SC)

The Scheduling Coordinator is responsible for all market processes aside from market registration. This includes managing resource creation and management with CAISO, resource adequacy, market bidding, dispatch notifications, performance calculations, and market settlements. Olivine is typically both the Scheduling Coordinator and wholesale DRP, but it is allowed for the DRP to be a different entity than the SC. All Scheduling Coordinators are required to pay a $1,000 for each month there is bidding activity in the wholesale market.

For both portfolios, Olivine was tasked as both the SC and wholesale DRP.

Pre-Market: Preparing a PDR Portfolio for Participation in the Wholesale Market

The regulatory and market procedural steps necessary to implement PDR in the CAISO wholesale market can be divided into three phases: pre-market, market and post-market (see Figure 3: PDR Lifecycle).

Figure 3: Steps to Prepare PDR in the Wholesale Market

Several pre-market steps were required before Olivine could register the PDR portfolios at the CAISO.

1. *Data Release Agreements*

Each participating DER site host customer, e.g., the Chino Hills Unified School District for Portfolio 1 and hotel ownership holding company, Evolution, LLC, for Portfolio 2, executed a Customer Information Service Request (CISR) to grant Olivine, the wholesale DRP for both portfolios, customer energy data access from each portfolio's UDC billing meter account. The terms of these agreements fall under SCE Rule 24 and SDG&E Rule 32 for Portfolios 1 and 2, respectively.[4] The CISR agreement also granted Olivine as DRP, permission to register each portfolios' specific resource locations (e.g., the five Chino Hills schools in Portfolio 1 and two San Diego-located Hilton hotels in Portfolio 2) into the CAISO Demand Response Registration System (DRRS).

2. *Eligibility Determination*

Upon receipt of customer information from each of the customer site hosts' UDC, Olivine conducted an initial eligibility screening for items that prohibit the location from enrollment in the market. Each utility has rules preventing dual participation in a utility program (either CAISO-integrated or rate-based). As the retail DRP for Portfolio 1, Tesla led the effort to disenroll the five participating school accounts from the SCE demand response programs (Peak Day Pricing) that they were enrolled under.

3. *Account Validation*

Olivine then completed each portfolio's location registration into the CAISO Demand Response Registration System (DRRS). The DRRS functions as a registry to ensure that there is no duplication of customers enrolled in the wholesale market. Required DRRS information includes the UDC account, customer name, address, LSE, and Sub-LAP for each account.

4. *Resource Registration (Data Template)*

Once the locations were validated, Olivine, the wholesale DRP, proceeded to create resource registrations that mapped into the Resource Data Template (RDT) at the CAISO.[5] The RDT is a spreadsheet all resource types are required to complete in order for CAISO to have record of and use in its market optimization. The RDT is generally designed for conventional resources, so Demand Response resources will need to estimate their operational characteristics to mimic those of generators. This is a major ongoing barrier for PDR in CAISO because the characteristics of PDR are not as accurately mapped as conventional generators according to the market optimization

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[4] Additional information regarding Rule 24/32 can be found at https://www.cpuc.ca.gov/General.aspx?id=8314.

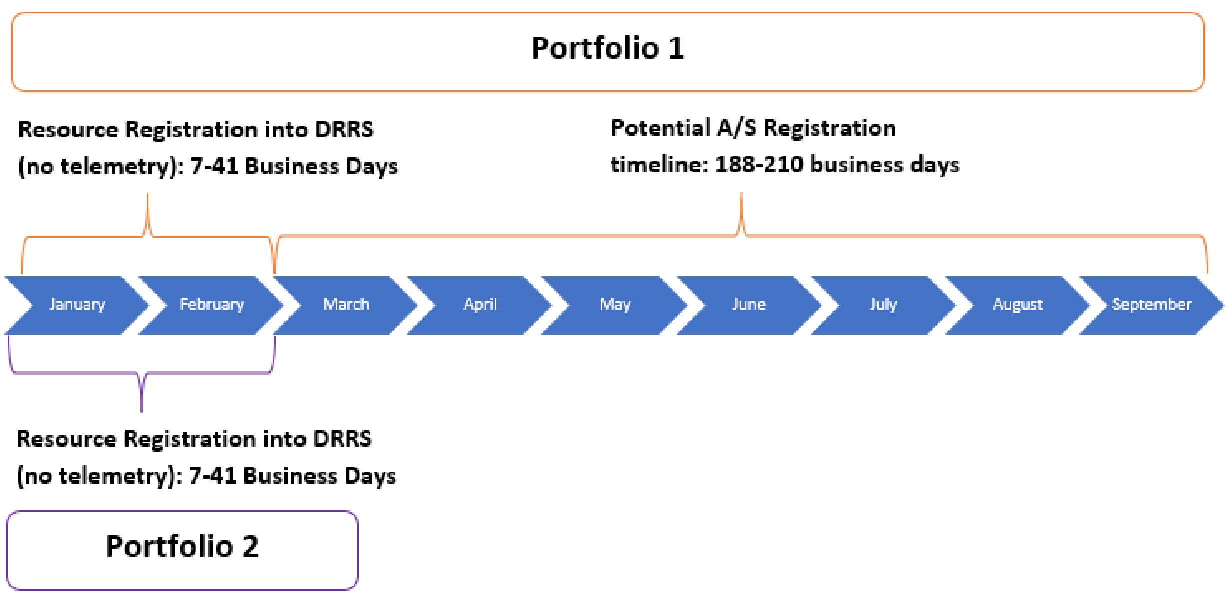
[5] Once the locations are validated, the DRP may register an individual location or an aggregation of several locations into a resource.

algorithms that drive market-based signaling decisions. For example, the maximum generation referred to in the RDT is the expected maximum curtailment level for DR. Required resource information included resource type, effective dates, and baseline measurement – which determines how payment will be calculated for performing in the wholesale market. A PDR resources can choose one of two baseline measurement options, pre-defined or custom:

- *Pre-defined Resource:* This is a resource that is assigned to an already-established aggregated Pricing Node (P-Node).
- *Custom Resource:* Requires constructing and validating a new CAISO Full Network Model (FNM)[6] via CAISO's New Resource Implementation (NRI) process, which is a minimum nine-month registration process.

The expected implementation timeline for the respective Portfolios is in Figure 4 below.[7]

Figure 4: Expected Time to Complete CAISO Market Registration for Both Portfolios



[6] The FNM is an electrical mapping of generation resources and transmission lines in CAISO territory. It is used as the basis for the power flow model that determines wholesale market prices and optimal generation dispatch.

[7] Note that CAISO registration for both portfolios will begin at the same time, even though entry into the market will be staggered.

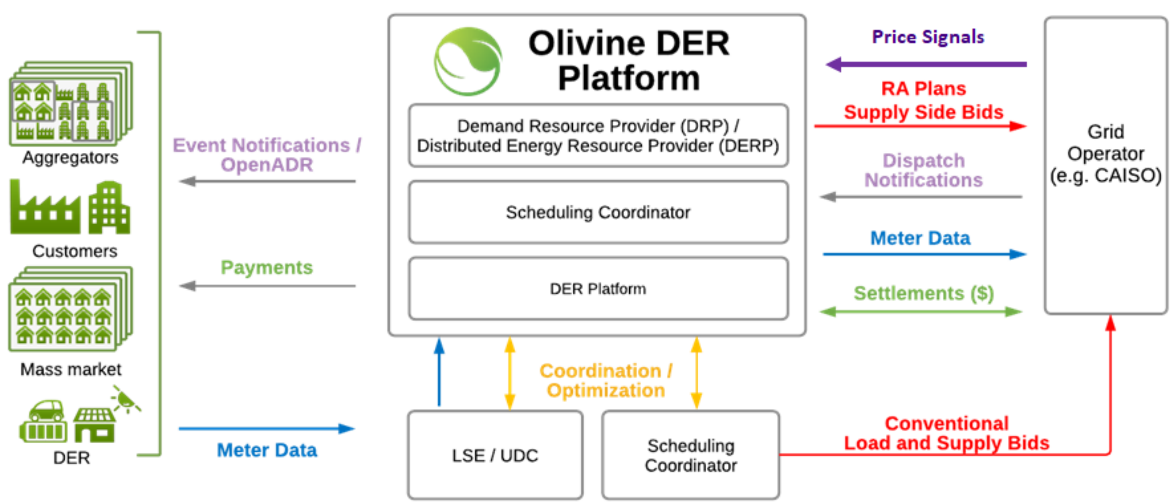
Because Portfolio 1 participated and performed ancillary services by providing spinning reserves, it required the custom resource pathway. Olivine therefore prepared an FNM and validated it with CAISO through the NRI process.

Price Responsive Technologies

A key feature of this project was to test the operability of technologies that can enable DERs to respond to price fluctuations in the wholesale market. For price responsive DER technology to work it must be it a utility and/or wholesale market price signal.

There are several hardware requirements for a DER price responsive system. To function effectively, the platform must establish connectivity to the grid operator as well as maintain visibility by keeping accurate and fresh data on the DER's energy use. This includes utility data from a customer's smart meter, with additional instrumentation as required for participation in specific markets (i.e., telemetry for ancillary services). For this project, Olivine's DER platform was the price responsive technology platform that was used by both portfolio for participating in the wholesale market (see Figure 5 below).

Figure 5: Overview of Olivine's DER Platform



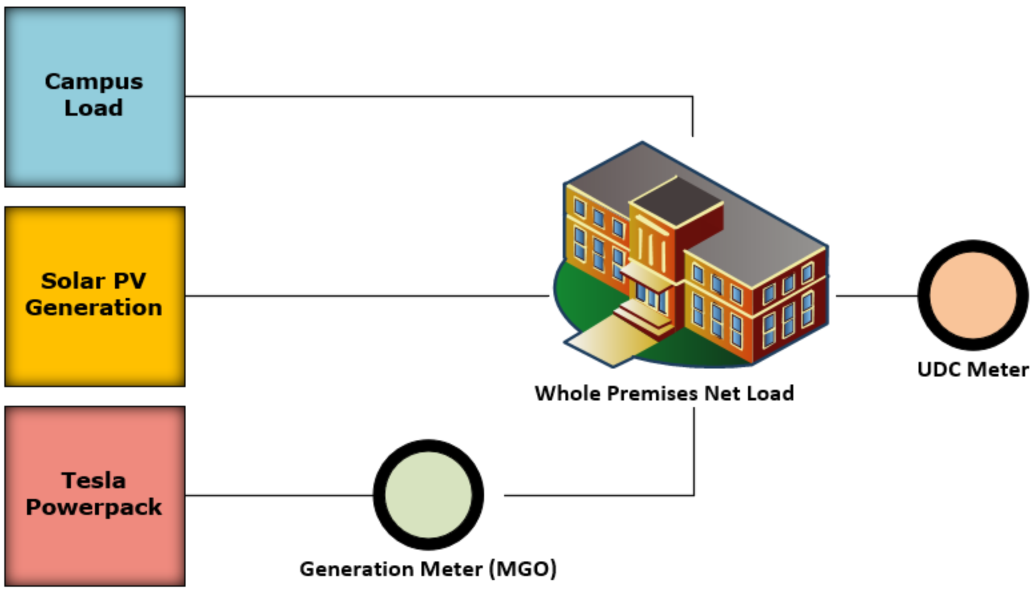
Metering

Both portfolios' metering systems needed to meet CAISO certification requirements. General requirements include the ability of metering systems to provide instantaneous demand (kW) measurements, are programmable for multiple time interval (e.g., 5, 15, 60 minutes) reads, have the ability store data for up to 60-days, and provide data measurements within a +/- 2% accuracy range.

Portfolio 1 Metering

Figure 6 illustrates the metered generator output (MGO) metering configuration for Portfolio 1. This configuration is applicable to all locations under the PDR aggregation where each public school facility is registered into the CAISO DRRS.

Figure 6: Portfolio 1 Metering Configuration



Under this configuration, the Tesla Powerpack storage device is sub-metered to determine the storage device's performance during a demand response event. A feature of this demonstration project is testing the ability of MGO as a mechanism to ensure accurate compensation, i.e., market settlement, of behind-the-meter (BTM) storage for its contributions to a DR event dispatch.

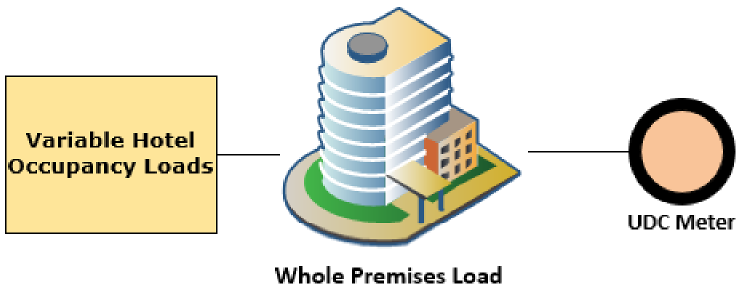
MGO metering requirements for resources located at Portfolio 1 are as follows:

- Any net export of energy recorded at the UDC premise-wide meter is accurately deducted from the performance of the sub-metered resource (i.e., when solar PV generation outpaces both the campus load and Tesla powerpacks' ability to charge (absorb), the excess solar PV generated electricity is exported back onto the local distribution grid).
- Sub-meter data must be set to zero (0) for any settlement interval that indicates the BTM storage device is in a "charging" state.

Portfolio 2 Metering

Portfolio 2 adopts the traditional, whole-premises metering configuration using the utility distribution company (UDC) meter as shown in Figure 7 in the diagram below.

Figure 7: Portfolio 2 Metering Configuration



In this configuration, all end uses – whether they are controlled for demand response or not – are aggregated together into the final UDC meter reading.

Dispatch and Communications (Telemetry)

Due to the different types of market services performed by each portfolio, the dispatch and communications (telemetry) configurations differed quite a lot between both portfolios. Table 2 provides a comparison across each portfolio of the various services offered, dispatch approaches and telemetry requirements.

Table 2: Comparison of Portfolios' Communications for Dispatch

Component	Portfolio 1	Portfolio 2
Market Services	Day-Ahead Energy Real-Time Energy Spinning Reserves Frequency Regulation (simulated)	Day-Ahead Energy Real-Time Energy
Dispatch Type	Direct	Indirect
Dispatch Integration	Tesla receives Customer Market Results Interface (CMRI) award and Automated Dispatch System (ADS) dispatches via integration with Olivine DER API Frequency Regulation simulation via Tesla	Email notification Operator manually sends event information to building energy management system

Component	Portfolio 1	Portfolio 2
	response to 4-second dispatch instructions from Olivine DER	
Telemetry	4-second telemetry utilizing existing equipment sent to CAISO via Olivine RIG	Utility distribution company interval meter (already installed)

Portfolio 1 Telemetry, Testing and Documentation Requirements for Ancillary Services

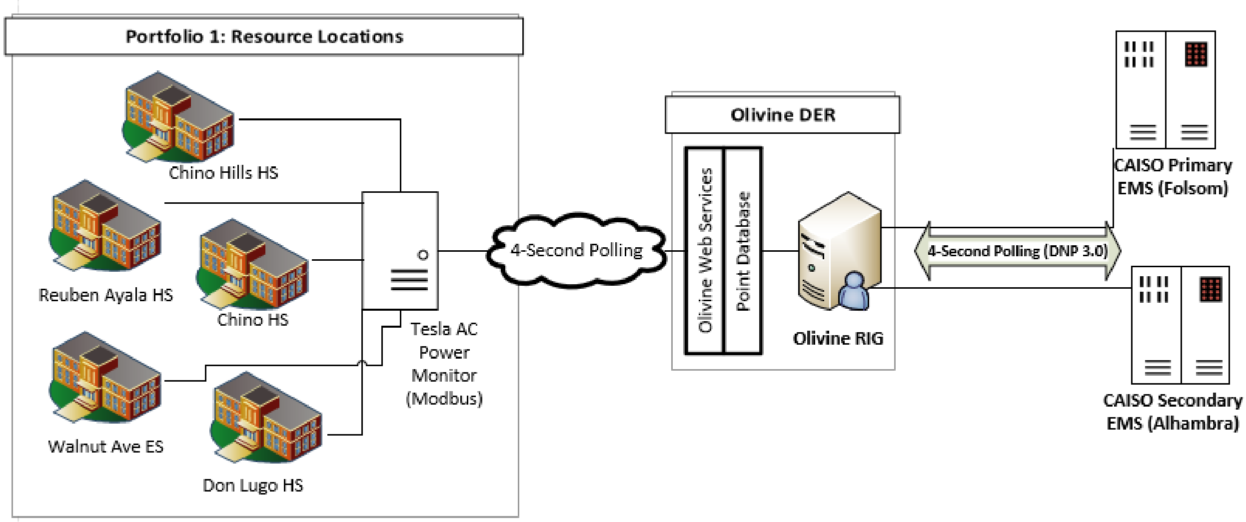
Extensive technology and testing requirements are required in order to perform ancillary services at the CAISO. This is primarily because ancillary services encompass critical grid reliability resources, such as spinning reserve, which is essentially a type of real-time backup resource that can help the grid remain operationally stable if an unscheduled grid contingency or emergency should happen. Each of the required technologies, necessary documentation and testing requirements required per the NRI process are summarized below:

Technologies

- *Remoted Intelligence Gateway (RIG*): a wholesale DRP must have a CAISO-certified Remote Intelligence Gateway (RIG) in place. Olivine has had a certified RIG with CAISO dating back to prior pilot projects involving ancillary service market participation.
- *Site Master Controller (SMC):* Each DER site resource needs to be aggregated into a single 'master' controller device that can maintain accurate and fresh energy data readings and signal specific controls to sites. Tesla owned and managed the SMC that maintained visibility and control of the aggregated battery energy systems.

Figure 8 shows the communications pathway from the Tesla batteries to CAISO systems. Tesla retrieves telemetry data via its SMC sends this data every 4 seconds to internal servers. Olivine's RIG queries Tesla's servers for this data and receives real-time battery output data for each location. Site data is aggregated and sent securely to CAISO via 4-second polling. This data is ultimately received by CAISO's energy management system (EMS). Olivine is required to maintain a dedicated phone line that CAISO uses to communicate any loss of site telemetry or if necessary, to communicate dispatch instructions manually in the event of a market software failure that prevents normal dispatch. Each site has Tesla meters, a wireless router, modem, cellular gateway, and site master controller utilized to retrieve and collect telemetry data.

Figure 8: Portfolio 1 PDR with Ancillary Services Communications Diagram



Technology Description (Engineering) Documentation

- *Project Details Form*: each Ancillary Services resource must be registered as a separate "project" in CAISO's databases. The initial "Project Details" form requires inclusion of a resource ID. At least one customer account must be fully registered prior to starting the certification process. This step can be a barrier for projects counting on Ancillary Services for initial revenue and the initial resource integration process must be completed for at least one location prior to beginning the NRI process.
- *Single Line Diagrams:* Conventional generating and front-of-the meter storage resources require detailed electrical engineering diagrams for each generation or storage resource, typically completed or stamped by a professional engineer. Olivine was not required to submit a PE-stamped SLD for this project.
- *Communications Block Diagrams*: This diagram outlines the communications pathways between actual sites and CAISO in relaying real-time information. Since much of the data transfer in this project is cloud-based, this does not necessarily represent a physical pathway.
- *RIG Details*: RIG device information is required prior to FNM implementation and Ancillary Service Registration. This includes the RIG device information and IP Address.

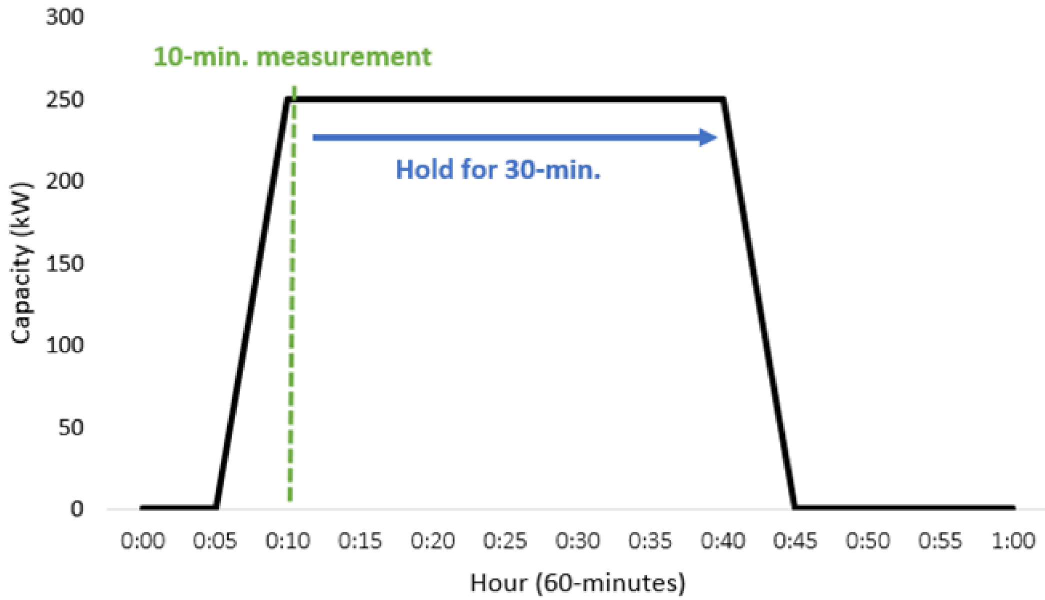
Contract and Settlement Information

- *Regulatory Contracts*: CAISO requires documentation for each resource that there is an agreement between the Scheduling Coordinator and the resource owner. Because Olivine acted as both the resource owner and the SC for this project, Olivine was the only party listed, but still was required to fill out the forms and be subject to CAISO verification.
- *Settlement Quality Metered Data (SQMD) Form*: CAISO requires documentation on meter data collection and submission processes for most generation resources without a CAISO meter. This includes a detailed description of meter data processing, calculations, and a description of internal audit procedures to ensure ongoing monitoring of data quality.

Resource Testing

- *Point-to-Point Testing*: Tests the telemetry reporting of DRPs such as Olivine who will be providing ancillary services. CAISO is mostly testing to ensure they can receive real-time data inputs as required for monitoring purposes. Once this testing is complete, final synchronization can take place.
- *Ancillary Services Testing*: The Spinning Reserves test assures CAISO that the PDR resource can drop load as instructed and that the telemetry communication is online throughout the test period (see Figure 9). The spinning reserves test has two components:
    - Ramp period (up to 10 minutes to reach certified capacity)
    - Hold Period (30 minutes for PDR to hold load below the expected capacity).

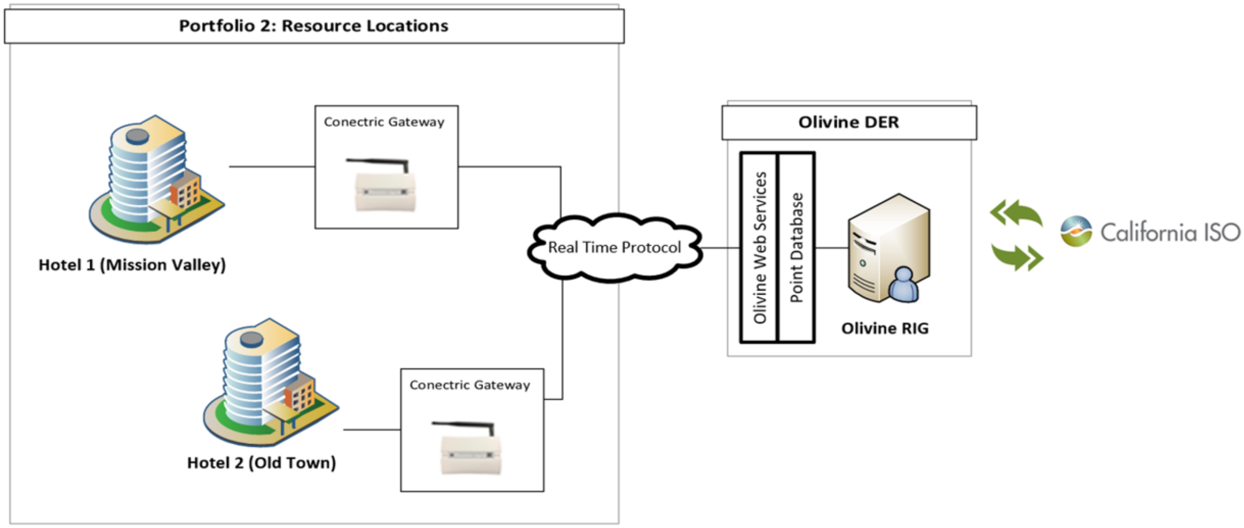
Figure 9: Spinning Reserve Service Test



Portfolio 2

For Portfolio 2, the Olivine DER platform is configured to receive notifications of day-ahead market awards from CAISO and then send out an automated email notification to the hotel facility operators detailing the energy quantity and dispatch hours. If the hotel operators accepted the day-ahead market notice, they then initiated a pre-programmed load-shed response in each facility. Conectric developed a load shed response based on the additional instrumentation that Conectric had set up in the hotels. As noted in the operational strategies section above, the load shed routine for the hotels included pre-cooling chiller water, building envelope, unoccupied rooms and adjusting thermostat set points to reduce energy use with minimal impact on thermal comfort. Figure 10 shows the communications architecture for Portfolio 2 that was established.

Figure 10: Portfolio 2 PDR Communications Diagram



Metering and Telemetry Equipment Costs

Resources at each portfolio have unique hardware and software capabilities to participate in the wholesale market. Metering infrastructure is evaluated for its readiness to participate in the market and incremental cost, e.g., to either retrofit an existing meter or replace the device altogether.

Resource owners may bear additional costs of installing or configuring metering or communications equipment, and connectivity charges, as well as software integration costs. Examples of such include purchasing a network interface card or a radio frequency module for an existing meter or installing a new meter altogether.

Tables 3 and 4 detail the relevant costs of equipment respective to each Portfolio.

Table 3: Cost of Price Responsive Equipment for Portfolio 1

Equipment	Description
Metering and Telemetry	Four of the public school facilities currently use Accuenergy ACCVim-IRR meter; quoted at $695 per unit. The Don Lugo High School location currently uses an SE-735 Power Quality meter with an estimated price tag of $1,500. The total cost for metering for Portfolio 1 is estimated at $4,280.
Network Interface	Portfolio 1 will utilize the existing communication infrastructure, carrying no additional incremental cost to either Tesla or Olivine.

Equipment	Description
Communication Protocols, Web Services and Security	It is expected that Tesla systems can meet the latency and frequency requirements for participating in spinning reserves.

Table 4: Cost of Price Responsive Equipment for Portfolio 2

Equipment	Description
Metering and Telemetry	No additional metering equipment is required beyond the retail utility meter provided by the local utility distribution company.
Network Interface	Conectric will either utilize a WiFi or LTE Network solution for the respective hotel sites. In the case of the former, total estimated costs are in the range of $350 for an advanced Conectric WiFi Edge G3 Gateway. The latter requires a LTE Edge G3 Gateway Modem (using T-Mobile carrier), estimated at $595, per site. Further tests between devices will reveal any potential upgrades necessary for frequency regulation simulations.
Communication Protocols, Web Services and Security	Conectric will leverage Olivine's existing communication protocols for telemetry; noting that issues in latency will not result in additional costs to either party as Portfolio 2 will be conducting frequency regulation market simulations only. The estimated cost is expected to be in the range of $150-$200 for software for Conectric's gateway. This includes device automation with Demand Conductor and Safety Store over a 3G/4G/LTE network.

Market Bidding

PDR are eligible to bid energy in the DAM and RTM, and participate in two ancillary services markets: spinning and non-spinning reserves.[8] The project team originally intended both portfolios to participate in both the day-ahead and real-time energy markets and for Portfolio 1 to provide spinning reserves. Additionally, the project team planned to simulate frequency regulation with Portfolio 1, which PDR is not currently eligible to provide in the market.

[8] CAISO has three ancillary service markets: Frequency Regulation (both up and down), Spinning Reserves, and Non-Spinning Reserves. However, CAISO only allows PDRs to provide Spinning Reserves or Non-Spinning Reserves.

PDRs are compensated for the energy they provide at the Locational Marginal Price (LMP).[9] Ancillary service compensation is driven by market-wide auction. The LMP itself consists of a single energy cost (i.e. the System Marginal Energy Cost), loss factors, and congestion prices, with the latter two determined from distribution factors applied to the LMPs of the underlying P-nodes, which the PDR is modeled. There are no non-performance penalties for PDRs in energy markets, but there are consequences for non-performance for ancillary services.[10] Bidding is submitted by the SC into the CAISO Scheduling Infrastructure Business Rules (SIBR) system, a platform utilized by the CAISO to validate and accept bids and make any necessary modifications.

The award and dispatch of energy is conducted by the CAISO Customer Market Results Interface (CMRI) and Automated Dispatch System (ADS), respectively. In the event of an energy award, Olivine, the SC, will receive market results, day-ahead energy schedules and ancillary services award information from the CMRI and proceed to send a notification to the respective Portfolios. During real-time market operations, the CAISO transmits dispatch instructions via the ADS. Transmitted signals may include startup and/or shut-down request along with possible curtailment and ancillary service instructions.

DAM energy and DASR market awards are paid the day-ahead clearing price. At minimum, resources are guaranteed to receive their energy bid price for any awarded quantity, but typically actual payment will be greater because the market price is set by the most expensive resource. For resources in the RTM 15-minute energy market, awards are paid the appropriate 15-minute market clearing price at an incremental award amount above the day-ahead award. (Under some circumstances, it is possible that RTM 15-minute energy awards could end up smaller than the participant's DAM energy awards, meaning participation in the RTM 15-minute market would yield a charge against the DAM award).

Resources with 15-minute ancillary service capacity awards will be paid the appropriate 15-minute market clearing price for any capacity incremental to day-ahead market awards.

Rules for Day-Ahead Market Energy Bids

Market participants typically need to submit bids by market close at 10:00 AM (on the day prior). The CAISO typically publishes DAM awards by 1:00 PM for each hour for the following day.

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[9] LMP = system marginal cost of energy + marginal cost of congestion + marginal cost of losses

[10] See page 7 of Navigant (2012*) Potential Role of Demand Response Resources in Maintaining Grid Stability and Integrating Variable Renewable Energy under California's 33 Percent Renewable Portfolio Standard*, Prepared for the California Measurement Advisory Council (CALMAC). Accessed December 18, 2017 at URL: http://www.calmac.org/publications/7-18-12_Final_White_Paper_on_Use_of_DR_for_Renewable_Energy_Integration.pdf.

- PDR energy bids must be between the *Net Benefits Test* (NBT) price and $1000/MWh (or $1/kWh). The NBT price is updated monthly and typically between $25/MWh and $45/MWh.[11]
- Participant may submit up to 24 different energy bids (one for each hour of the day).
- Participants have an option to bid with a *Daily Energy Limit*. The daily energy limit is the maximum amount of energy (MWh) that can be awarded to a given PDR in a day. This parameter allows PDR with limited resource availability (such as a battery) the opportunity to bid across a wide availability window. For example, a participant with a 1 MW / 4 MWh rated battery available for curtailment could bid 8 hours at $50/MWh and submit a 4 MWh energy limit. If market energy prices were to then be greater than $50/MWh (and thus be above the bid clearing price of the PDR) for all hours, the PDR would only contribute up to its 4 MWh daily energy limit.
- Energy bids must be at a quantity between their rated minimum and maximum curtailment level, known at CAISO as "P_{MIN}" and "P_{MAX}".
- PDR participants can submit multiple bid segments (up to 11) during a given time period up to its rated capacity. For example, a 1 MW resource could bid:
  - 0-0.1 MW: $30/MWh
  - 0.1-0.5 MW: $50/MWh
  - 0.5-1 MW: $100/MWh

Rules for Day-Ahead Ancillary Service [Spinning Reserve] Bids

The following rules apply for resources that are certified to provide ancillary services, such as Portfolio 1:

- DASR bids may be between $0 to $250/MW
- Bids can be submitted simultaneously for DAM energy and DASR.
- Bids can be up to the certified quantity, but only one bid segment is allowed (unlike the case for energy bids).

CAISO co-optimizes the DAM energy and DASR bids, which means the market will reward the opportunity cost of foregone DASR bid amounts in the form of a DAM energy award. PDR resources can thus bid both energy and ancillary services for the same capacity without carrying the risk of reduction in revenue. This is one reason why spinning reserve prices correlate very strongly with DAM energy prices. Spinning reserve bidding scenarios are further described below.

- *Example 1*: A 1 MW-rated resource bids 1 MW at $50/MWh for DA energy and bids $0/MW for 1 MW spinning reserve. CAISO market optimization results in an energy LMP of $150/MWh and 1 MW of awarded spinning reserves.

[11] The NBT was a result of Federal Energy Regulatory Commission's (FERC) Order No. 745, which effectively allowed power market operators such as CAISO the authority to compensate demand response resources at the same locational marginal prices that generating resources receive in the energy market.

- Thus, opportunity cost is $150 - $50 = $100/MWh.
- The resource will set the spinning reserve cost at $100/MWh

- *Example 2*: A 1 MW resource bids 0.5 MW energy at $50/MWh and 0.5 MW Spinning Reserves at $0/MW.
  - Opportunity costs will be considered if the energy award is less than 0.5 MWh (e.g., for example, if energy award is 0.4 MWh and Ancillary Services Capacity is 0.5 MW, then opportunity costs are calculated as in Example 1). If energy award is 0.5 MWh, the resource is already compensated for its energy as profitable.

- *Example 3*: A 1 MW resource bids 0.8 MW energy and 0.5 MW spinning reserves.
  - As in Example 2, opportunity costs are not included for the first 0.5 MWh but are considered for energy awarded beyond 0.5 MWh.

Post-Market Settlement

Settlement involves reviewing the actual DER response using the agreed-upon settlement terms of each portfolio when it registered with the CAISO. Historically, DR performance has been computed from whole-premises metering only, utilizing a baseline methodology to determine the counterfactual (i.e., whole-premises behavior if the DR event did not occur).

Portfolios' Settlement Constructs

Portfolio 1 used the CAISO Metering Generator Output (MGO) method to calculate demand response performance by relying on a sub-meter that directly measures the contribution (energy delivered) by the registered generation device located behind the whole-premises revenue meter. The MGO baseline is based on the average storage discharge during the specific event hours. Having the baseline based on event hours only is an important beneficial distinction from other typical DR baseline methodologies (see Portfolio 2 below). The usage of "event hours only" means it is possible to have several different sets of baseline days that can be segmented to a given events' duration. For example, a 4-hour event could utilize a different set of 10 baseline days for each hour if there were 1-hour events in the past. For participants providing ancillary services such as DASR that Portfolio 1 provided, CAISO has additional settlement rules and procedures, which are described in more detail in the next section, "Ancillary Services Settlements and Penalties."

Portfolio 2 used the standard "10-in-10" commercial baseline methodology. The 10-in-10 baseline load methodology is calculated based on the average customer load during the same event hours for the ten most recent non-event similar days, e.g., weekdays versus weekend days and holidays. A limitation with this approach is customer participation in too many events over a brief span of time can lead to degradation of the facility's calculated baseline, i.e., by reducing the availability of similar non-event days’ time periods average energy use, which would cause a reduction in the potential settlement award.

Ancillary Services Settlements and Penalties

For ancillary services specifically, CAISO can claw back ancillary service capacity awards if there is non- or under-performance during an event where the reserves are called upon (as well as if there is non- or under-performance during a CAISO-commissioned test dispatch). All ancillary service awards within the past 12-months may be subject to claw back for non- or under-performance.[12] CAISO maintains strict non- and under-performance penalties for ancillary services such as spinning reserves that Portfolio 1 is providing because these services are considered essential to maintain grid reliability (akin to procuring “on demand” backup) should an unforeseen grid disturbance occur.

[12] All payment rescission criteria are outlined in CAISO’s applicable Business Practice Manual (BPM) http://www.caiso.com/rules/Pages/BusinessPracticeManuals/Default.aspx.

CHAPTER 3: Project Results

In this section we discuss the actual encounters regarding customer and vendor experiences, perceptions and feedback received over the course of project implementation. We also discuss the unanticipated challenges, how we overcame them, and lessons learned, including but not limited to, contracting-legal issues encountered during the project preparatory phases. This section is subdivided into three sections, Portfolio 1, Portfolio 2, and a cost-benefit analysis.

Portfolio 1

Customer Acquisition and Engagement

Due to previously installed battery energy storage at the Chino Hills Unified School District school sites, the project team was able to get all customer agreements and contracts signed in order to register the sites in the market, retrieve customer utility meter data, schedule site visits and testing, and ultimately participate in the market. The project team leveraged the pre-existing relationship that Tesla had with the school sites, which helped in expediting the administrative processes with customers.

The project team found the school sites were very eager to implement new, innovative strategies, and this mindset helped in getting approval to conduct the project. Prior to project participation, the schools had already implemented energy efficiency upgrades and installed solar PV and energy storage systems. The opportunity to receive additional value from these DERs caused the schools to be responsive and cooperative throughout the duration of the project period.

Customer Data Release and Market Participation Agreement

The Chino Hills Unified School District was enrolled in the Summer A/C Cycling program at SCE. Per Rule 24 program disenrollment rules, the project team needed to wait at least one full billing period before being able to participate in the wholesale market.

Because the Tesla batteries were prepared to perform spinning reserve, a type of ancillary service in the wholesale market, it meant a risk of market non-performance would lead to a potential "penalty." (Whereby the owner of the resource would have to pay CAISO for not delivering the precise amount of energy that was bid, i.e., promised, in the spinning reserve market at CAISO). This potential market/financial risk due to potential non-performance of Tesla's battery resources meantTesla and Olivine needed an extended period of time to negotiate a partner contract agreement that clarified what the foreseen non-performance risks were and who would be responsible for paying the market penalty in each possible non-performance occurrence.

CAISO Registration and Resource Testing

Olivine initially expected to be able to participate in ancillary service markets starting in June 2019. Upon official un-enrollment from SCE's A/C cycling demand response program, Olivine was able to register Portfolio 1 in the CAISO DRRS with no significant issues or delay. In the first phase of the NRI process, the development and validation of the Full Network Model (FNM), generally went along as expected as far as scope and timeline. However, during the ladder part of the NRI process the project team encountered several unforeseen delays and issues.

Pre-Market Integration Challenges

These procedural and technical challenges were due to the unique and innovative nature of Portfolio 1 PDR providing ancillary services — representing one of the first PDR portfolios to do this in the CAISO market. Staff at CAISO learned how to integrate a PDR of this nature for the first time alongside Olivine staff. This often led to misunderstandings regarding how and when certain procedures would be completed in the NRI process.

There were also several technical challenges encountered between Olivine and CAISO, which included initial communication protocol issues between Olivine's remote intelligence gateway (RIG) and CAISO's notification and signaling system, as well as during the point-to-point testing required for final spinning reserves certification. Though the technical challenges were resolved in a reasonably timely manner, they contributed approximately two additional months to the initially expected pre-market portfolio integration timeline. The issues encountered highlight the overall uncertainty regarding the NRI timeline for ancillary services market integration. This project provided important insights into the likely hurdles and possible resolutions necessary to streamline the process in the future.

Table 5 below documents Olivine's experience in the ancillary services integration process.

Table 5: Full Network Model and Ancillary Services Testing Timeline

Task	Date Completed
Project Details submitted to CAISO	2/15/2019
Single Line Diagram Accepted	2/21/2019
Communications Block Diagram Accepted	2/26/2019
RIG Details/IP Address Accepted	2/26/2019
RIG Reconfiguration Project	3/22/2019

Full Network Model Implementation	5/23/2019
MGO Performance Evaluation Methodology Accepted	4/12/2019
SQMD Plan Accepted	8/23/2019
Point-to-Point Test Completed	12/5/2019
Spinning Reserves Test Completed	1/22/2020

Pre-Market Integration Solutions

The pre-market integration challenges encountered by the project team are broken down into the following key issues and solutions — some of which were resolved or started on the path toward resolution as a result of the activities undertaken by this demonstration project.

Retail DR Program Unenrollment Opportunity Cost

For a PDR portfolio intending to participate in ancillary services such as spinning reserve, there is a significant opportunity cost on the part of the resource owner not being able to participate in either a UDC-provided retail DR program or participate in the market as an ancillary service such as spinning reserve during months-long pre-market integration NRI process. All five of the specific customer accounts utilized for this project were enrolled in a retail DR program prior to participation in this project. Chino Hills school district ended up losing out on at least ten months of retail DR program participation value as a result.

One possible solution to this customer unenrollment issue is to allow DRPs such as Olivine to complete the resource ID reservation process at CAISO, specifically for the NRI process prior to customer unenrollment from a retail DR program. A second possible solution would allow for utilities to play a role in the resource ID reservation process at CAISO by helping customers facilitate and validate the registrations in CAISO's resource ID system. Olivine has found that utilities would be willing to aid in this process, including the electric utility provider for Portfolio 1, SCE. A more formalized process of this nature would provide DRPs and potential customers more certainty regarding timing and hopefully a lower opportunity cost prior to deciding to go through the steps necessary to participate in ancillary services markets. CAISO's transition from a quarterly to monthly Full Network Model implementation may also resolve some concerns over lag between unenrollment a retail DR program and participation in ancillary service markets in the future.

NRI Process Documentation

At the time that Olivine began the NRI process, CAISO had not provided detailed integration steps regarding how to register a PDR expecting to provide ancillary services. Throughout the resource integration process, there were several complications due to uncertainty over proper procedures and expected timelines.

Since Olivine started the integration process in early 2019, CAISO posted additional documentation regarding the registration process for PDRs that intend to provide ancillary services in CAISO markets. Olivine has since provided additional feedback to CAISO on the process based on this project's experience. The project team considers this issue to be mostly resolved at this point.

Sub-Metered Telemetry

Current CAISO documentation allows for several different methods to provide real-time data communications, i.e., telemetry, in order to qualify for provision of applicable ancillary services. Generally acceptable telemetry arrangements include data retrieval from utility meters or building-level Energy Management Systems. However, Olivine's previous research indicated 4-second telemetry required by CAISO in order to provide spinning reserves is not currently retrievable from typical utility meters. While Tesla's battery installations included sufficient sub-metering telemetry to meet CAISO ancillary service requirements, not all storage installations in the future may provide this capability.

Over the course of this project, Olivine made suggestions to CAISO to allow for PDRs to provide telemetry data for sub-metered devices like Tesla's battery portfolio. This would give CAISO greater visibility into the actual devices that are meeting ancillary service needs as opposed to relying on whole premise utility meter data. CAISO agreed with Olivine, and as a result of this project, CAISO now has a better understanding of sub-metering configurations of BTM battery energy storage configurations like Tesla's battery aggregation.

Wholesale Market Participation

Day-Ahead Market

Portfolio 1 participated in the day-ahead and real-time energy markets from September 2019 through February 2020. Throughout market operation period, Tesla directly entered and submitted bids to the CAISO day-ahead market. Due to a combination extended agreement negotiations between Olivine and Tesla, and delays during the CAISO market integration processes, the Tesla batteries only performed a total of eight events at the time of drafting this report. Olivine analyzed the post-market event data and compared the potential financial impact of utilizing MGO baseline versus the typical 10-in-10 baseline methodology. Table 6 below shows Tesla's market bids, market revenues and the potential market revenue differences between the whole premise meter 10-in-10 settlement baseline versus MGO.

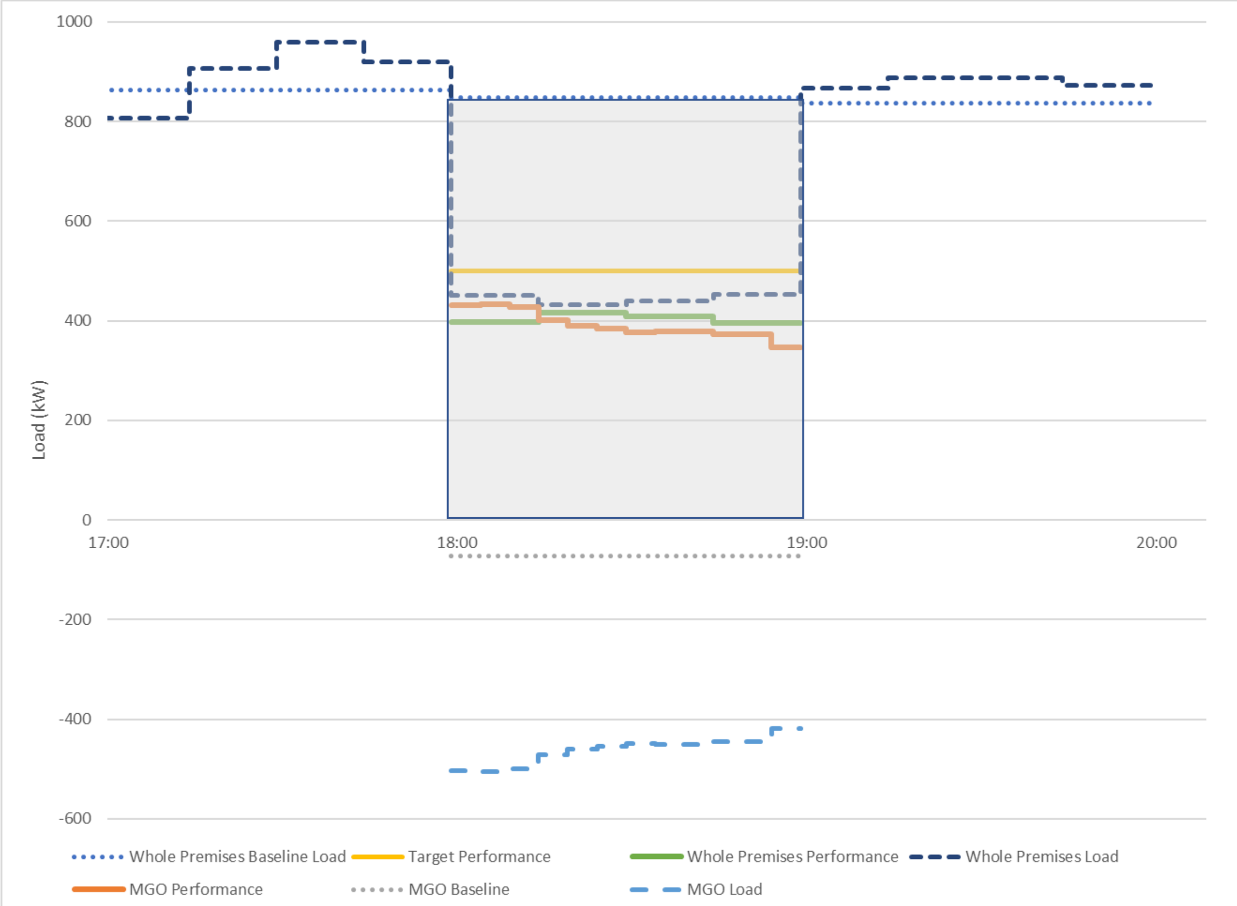
Table 6: Baseline Performance Comparison of MGO to Whole Premise Meter 10-in-10

Event #	Target Performance (kWh)	10-in-10 Performance (kWh)	MGO Performance (kWh)	Market Revenue (10-in-10)	Market Revenue (MGO)
1	500	686.6	638.1	$24.79	$22.93
2	500	244.6	256.9	$16.81	$17.18
3	500	461.8	352.6	$13.73	$15.77
4	500	288.4	257.4	$7.61	$6.59
5	500	403.8	390.8	$17.95	$17.64
6	500	363.0	425.4	$13.32	$15.26
7	500	161.7	264.0	$8.37	$11.24
8	500	359.5	467.0	$15.59	$19.08
Total	**3,750**	**2,969.3**	**3,062.2**	**$118.16**	**$125.69**

On average, there was not a significant difference in performance calculation using the sub-metered MGO data versus the whole premise 10-in-10 calculation. However, analyzing a small sample size of eight events is likely too small to draw any conclusions over whether the MGO methodology is more favorable or more accurate. Overall, the average performance using MGO was about 5% higher than the average performance using whole premises metering, though this ranged from a 24% lower calculated performance in Event #3 to 64% higher in Event #7. Most of these events were in the evening in February and there was not as much solar generation that went into influencing the whole premise 10-in-10 baseline calculation, which could change during the late spring and summer months when the sunset occurs later in the evening.

Figure 11 below provides a closer look at the 5-minute interval level in comparing whole premise meter data reads (used for 10-in-10 baseline methodology) to the sub-metered battery reads (used for MGO) for Event #6. In this case, the difference in the hourly average performance calculation between the 10-in-10 and MGO was below 2.5%.

Figure 11: Event #6 Metering Comparison of Whole Premise Meter Versus MGO



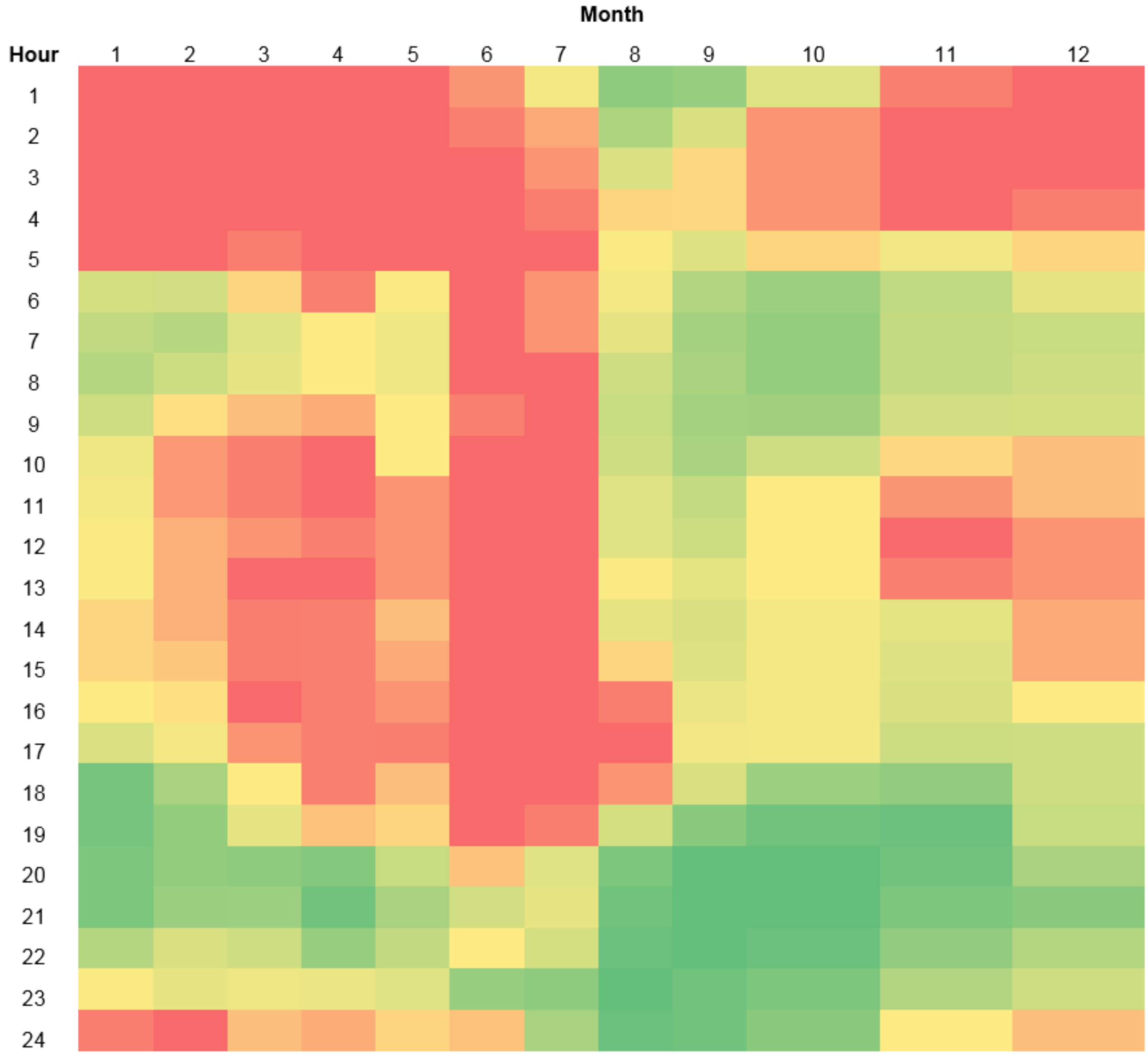
Spinning Reserve

Though Portfolio 1 was not prepared for ancillary service participation until after this report was in final stages of drafting in late March 2020, Olivine modeled potential market revenues for portfolio 1 based on facility load data and day-ahead spinning reserve market prices in 2019.

Olivine's 2019 spinning reserve analysis for Portfolio 1 indicated the majority of evening hours (6 PM-10 PM), particularly on weekdays, showed site loads that were greater than 500 kW on a consistent basis.[13] The darker green cells in the heat map below in Figure 12 represent the hours with the most available spinning reserve potential.

[13] Recall that grid exports are not eligible for market revenues under the current CAISO PDR construct, thus site load "demand" must be high enough to utilize what is assumed to be full battery capacity for this modeled analysis.

Figure 12: Hourly Load Heat Map by Month for Portfolio 1



Olivine's analysis showed that only 2,550 hours would be available with enough total site load to meet the minimum 500 kW bid threshold for spinning reserves. The average annual market clearing price for day-ahead spinning reserve was $9.46, which would have yielded a total annual revenue of around $48,000. Olivine also calculated that if the Portfolio 1 were able to use grid exports as spinning reserve and could maintain 500 kW available for spinning reserve for all 8,760 hours in the year, Portfolio 1 could have yielded spinning reserve market revenues as high as $115,000.

Post-Market Settlement

MGO Calculations During Periods of Charging or Net Export

In the process of analyzing MGO performance calculation, Olivine discovered a particular issue with accounting for battery charging during relevant calculation hours. CAISO's documentation stated that any period with net charging should not be counted, i.e., equating to a baseline of zero. However, Olivine noted there may be some situations where there is charging for part of an interval even if there is mostly discharging throughout the period. This is especially a concern if data is reported at 15-minute rather than 5-minute granularity. After reviewing the issue, CAISO agreed with Olivine's proposal to calculate the net discharge amount during any given period, thus accounting for both charging and discharging.

There was an issue regarding situations where an account with storage was expected to be dispatched during a period of net facility export. Olivine questioned how this could be accounted for in calculating MGO baselines and performance. It was agreed that to the extent there is any grid export, Olivine will calculate net contribution of storage resources as necessary. For example, if there is 1 MWh of export onto the grid and happens to be 2 MWh of battery discharge, Olivine would use the 1 MWh not contributing to grid export for any baseline or performance calculations.

Ancillary Services Market Settlement

Current settlement rules for PDR resources may discourage PDRs from economically bidding in both spinning/non-spinning reserves and energy markets. The CAISO calculation for ancillary service no-pay provisions is based on a "meter before - meter after" analysis without regard to any related energy dispatches. Consider the following example:

- Resource dispatched for 1.2 MW between 3-4 PM
- Resource awarded Spinning Reserves for 0.6 MW between 4 PM and 5 PM.

Suppose the typical load for the resource is 1.2 MW. This means the load from 3-4 PM will be 0 MW. This value from 3:55-4 PM would then be carried over as the meter-before baseline for ancillary services in the current no-pay calculation. Operationally, the resource still would have the capability of reducing load, but it will not receive any credit for the spinning reserves capacity. If there happens to be a real-time market dispatch from 4 PM to 4:55 PM, it may also appear the resource did not meet its obligations because the load will actually increase from 0 MW to 0.6 MW. In this case, there would still be an energy settlement for reducing load relative to the 1.2 MW baseline even though there is no accounting for this with the spinning reserves settlement.

Olivine alerted CAISO about this issue; however, at the time of drafting this report had not received feedback or resolution from CAISO on this issue.

Inflexibility in Availability Requirements for Ancillary Services Resources

In CAISO energy markets, most DR have some variability in availability by hour. DR programs are often limited to a certain subset of peak hours throughout the day, with some programs also allowing for inter-hour availability. Third-party aggregations participating in CAISO markets have full flexibility on bid quantities in energy markets. For each hour, a resource can submit bids anywhere from the minimum to maximum curtailment quantity. CAISO's rules regarding resources certified for participation in ancillary services markets require availability for the full certified ancillary services capacity for all hours of participation. Variable-availability customer-sited resources providing ancillary services may need to either need to certify for a lower quantity than possible, severely limit the hours of participation, or both.

For portfolio 1, Olivine thus submitted a 0.5 MW quantity for spinning reserves even though the total battery capacity available was at least 0.8 MW and the certified quantity was 0.65 MW. Relaxing the CAISO's bid requirements and bid insertion rules for distributed energy resources participating in ancillary services markets could increase potential revenue and enhance market participation.

Counting PDR Grid Exports

A significant challenge in assessing the resource availability for Portfolio 1 was the significant generation of on-site solar, which occasionally exported electricity resources onto the respective local distribution grids. CAISO PDR settlement rules do not allow grid export from BTM resources to be counted as a market resource, forcing a significant amount of market revenue potential was lost (as shown in Olivine's 2019 modeled analysis of potential ancillary services revenue). This restriction also applies to PDR providing spinning or non-spinning reserves. Olivine estimated this limitation reduced ancillary services revenue 20-50%, further lowering the value proposition for PDR to invest in the necessary sub-metering telemetry equipment and go through the CAISO's NRI process.

Olivine has devised a potential compromise to CAISO's export restriction by allowing PDR to export solely for the purpose of providing ancillary services, without a corresponding energy settlement. Since CAISO rarely utilizes spinning or non-spinning reserves for energy provision, this would not likely result in significant operational changes at the CAISO. However, it would allow for customer-sited clean energy resources to displace conventional fossil generation that is currently widely utilized for these services, potentially improving grid operational efficiency and helping to clean the grid. As it stands today, fossil generation power plants are kept online to meet ancillary service requirements even while there is excess solar on the grid.

Portfolio 2

Customer Acquisition and Engagement

Unlike Portfolio 1, Portfolio 2 did not have vendor technology installed at the customer sites prior to project implementation. Though the management overseeing the two hotel sites allowed Conectric to perform equipment installations in its initial round of IoT sensors in hotel common areas, central plant and HVAC equipment, and limited hotel guest rooms (for technology testing purposes) at the outset of the project, a significant amount of project developers' time was spent on educating host customers about the necessary regulatory and market entry procedural steps to participate in the wholesale electricity market. Through Portfolio 2's customer experience, the project team learned that:

- Long timeline delays can cause customers to withdraw from projects if priorities change. In commercial properties this can include changes in property management and ownership.
- It is essential to thoroughly develop the project plan and timelines to anticipate and avoid potential delays.
- Customers need clear, simple explanations of wholesale market participation concepts. The better customers understood these concepts, the more they were willing to participate.

Facilities' Diagnostics: IoT Sub-Meters and Sensors Installation and Calibration

In the first phase of the process, the project team conducted a facilities' diagnostics study to get a more robust understanding of energy usage behaviors and drivers in each hotel. The facilities' diagnostics study started with a detailed scheduling of all electrical equipment in the hotels using a mobile software tool. This scheduling took the form of a Level II ASHRAE type audit which the hotel management had not conducted previously. All electrical consuming pieces of equipment in each facility were tallied into a database with nameplate energy use data, quantity and end-use.

Equipment were then sorted according to whether they are under control of the existing Building Management System (BMS) and whether they were controllable.

Dr. Ekawahyu Susilo of Conectric reviews the dashboard of controllable load capacities at one of the Portfolio 2 facilities

Credit: Philip Kopp

Examples of controllable equipment included variable frequency drives (VFDs), fan coil units, air handling units (AHUs), exhaust and fan motors. Examples of uncontrollable equipment included elevators, information technology (IT) equipment, kitchen equipment and most lighting. Tables 7 and 8 below provide summary diagnostics reports of potential controllable loads for each hotel facility. Figure 13 shows the combined total potential controllable load capacity for the entire portfolio for a hypothetical 3-week time period in late July.

Table 7: Summary Diagnostics Report for the Hilton Mission Valley [San Diego] Hotel Controllable Electrical Loads

General Equipment Category	Controllable
HVAC (Pump/VFD)	Yes
HVAC (Pump/VFD)	Yes
HVAC (Chiller-Backup)	Yes

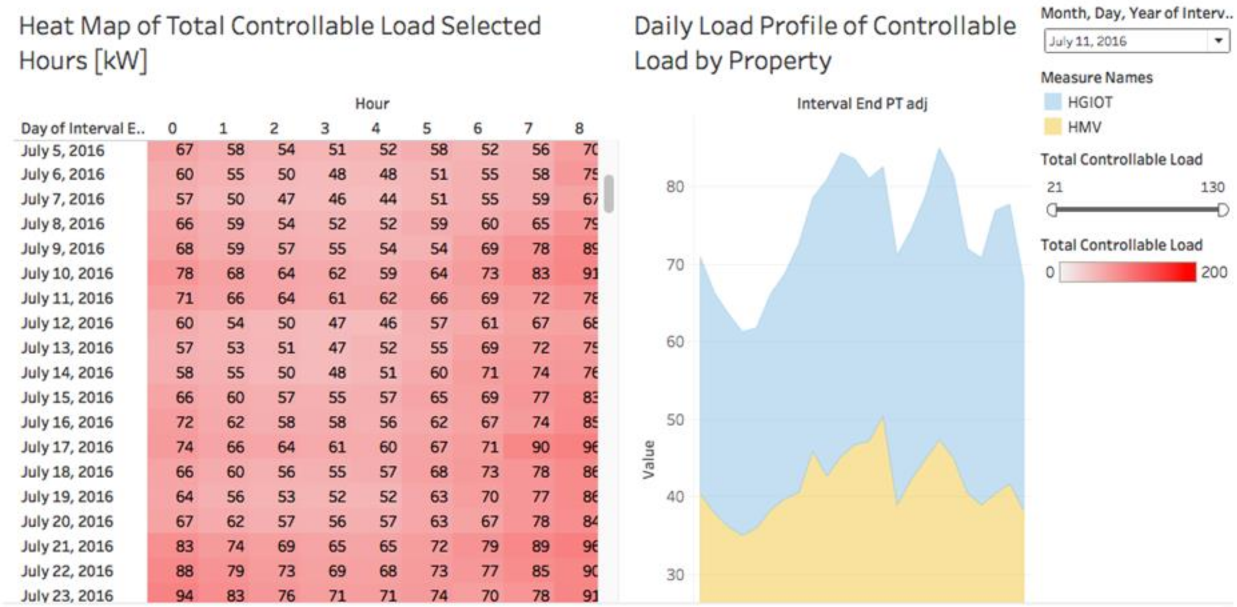
General Equipment Category	Controllable
HVAC (Chiller Primary)	Yes
Guestrooms (Interior Light/Plugs/Fancoils)	Partially (daytime)
Elevators	No/Partially
Ventilation (AHUs)	Yes
HVAC (cooling tower fan), Ventilation, Pumps (hot water)	Yes
Pumps	Yes
Other: Common area lighting, outdoor lighting, IT, Recreational Areas, Kitchens, Laundry Services	No/Partially (unknown)

Table 8: Summary Diagnostics Report for the Hilton Garden Inn Old Town San Diego Controllable Electrical Loads

General Equipment Category	Controllable
HVAC, Hot Water, Water Pumps	Yes
Outdoor Lighting	Yes (during daytime hours)
Indoor Lighting, IT	No
Elevator	No/Possible to run 1 at a time
Elevator	No/Possible to run 1 at a time
Elevator	No
Recreational Facilities	Yes
Kitchen	No
HVAC	Yes
IT	No
Indoor Lighting, Ventilation	Partially
HVAC, Guestrooms	Yes
HVAC, Guestrooms	Yes

General Equipment Category	Controllable
Ventilation as Make Up Air	Yes
Ventilation as Make Up Air	Yes
Misc.	Yes

Figure 13: Conectric Dashboard of Controllable Load Capacity Across Both Hotel Facilities (Portfolio 2)



A total of 18 rooms, including 10 control rooms and 8 experimental rooms were monitored and controlled for the HVAC behavioral analysis. An additional 16 sensors, including 8 Passive Infrared Type occupancy sensors to monitor human presence and 8 contact switch sensors were installed to monitor door entry and exits into rooms.

Additionally, a total of 25 Revenue Grade type certified sub-meters were installed (9 at the Hilton Mission Valley and 15 at Hilton Garden Inn Old Town properties) to disaggregate loads, assess resource potential and performance delivery. Sub-meters were used to monitor major loads such as pumping systems, ventilation, cooling systems, guestroom energy and lighting. Sub-meters were networked using IoT data hubs around the facilities including in the basement mechanical rooms, electrical closets, meeting rooms and rooftop motor control centers.

Guest room placement of Conectric Networks' occupancy, temperature and fan coil sensors in one of the hotel facility guest rooms

Credit: Philip Kopp

Significant equipment changes happened during the nearly three year implementation period of the project. In one property a previously installed thermal storage system was removed and new boilers were installed, all the while renovating an entire floor as executive suites and installing a new staff lounge. At another property the main cooling tower was replaced. Without the Level II audit and detailed facility diagnostics performed by Conectric the varying load impacts of these major equipment changes could have very well gone unnoticed had one only assessed the facility level utility meter data.

The results of Conectric's facility diagnostics load control analysis revealed for both hotel facilities, the thermal mass, pre-cooling potential of the buildings' envelope outweighed the potential demand response potential of numerous other individual components or equipment in the hotels, e.g., guest room HVAC, common area lighting, pool pumping. Both hotel facilities' DR potential was reasonably high for the most common form of DR event – summer and fall heatwaves. Conectric showed a two-staged building envelope pre-cooling approach would yield the greatest demand response load capacity without significantly sacrificing hotel occupant comfort or disrupt normal operations. Stage one consisted of pre-cooling the HVAC cooling system chiller water (ideally beginning during the overnight through early morning hours) and pre-cooling facility common areas along with unoccupied rooms during the morning and early afternoon period. This would yield the highest potential demand response load capacity and by extension, wholesale market revenue in the day ahead market.

The full suite of Conectric's sensors, metering, control devices and dedicated wireless networking hubs cost around $47,000 per facility. The cost of the remote analytics software and integrating it with existing building automated systems added an additional $15,000. It cost around $2,000 per facility for the necessary labor to install and commission the devices.[14]

Customer Data Release and Market Participation Agreement

Despite Conectric finishing out its first phase of IoT technology implementation, due to the lengthy delays caused by a combination of project implementation interruptions and a difficult-to-reach hotels' corporate energy manager, the final phase of customer engagement—executing the market participation agreement—never happened. This unfortunate outcome came after the Hilton hotels energy manager told the project team during a project development meeting that he noticed a 25% increase in total electric utility costs as a result of utility bill rate design changes that had occurred during the prior two years. His attention and ability to address the utility cost increase of the hotel portfolio by leveraging Conectric's technology package was dwarfed by his other job duties that included managing numerous unforeseen emergencies and complex priorities such as new facility construction, changes in corporate management stakeholders and managing major equipment upgrades such as cooling tower and boiler replacements.

Despite this unfortunate outcome, the project team pivoted in a new direction and made use of historical energy data from both hotel facilities (from Conectric's IoT network and utility meter data). Olivine conducted a market participation simulation model for Portfolio 2 hotel facilities for the year 2019.

Wholesale Market Participation Simulation Model

Conectric's facilities' diagnostics modeling showed that approximately 100 kW of demand response load shed could be achieved from measures that included facility precooling and avoiding pumping water through each facility's swimming pool. Both the precooling and pool pumping strategies could allow the hotels to participate as a grid resource without significantly impacting normal operating conditions. Figure 14 illustrates the demand response impacts on capacity load for Portfolio 2 on a given event day.

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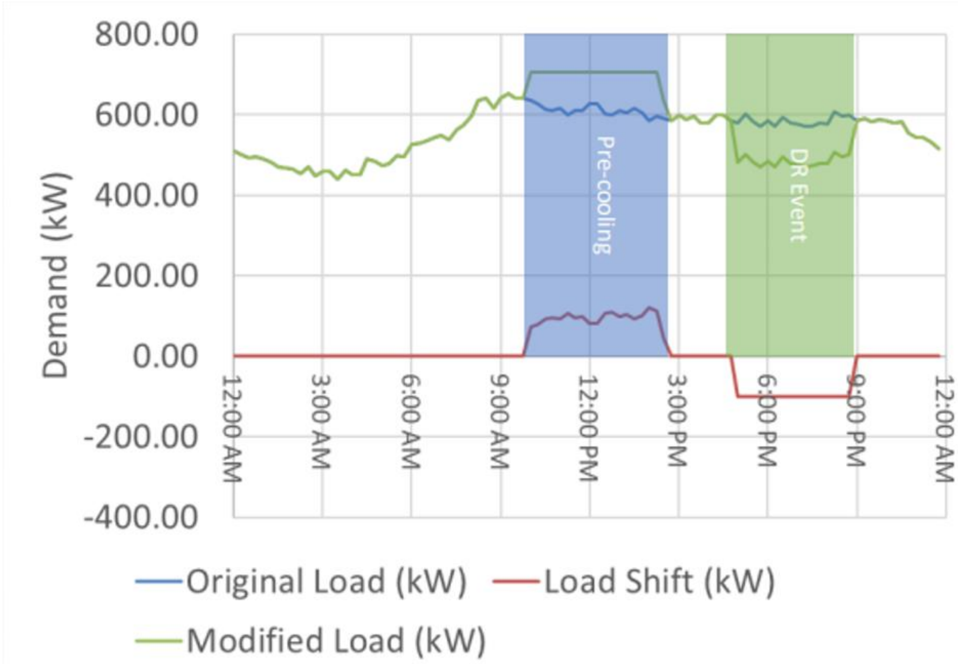
[14] Noting that the project complied with all applicable California state prevailing wage labor rates and reporting.

Figure 14: Portfolio 2 Load Profile on a Simulated Demand Response Event Day



Olivine conducted the market participation simulation model analysis for the year 2019 using its Distributed Energy Resource Valuation Model (DER-VM). The Olivine DER-VM calculates the value of operating a DER according to a given cost reduction or revenue generating strategy. Olivine included 15-minute historical load data, utility retail rate data, program information, and other financial parameters to calculate the associated costs and benefits of operating the resource under various use cases in the DER-VM (see Figure 15).

Figure 15: Olivine DER-VM Calculation Flowchart

DER IMPACT ANALYSIS			
Energy	Capacity	Grid Services	Environmental

DER VALUE STREAM ANALYSIS			
Demand Charge Management	TOU Price Arbitrage	Demand Response Revenue	Distribution/Transmission Infrastructure Deferral
Other Indirect & Societal Benefits			

DER USE CASE PRO FORMA ECONOMIC ANALYSIS RESULTS		
Lifecycle Cash Flow	Net Present Value	Average Annual Cash Flow
Years to Cash Flow Positive	Benefit-Cost Ratio	Internal Rate of Return
Levelized Cost of Energy		

Olivine modeled two use cases for Portfolio 2. Wholesale market participation (day ahead market) and performing demand response through a traditional demand response utility program, the Capacity Bidding Program (CBP) offered by both Hilton hotels electric utility service provider, San Diego Gas and Electric (SDG&E).

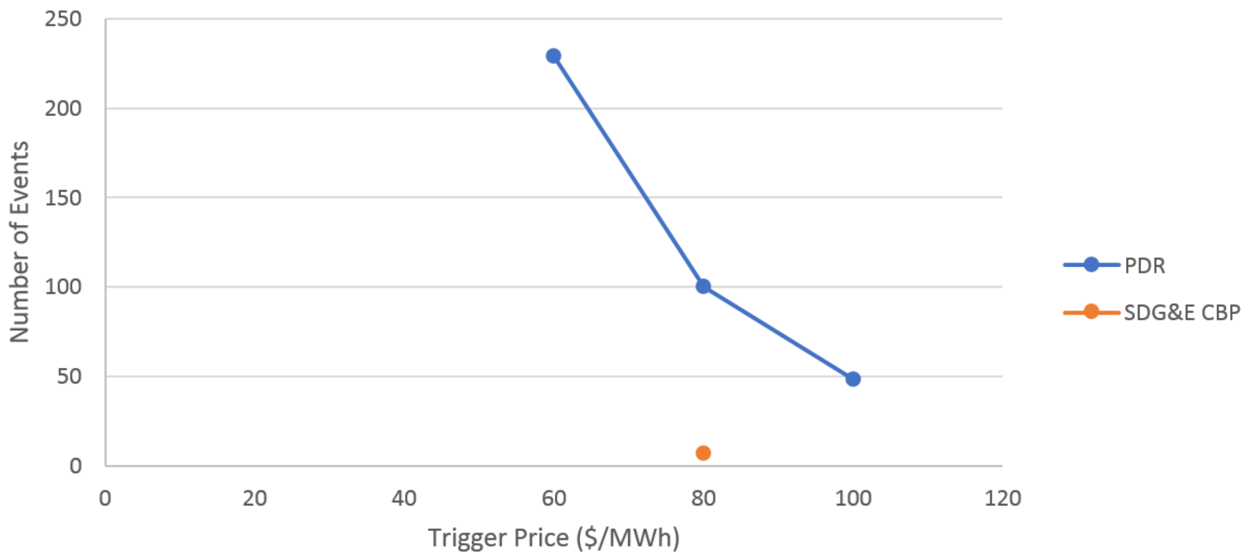
Use Case 1: Wholesale Market Participation

This modeled use-case encapsulated Portfolio 2 participation in the wholesale market day-ahead CAISO energy market as a Proxy Demand Resource (PDR). The hotels would bid energy into the day-ahead market with a third-party Demand Response Provider (DRP) and Scheduling Coordinator, e.g., Olivine, Inc. If the bid is accepted an award is dispatched and the hotels would curtail energy use during the award hours and shift energy use to the hours preceding or after the dispatch period. Olivine established three trigger prices, $60/MWh, $80/MWh, and $100/MWh for use-case 1 simulation.

Use Case 2: SDG&E Capacity Bidding Program

This modeled use case was based on both Hilton hotels participating in SDG&E’s CBP, assuming both facilities would provide demand response at the same time on similar event days (i.e., mirroring their demand response behavior in use-case 1 as a single PDR portfolio). Under this program the Hilton hotels would nominate a set amount of capacity available during certain periods of the day. Revenue, i.e., utility bill savings, is based on capacity payments from the SDG&E program and energy payments from wholesale market participation resulting from SDG&E's trigger price schedule. Figure 16 shows the number of modeled DR events across PDR trigger prices ($60/MWh, $80/MWh, and $100/MWh) and participation in SDG&E's CBP program (assumed average trigger price $80/MWh).

Figure 16: Comparison of Simulated Event Days for Portfolio 2 for Both Use Cases



Modeled Simulation Results

Participation in SDG&E's CBP demonstrated considerably higher customer return value than PDR. As shown in Table 9, CBP annual cash flow savings was over $9,300 above baseline (status quo) and $6,000 more than participating in the wholesale day-ahead energy market as PDR. This is primarily due to the increased revenue from capacity payments established in SDG&E CBP from May through October being substantially greater than the potential revenue-gaining opportunity lost by not participating in the wholesale energy market. CBP participation also yielded a 27:1 benefit-cost ratio over a 10-year time span. Participation in the CBP would also provide a more stable source of revenue generation because it is less dependent on a trigger price — the primary revenue source from the CBP is held to a set monthly value whereas the revenue source from the day-ahead energy market is dependent on the number of events that are called. For these reasons, Olivine strongly recommends the HMV and the HGIOT facilities in Portfolio 2 ultimately enroll in SDG&E's CBP per the results of this simulated analysis.

Table 9: Modeled Simulation Results for Use Case 1 and 2

Economic Metric	Use Case 1		Use Case 2
	PDR Market Trigger Price		SDG&E CBP
	$80/MWh	$100/MWh	
Nominal Value of Lifecycle Cash Flow	$30,167	$19,114	$93,142
NPV of Lifecycle Cash Flow	$22,442	$14,221	$69,004
Average Nominal Value of Lifecycle Cash Flow	$3,017	$1,911	$9,314
Benefit-Cost Ratio	2.16	2.39	27.03

Costs and Benefits: Modeling the Grid and Ratepayer Impacts of Increased Behind-the-Meter Storage Penetration in CAISO Wholesale Market

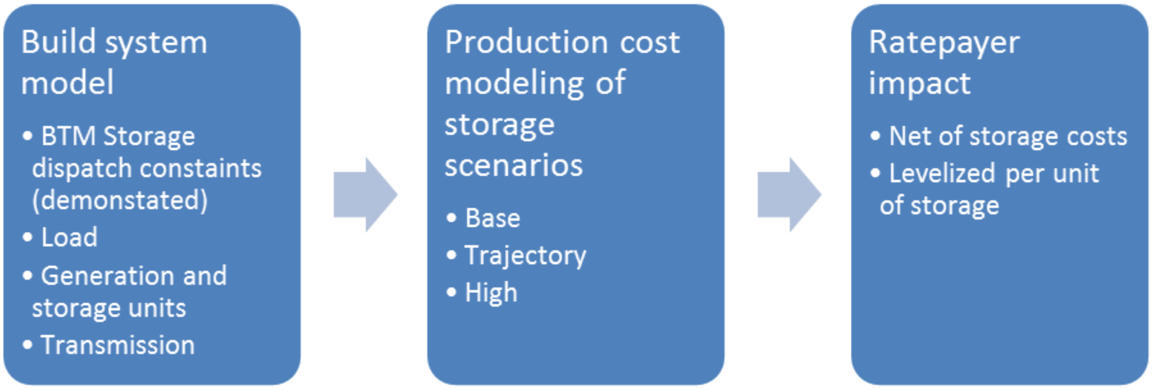
Modeled BTM Storage Scenarios

Three cases were analyzed for the future year 2026 to compare the impact of BTM storage in the market:

- Base case: In this case, no BTM storage participates in the market.
- Storage case: The storage case assumes trajectory deployment of 3,000 MW of BTM storage
- High case: The high case assumes very high adoption of 6,000 MW of BTM storage participating in the market.

The market benefits of BTM storage were netted with ratepayer costs to determine the per unit benefits of BTM storage to ratepayers. Figure 17 shows the overall approach for the modeled analysis.

Figure 17: Benefits Analysis Approach



Modeling Construct

DNV GL used its production cost modelling tool, Pydome (Python-based Dispatch Optimization Model for Electricity), to determine the market benefits. Pydome models electricity systems and markets and optimizes unit commitment and economic dispatch of power plants, renewables, and energy storage based on minimization of overall system costs. The optimization results provide insights on electricity prices, overall system costs, and cost-optimal dispatch. Pydome uses Mixed Integer Linear Programming (MILP) for its optimization formulation, similar to PLEXOS, and is used for simulations of existing and future power systems.

The Pydome tool considers numerous constraints of the power system, such as flexibility constraints, ramp rates and minimum stable levels, transmission constraints, reserve requirements and storage constraints. It is used to model small island systems as well as larger interconnected electricity markets. The output is an hourly dispatch of the all the resources within the system and the associated costs and emissions.

Model Input Sources and Key Assumptions

Model assumptions were mainly from CAISO's LTPP 2026 model[15] and E3's 2017 RESOLVE model[16]. The RESOLVE model provided the base case development from 2016 to 2050. RESOLVE distinguishes 6 zones in California: CAISO, BANC (Balancing Authority of Northern California), LADWP (Los Angeles Department of Water and Power), IID (Imperial Irrigation District), NW (Pacific Northwest) and SW (Desert Southwest). This zonal approach was used in the PLEXOS and Pydome model as well.

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[15] CAISO Transmission Planning Process http://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=C478BAE1-0234-4D41-93EA-260A547126F5

[16] RESOLVE Model with 2017 IEPR https://www.cpuc.ca.gov/General.aspx?id=6442457210

To simplify the model, Pydome utilized zonally-aggregated inputs with respect to generation, load, and energy storage. Specifically, the generation was represented as aggregated power capacity per technology-fuel combination per zone – for example all coal-plants in NW were aggregated as one unit. Each generation block is modelled with an average heat rate and Variable Operations and Maintenance (VO&M) charge. This high-level representation reduced the model complexity and thereby limited the calculation times to realistic timescales.

The Pydome model captures inter-regional transfer limitations. It does not include a full transmission model which analyzes base transmission thermal rating and line outage contingencies, otherwise referred to as N-1 contingencies. The model captures inter-zonal transfer limitation based on the RESOVLE model. However, it does not simulate a nodal system to capture intra-zonal transmission constraint.

Finally, it was assumed that a typical BTM storage unit would be dispatched to optimize for market needs. It was assumed there would be 15 GW/60 GWh of grid-scale (i.e., in front of the meter) battery energy storage installed in CAISO by 2026. The round-trip efficiency (RTE) of grid-scale BESS was assumed to be 85%. The trajectory case included 3 GW/7.5 GWh of BTM BESS installed in CAISO while the high adoption case included 6 GW/15 GWh of BTM BESS. The RTE of BTM BESS was assumed to be 90%.

Modeled BTM Storage Scenarios Results

Storage Operations

As shown in Figure 18, BTM storage was optimally dispatched between 3pm-6pm when CAISO load peaks. The battery then charges up during the middle of the night to take advantage of low prices, likely from excess wind. During most of the day, the BESS is idle and therefore available to perform other applications such as customer bill management, resiliency, and integration of DER on the distribution system.

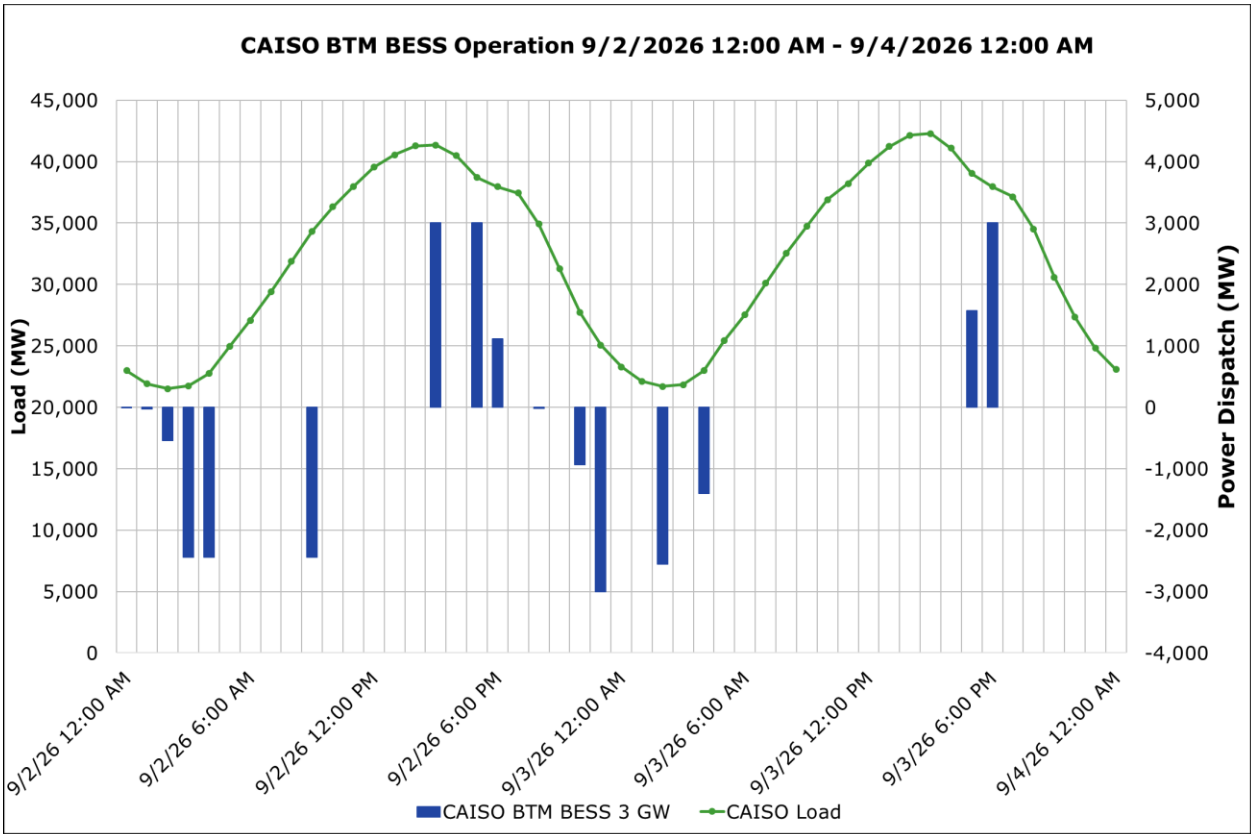


Figure 18: Modeled CAISO BTM BESS operation over a 48-hour timespan

Impact on Generation Mix and Emissions

Among the three modelled scenarios, it was observed the total annual generation of the state did not change significantly with BTM storage adoption in CAISO. The adoption of 3 GW and 6 GW BTM BESS resulted in 0.19% and 0.54% reduction, respectively, in California's total generation cost. Therefore, the variations in the generation mix with BTM storage at the modelled levels were negligible.

This also meant the total number of fossil fuel unit starts and the total emissions impacts for 2026 did not show any clear trends with respect to the number of fossil fuel starts.

Impact on Ratepayers

The total ratepayer benefits and benefit per ratepayer were calculated using the Ratepayer Impacts Measure test as follows:

$$\text{Total Ratepayer Benefits} = \text{Total Production Cost Reduction} - \text{Storage Incentives}$$

$$\text{Benefit per Ratepayer} = \frac{\text{Total Ratepayer Benefits}}{\text{Number of Ratepayers}}$$

The storage incentives were assumed to consist of the remaining budget of the Self Generation Incentive Program (SGIP) for small residential storage. The small residential storage incentive is currently in Step 5 and has a remaining budget of $ 349,849.95.

Based on the results of this study, the overall market system-wide benefit of BTM BESS is low. As shown in Table 10 below, the net present value annual savings per ratepayer in 2026 was $0.71 for 3 GW and $2.11 for 6 GW of BTM BESS.

Table 10: Modeled Ratepayer Benefits for Trajectory and High Cases

Scenario	Reduction in Production Cost in 2026	Storage Incentives	Total Ratepayer Benefits	Benefit per Ratepayer
Trajectory Case - 3 GW BTM BESS	$9,037,911	$349,849	$8,688,061	$0.71
High Case - 6 GW BTM BESS	$26,007,315	$349,849	$25,657,465	$2.11

While the market benefit is low, BTM storage yields other customer and social benefits such as customer bill management, DER integration on the distribution system, emission reductions, and resiliency. Since BTM BESS is only needed for a fraction of hours during the day to participate in the market, there are many opportunities for it to participate in other storage applications. Most significantly, if a customer has a peak demand that does not coincide with system peak, then the BESS can perform bill management (i.e. demand charge reduction) and also participate in the market. However, if the customer peak matches the system peak, then the customer would likely prioritize demand charge reduction, but the market will be able to freeride on its peak reduction benefits.

CHAPTER 4: Technology/Knowledge/Market Transfer Activities

This chapter summarizes the knowledge transfer planning, activities and outcomes in the overall effort to convey data and information gained from the project and make it available to the public, including the targeted market sector and potential outreach to end users, utilities, regulatory agencies, and others.

Knowledge Transfer Approach

The general aim of transferring knowledge was to move people through the journey from initial awareness of the demonstration pilots to the application and adoption of specific DER technologies, practices and policies. We subdivided our knowledge transfer approach into individual strategies based on key audience type, which were further subdivided into detailed tactics framed by goals, key performance indicators and tracking metrics tied to strategic outreach channels per given audience type.

Audiences

Reaching people involves understanding and speaking to their specific needs. Different audiences will respond better to key messaging and tactics tailored to highlight the benefits for that specific audience. We categorized people into different target audiences with specific roles, program benefits and audience split, which are highlighted in Table 11.

Table 11: Target Audiences for Knowledge Transfer

Audience	Role	Program Benefits	Audience Split
Commercial site managers & energy managers	Participate in bidding into the wholesale market while meeting on-site electricity needs	Earn revenue in the wholesale market while still meeting on-site energy needs	30%
Consultants (e.g., subcontractors Olivine, DNV-GL, etc.)	Conduct audits, assessments and system evaluations using data and research	Research that helps back their advisory services	20%

Audience	Role	Program Benefits	Audience Split
Vendors (e.g., Tesla, Conectric)	Install DER technologies	Sales tactic to acquire new customers	30%
Regulatory bodies (e.g., CAISO, Energy Commission, CPUC)	The client and other connected regulatory bodies	Research that helps inform their regulatory policies	15%
Technical Advisory Committee	Representatives from regulatory bodies, consultants, academics	Research that their audiences would be interested in	5%

Channels

Recognizing that some channels are more effective with certain target audiences than others, our approach also aimed to ensure that the most efficient and effective channels would be used for each audience.

The following Table 12 indicated what channels were used to reach each target audience.

Table 12: Channels for Reaching Target Audiences

Channel / Audience	Commercial Site and Energy Managers	Vendors	Consultants	Regulatory Bodies	Technical Advisory Committee
DIGITAL					
Emails					
Reports					
Webinars					
Website					
IN-PERSON					
Conferences					
Content kit					

Channel Audience	Commercial Site and Energy Managers	Vendors	Consultants	Regulatory Bodies	Technical Advisory Committee
Tours and events					
MEDIA					
Trade publications					

Knowledge Transfer Results

The project team estimates at least 1,500 individuals were directly reached and educated about the project from numerous presentations, conferences, forums and meetings attended by members of the project team. We estimate hundreds more individuals were reached through digital collateral and outreach, which included a dedicated project website, blogs and email announcements. These activities are summarized in the sections below.

Conference Presentations and Attendance

The project team was able to present at numerous conferences and share the project concept and lessons learned to date. These conferences included the CEC 2018 EPIC Symposium (February 2018, Sacramento), Infocast's California Energy Summit (July 2019, Los Angeles) and Renewable Energy Markets 2019 Conference (September 2019, San Diego).

As a result of these conferences, the project team networked with regulatory, project developer, and industry representatives. Several load-serving entities, including CCAs, were interested in implementing similar projects in their territories. The project team met with one CCA in particular to share in detail the project design and guide on best practices, and the CCA has since released a request for proposals to procure several megawatts of BTM storage capacity for the purposes of peak load reduction and wholesale market participation.

Trade Publication Articles

The project team wrote and published several articles on the project. In April 2019, CSE wrote an article for the Peak Load Management Association (PLMA) DER Compendium, which discussed the project concept and goals.[17] Additionally, CSE published an article in Whiley's Natural Gas on multiple use applications for DERs and highlighted the STEEL project as an example of value stacking.

[17] Footnote: DER Compendium citation

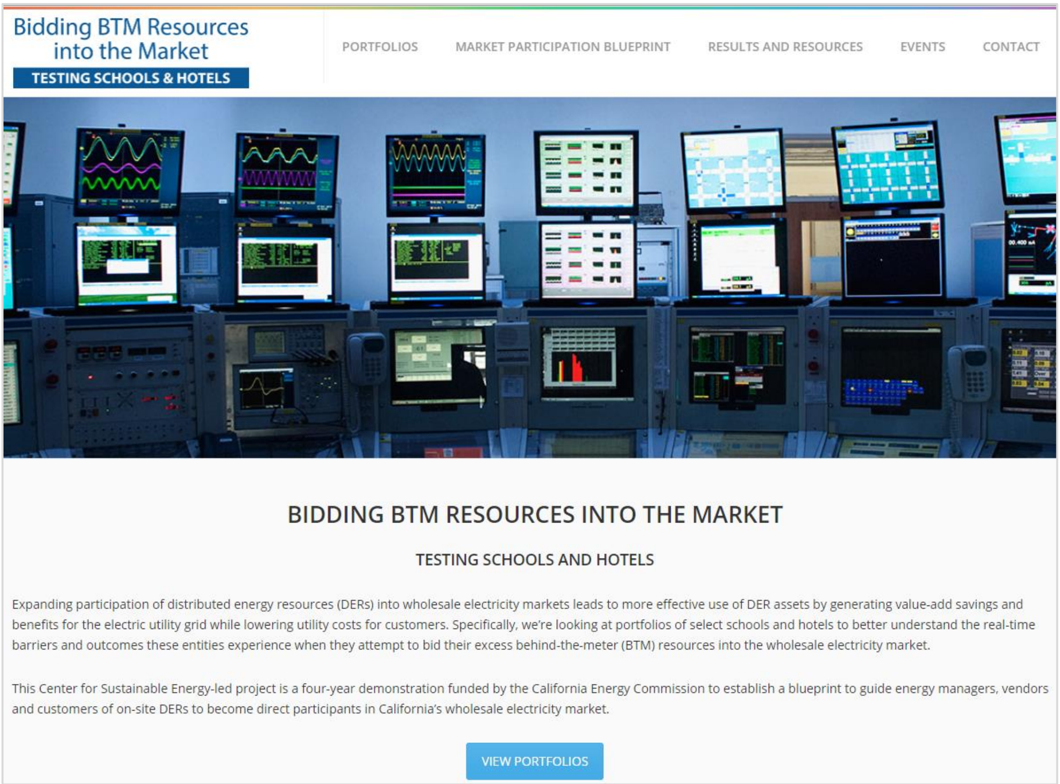
Digital Collateral and Outreach

Digital-based outreach collateral included a project homepage, which included links to reports, detailed descriptions of each portfolio, email sign-up, and a dedicated webpage and link to the final project fact sheet titled, *Wholesale Market Participation Blueprint*.

CSE created a final market blueprint report to educate potential customers and vendors on steps to assess market potential and market enrollment processes at CAISO.

Project Website

CSE developed and hosted a full-scale project website that went live in 2019. The project website was titled, "Bidding Behind-the-Meter (BTM) Resources into the Market".[18]



Screenshot of the CSE's dedicated project website homepage

Credit: CSE 2019

Webinars

Two webinars that included a summary of the project were presented to an estimated combined audience of 200 individuals.

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[18] URL: http://sites.energycenter.org/btmbidding.

Blogs and Social Media

The project team posted several blogs and social media announcements of major project milestones, including the Energy Loop blogsite hosted by CSE and announcements on LinkedIn.

Regulatory Participation

The project team participated in several key California policymaking forums to share the lessons learned of the demonstration project.

Energy Commission

2020 Load Management Rulemaking Draft Scoping Memo (Docket No. 19-OIR-01): CSE provided comments in January 2020 in response to the specific questions posed by the Energy Commission to inform the scope of the Load Management Rulemaking Proceeding. A key learning indicated direct compensation from the wholesale market for BTM DER is comparatively smaller than avoided-retail utility tariff costs, like demand charges for commercial-type customers. Instead, allowing customers to choose more dynamic utility rates that mimic the price signals in the wholesale market could be an effective alternative to signal wholesale market prices to customers and elicit more customer interest and investment in price-responsive BTM technologies.

Public Utilities Commission

Demand Response (R.13-09-011): Rulemaking to enhance the role of demand response for resource planning. This proceeding considered changes to demand response programs that participated in the wholesale market. Specifically, the proceeding created the Supply-Side Working Group (SSWG) in which Olivine has participated as an active member. The SSWG sent a final report to the CPUC in late 2019, which included policy recommendations from Olivine that were in part informed by the STEEL project.

Self-Generation Incentive Program (R.12-11-055): Over the three-year course of the project, CPUC solicited feedback on behind-the-meter storage's ability to participate in the wholesale market and whether SGIP-incentivized projects should be allowed to and/or required to participate in the market. CSE filed several sets of comments to the CPUC providing recommendations, lessons learned, and best practices on wholesale market as developed through the project. As a result, SGIP-incentivized energy storage systems are eligible to participate in demand response opportunities and in California's wholesale market.

Energy Storage (R.15-03-011): This proceeding refined policies and program details for the Energy Storage Procurement Framework and considered recommendations from the California Energy Storage Roadmap, jointly developed by the CAISO, Energy

Commission and CPUC. CSE participated in the Multiple Use Applications (MUA) for Energy Storage Working Group from February to August 2018. The MUA Working Group was identified in D.18-01-003 to conduct related storage rule refinement and discussion of issues. CSE noted the Tesla batteries across the Chino Hills Schools in Portfolio 1 represented one of the few BTM storage resource that is participating in the CAISO wholesale market as MUA resources. The MUA Working Group final report was issued in August 2019.

California Independent System Operator

Energy Storage and Distributed Energy Resources (ESDER) Initiative: Through this initiative, the CAISO continues to reform participation rules and models for energy storage systems and BTM resources. The changes made through this proceeding had a direct impact on this demonstration project, and this project's lessons learned could directly inform future iterations of the ESDER initiative. CSE and Olivine participated in ESDER stakeholder meetings spanning both Phase III (2017-2018) and Phase IV (2018-current).

CHAPTER 5: Conclusions/Recommendations

This project mapped a pathway for BTM DER to participate in the wholesale market and showed that customer-sited DER assets and strategies, including passive and active load management, battery storage and rooftop solar can generate sustainable market revenues from DER assets.

Customer Acquisition and Engagement

The project team found successful customer acquisition ultimately came down to pitching a simplified and compelling business proposition using financial and risk metrics that are pertinent to the given customer's industry. The business proposition should be able to answer key questions: What are the rewards? What are the costs? What are the demands? What are the risks. The complexity that may come with a given DER vendor's technology or strategy should be packaged well and pitched with clarity and simplicity.

DER vendors and project developers should consider the following when implementing new DER technologies:

- Customers are eager to understand their energy usage and how to reduce energy costs. New DER technologies and value-stacking opportunities can help customers accomplish these goals.
- Simple fact sheets and educational materials are necessary for customer to understand and adopt new technologies.
- Automated technologies that do not disrupt customer comfort or operations are more likely to be adopted.

Developing Operational Strategies

Successful DER technology systems such as Tesla's battery energy storage system and Conectric's IoT system demonstrated in this pilot draw upon learning-based adaptive algorithms that can dynamically balance customer needs and critical operations with the ability to avoid expensive usage of electricity as dictated by the customer electric utility tariff and wholesale market pricing signals. The project team found that through data collection, machine learning, and advanced analytics, it is possible to develop operational strategies for these technology systems to generate direct monetizable utility bill savings and market participation revenues as well as indirect customer value such as enhanced visibility into facility and campus critical equipment operations.

Regulatory and Wholesale Market Support

The project team provided considerable feedback with suggested regulatory, rule and procedure improvements to key state regulatory agencies, the CPUC and CEC, and the state's wholesale market operator, CAISO. To recap the work of the project team:

Energy Commission

2020 Load Management Rulemaking Draft Scoping Memo (Docket No. 19-OIR-01): A key learning from this project indicated direct compensation from the wholesale market for BTM DER is comparatively smaller than avoided retail utility tariff costs, like demand charges for commercial-type customers. Instead, allowing customers to choose more dynamic utility rates that mimic the price signals in the wholesale market could be an effective alternative to signal wholesale market prices to customers and elicit more customer interest and investment in price-responsive BTM technologies.

Public Utilities Commission

Demand Response (R.13-09-011): The proceeding created the Supply-Side Working Group (SSWG) in which Olivine has participated as an active member. The SSWG sent a final report to the CPUC in late 2019, which included policy recommendations that were informed by learnings and challenges of this demonstration pilot.

Self-Generation Incentive Program (R.12-11-055): CSE filed several sets of comments to the CPUC providing recommendations, lessons learned, and best practices on wholesale market as developed through the project. As a result, SGIP-incentivized energy storage systems are eligible to participate in demand response opportunities and in California's wholesale market.

Energy Storage (R.15-03-011): This proceeding included the formation of the Multiple Use Applications (MUA) for Energy Storage Working Group from February to August 2018, which included CSE and Olivine as contributing parties. Portfolio 1 represented one of the few behind-the-meter storage resource that was participating in the CAISO wholesale market as a MUA resource and provided early learnings from an actual use case of battery energy storage providing multiple use applications.

California Independent System Operator

Energy Storage and Distributed Energy Resources (ESDER) Initiative: The changes made through this proceeding have had a direct impact on this demonstration project, and this project's lessons learned could directly inform future iterations of the ESDER initiative.

Pre-Market Integration

Retail DR Program Unenrollment: For a PDR portfolio intending to participate in ancillary services such as spinning reserve, there is a significant opportunity cost on the part of the resource owner not being able to participate in either a UDC-provided retail DR program or participate in the market as an ancillary service such as spinning reserve during months-long pre-market integration NRI process. One possible solution to this customer unenrollment opportunity cost issue is to allow for DRPs such as Olivine the ability to complete the resource ID reservation process at CAISO specifically for the NRI process prior to customer unenrollment from a retail DR program. A second possible solution would allow for utilities to play a role in the resource ID reservation process at CAISO by helping customers facilitate and validate the registrations in CAISO's resource ID system. Olivine has found that utilities would be willing to aid in this process, including the electric utility provider for Portfolio 1, SCE.

NRI Process Documentation: At the time that Olivine began the NRI process, CAISO had not provided detailed integration steps regarding how to register a PDR expecting to provide ancillary services (spinning reserves). As a result of this project pushing the envelope on CAISO's NRI process, CAISO has posted additional documentation regarding the registration process for PDRs that intend to provide Ancillary Services in CAISO markets.

Sub-Metered Telemetry: Over the course of this project, Olivine made suggestions to CAISO to allow for PDRs to provide telemetry data for sub-metered devices like Tesla's battery portfolio. This would give CAISO greater visibility into the actual devices that are meeting ancillary service needs as opposed to relying on whole premise utility meter data. As a result of this project, CAISO now has a better understanding of sub-metering configurations of behind-the-meter battery energy storage configurations like Tesla's battery aggregation.

Post-Market Settlement

MGO Calculations During Periods of Charging or Net Export: In the process of analyzing MGO performance calculation, Olivine discovered a particular issue with accounting for battery charging during relevant calculation hours. After reviewing the issue, CAISO agreed with Olivine's proposal to calculate the net discharge amount during any given period, thus accounting for both charging and discharging.

Ancillary Services Market Settlement: Current settlement rules for PDR resources may discourage PDRs from economically bidding in both spinning/non-spinning reserves and energy markets. The CAISO calculation for ancillary service no-pay provisions is based on a "meter before - meter after" analysis without regard to any related energy dispatches. Olivine alerted CAISO about this issue; however, at the time of drafting this report had not received feedback or resolution from CAISO on this issue.

Inflexibility in Availability Requirements for Ancillary Services Resources: In CAISO energy markets, most Demand Response have some variability in availability by hour. DR programs are often limited to a certain subset of peak hours throughout the day, with some programs also allowing for inter-hour availability. However, CAISO's rules regarding resources certified for participation in ancillary services markets require availability for the full certified ancillary services capacity for all hours of participation. This means that variable-availability customer-sited resources providing ancillary services may need to either need to certify for a lower quantity than possible, severely limit the hours of participation, or both. Relaxing the CAISO's bid requirements and bid insertion rules for distributed energy resources participating in ancillary services markets could increase potential revenue and enhance market participation.

Counting PDR Grid Exports: A significant challenge in assessing the resource availability for portfolio 1 was the significant generation of on-site solar, which on occasion exported electricity resources onto the respective local distribution grids. And because CAISO PDR settlement rules do not allow grid export from BTMresources to be counted as a market resource, a significant amount of market revenue potential was lost. Olivine devised a potential compromise to CAISO's export restriction by proposing to allow PDR to export solely for the purpose of providing ancillary services. it would allow for customer-sited clean energy resources to displace conventional fossil generation that is currently widely utilized for these services, potentially improving grid operational efficiency and helping to clean the grid. As it stands today, fossil generation power plants are kept online to meet ancillary service requirements even while there is excess solar on the grid.

Future Grid and Ratepayer Impacts of Increased Behind-the-Meter Storage Penetration in CAISO Wholesale Market

A final task of this project included a modeled future analysis of three hypothetical cases of potential BTM storage growth through the year 2026 to compare the impact of BTM storage participating in the wholesale market:

- Base case: No BTM storage participates in the wholesale market
- Storage "mid" case: Trajectory deployment of 3,000 MW of BTM storage
- High case: Trajectory deployment of 6,000 MW of BTM storage

Among the three modelled scenarios of BTM storage adoption in CAISO, it was observed the total generation mix did not change significantly. Nor was California's total generation cost impacted much where modeled results showed the adoption of 3 GW and 6 GW BTM storage resulted in 0.19% and 0.54% reduction, respectively. The cost savings translated into $0.71 and $2.61 annual utility bill savings per rate payer in California.

While the modeled market benefit was low, BTM storage yields other customer and social benefits such as customer bill management, DER integration on the distribution system, emission reductions, and resiliency. Since BTM BESS is only needed for a fraction of hours during the day to participate in the market, there are many opportunities for it to participate in other storage applications, including but not limited to customer demand charge management.

CHAPTER 6: Benefits to Ratepayers

The project delivered an improved understanding of the benefits and barriers of expanding DR participation in California. Specific qualitative and intangible benefits include:

- Increased understanding of options and best practices for supply-side DR to integrate and operate in CAISO wholesale markets. This would lower technical, institutional and regulatory barriers for wholesale integration.
- Increased understanding of the economics for supply-side DR to participate in CAISO markets with the benefit of developing strategies that maximize value to customers and the grid.
- Facilitating the development of new value streams for DERs and helping these technologies become more cost-effective for customers.
- Increased understanding of options and best practices for BTM storage to participate in the wholesale market. This would lower technical, institutional and regulatory barriers for wholesale integration.
- Increased understanding of the avoided costs and benefits of large-scale supply-side DR deployment. This may influence policy makers, regulators, and CAISO to effectively leverage the benefits of DR to plan for the grid and design wholesale market rules.

Expanding participation of DERs into wholesale electricity markets leads to more effective use of DER assets by generating value-add savings and benefits for the electric utility grid while lowering utility costs for customers. The two demonstration portfolios have allowed us to better understand the real-time barriers and outcomes these entities experience when they attempt to bid their excess behind-the-meter (BTM) resources into the wholesale electricity market.

The project resulted in significant technological knowledge advancements in the characterization, aggregation, and grid integration of DERs. The project demonstrated practical operational strategies for DERs to participate in wholesale markets as supply-side resources.

The project team established a blueprint to guide energy managers, vendors and customers of on-site DERs to become direct participants in California's wholesale electricity market.

LIST OF ABBREVIATIONS

Abbreviation	Definition
ADS	Automated Dispatch System
AGC	Automatic Generation Control
API	Application Program Interface
AS	Ancillary Services
BTM	Behind the Meter
CAISO	California Independent System Operator
CCA	Community Choice Aggregator
CMRI	Customer Market Results Interface
DA	Day-Ahead Market
DER	Distributed Energy Resource
DLF	Distribution Loss Factors
DNP3	Distributed Network Protocol 3
DOT	Dispatch Operating Target
DR	Demand Response
DRP	Demand Response Provider
DRRS	Demand Response Registration System
EMS	Energy Management System
FNM	Full Network Model
kW	Kilowatt
kWh	Kilowatt-Hour
MGO	Meter Generation Output
MW	Megawatt

NRI	New Resource Implementation
PDR	Proxy Demand Resource
PV	Photovoltaic
RIG	Remote Intelligent Gateway
RT	Real-Time Market
SC	Scheduling Coordinator
SCE	Southern California Edison
SR	Spinning Reserves
Sub-LAP	Sub-Load Aggregation Point
SQMD	Settlement-Quality Meter Data
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol

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APPENDIX A: Day-Ahead and Real-Time Wholesale Market Price Analysis 2016 to 2019

The project team analyzed day-ahead and real-time market data from January 1, 2016 – August 26, 2019 for the "*SDG1-APND*" Sub-LAP, which encompasses Portfolio 2. We examined seasonal and hourly trends in the wholesale market prices and compared prices between the day-ahead and real-time markets. The objective was to increase our understanding of the seasonal and daily fluctuations, patterns and relationships in wholesale market prices to inform wholesale market participation for the project.

Approach and Data

The day-ahead and real-time market data were downloaded from CAISO's OASIS platform on August 26, 2019 for the "*SDG1-APND*" Sub-LAP. The day-ahead market data are hourly and the real-time market data are provided in 5-minute intervals. The data range from January 1, 2016 – August 26, 2019. Only the LMP price was used in the analysis.

The data platform can be found on CAISO's website.[19] The day-ahead market prices were downloaded from the Locational Marginal Prices option under the Prices menu item, and the real-time market prices were downloaded from the Interval Locational Marginal Prices option.

Day-Ahead Wholesale Market Prices

Day-ahead market prices had a median of $32/MW with a vast majority of prices (~97%) falling within $0/MW to $100/MW (Figure 1, left). However, there was significant variability (standard deviation = $32/MW) with prices ranging from approximately -$10/MW to $1000/MW. Figure A-1 (right) shows a time-series plot of the prices that indicates periods of strong price variability, particularly following the summer of 2018, with price spikes surpassing $1000/MW. The black line is a 30-day moving median and highlights that price spikes typically correspond to sustained periods of unusually high or low median prices.

[19] CAISO OASIS URL: http://oasis.caiso.com/mrioasis/logon.do

Figure A-1: Relative frequency of day-ahead market prices for 2016-2019 (left) and a time-series of the prices (right)

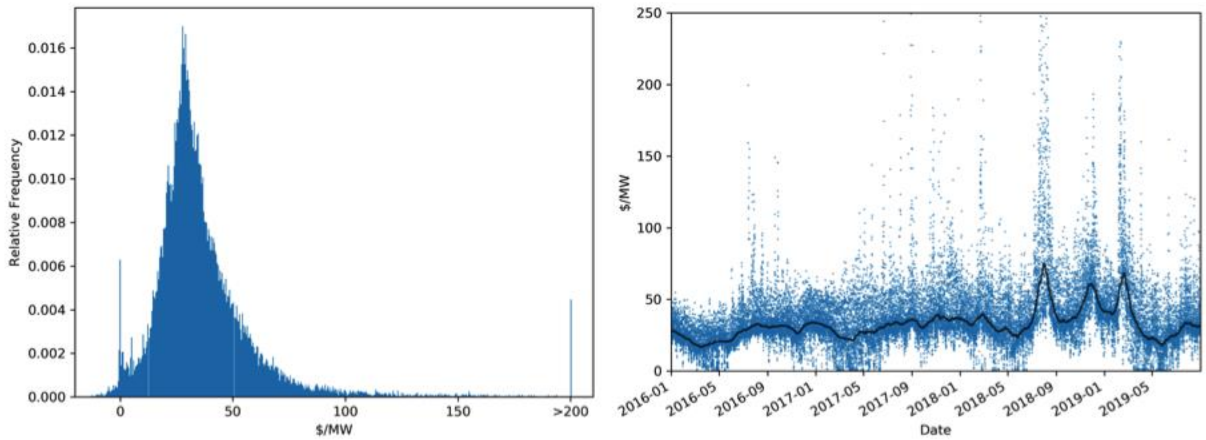
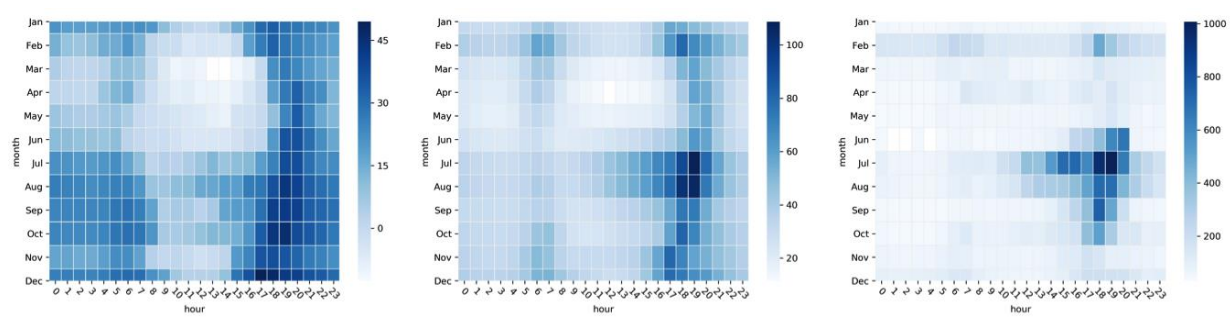


Figure A-2 shows the minimum, median and maximum prices by hour and month. The pattern is generally consistent across all three measures, with the highest minimum, median and maximum prices occurring from 5-8 PM, particularly in June-October, whereas the lowest prices typically occurred from 10 AM - 2 PM in March-May. Minimum prices overnight also are relatively high during the July-October period, e.g., they are nearly commensurate with peak prices during the winter.

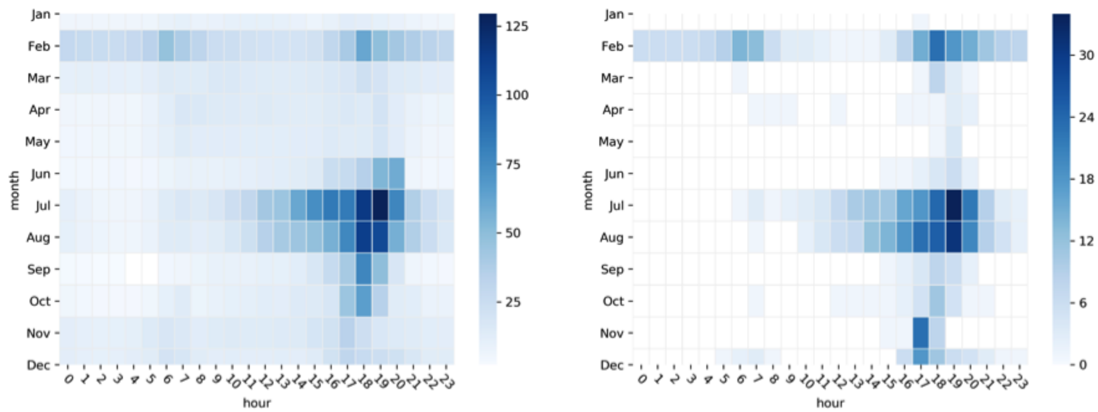
Figure A-2: Minimum (left), median (middle) and maximum (right) price by month and hour for 2016-2019.



The greatest amount of variability occurs in the peak period during the summer months, whereas the lowest amount of variability occurs in the early morning hours, especially in the spring and fall (Figure A-3, left). Large spikes in the prices (>$100/MW) typically occur from 3-8 PM during July-August.

It should be kept in mind that the large fluctuations beginning in the summer of 2018 have increased influence on the results when the data are aggregated across years. For example, there was a significant number of price spikes in February associated with the unusually higher prices and greater volatility in February 2019 that can be seen in Figures 1 (right), 2 and 3. But, these increases were not observed in the other years and likely do not represent a general pattern of increased prices for the month of February.

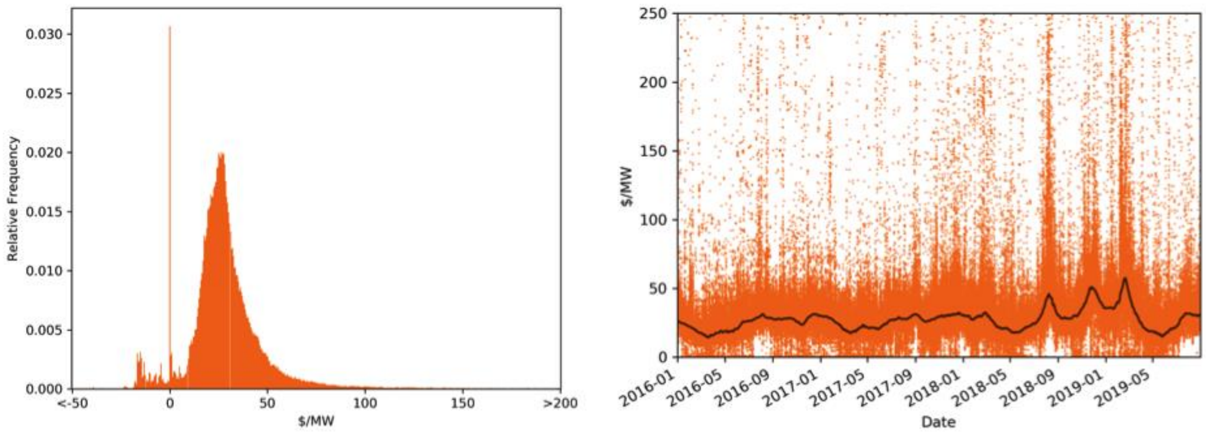
Figure A-3: Standard deviation by month and hour (left) and the frequency of >$100/MW prices (right) in the real-time market.



Real-Time Wholesale Market Prices

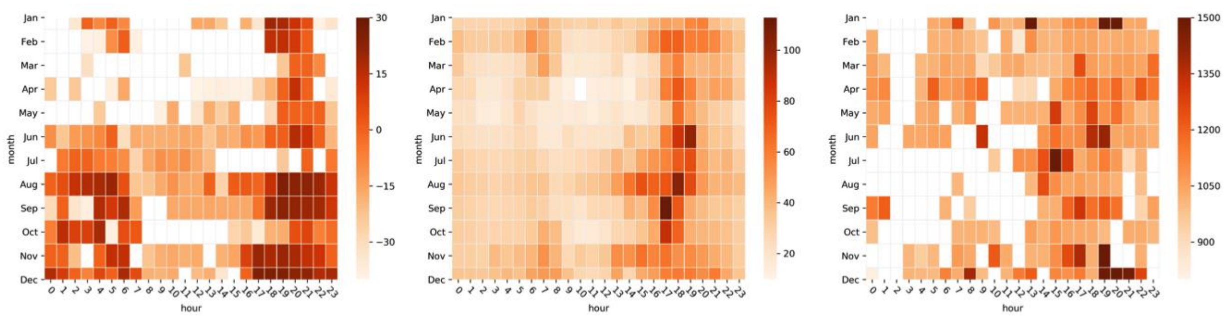
The median real-time market price was $27/MW, and 71% of prices were between the $15-45/MW range (Figure A-4, left). However, the range of prices in the real-time market were large with prices surpassing $1750/MW and declining below -$550. The 30 day moving median (black line) shows that the real-time market also experienced the price fluctuations in 2018-2019 that were observed in the day-ahead market.

Figure A-4: Time-series plot of real-time market prices (left) and the relative frequency of the prices for 2016-2019 (right).



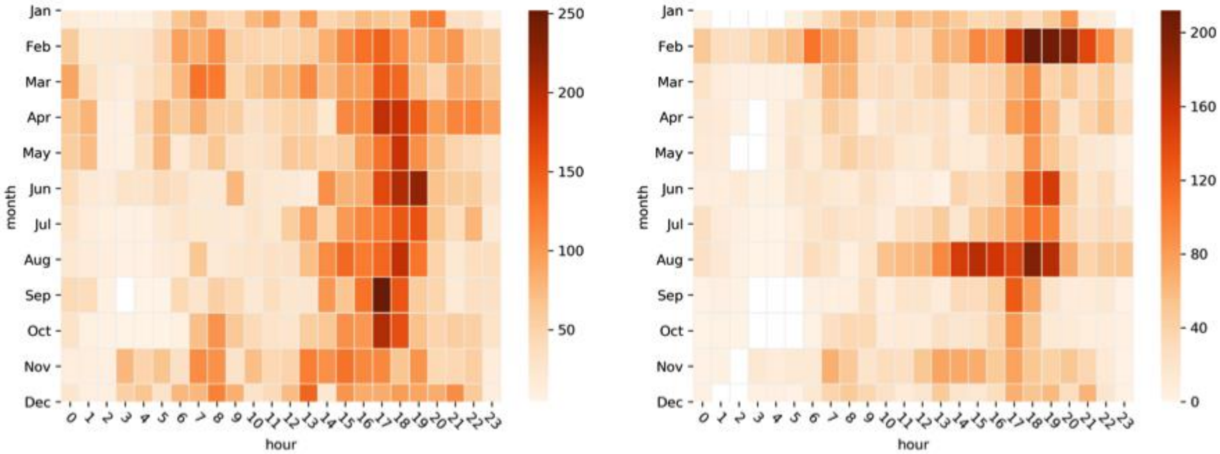
There are also strong daily and seasonal trends in real-time prices. Figure A-5 shows the minimum, median and maximum hourly prices by hour and month. The lowest prices tended to occur in the daytime hours in March-May for minimum and median prices, but maximum values during these periods were not the lowest across all months and hours. Indeed, the standard deviation of prices during this period of time were the lowest (Figure A-6, left), indicating that the prices generally remained within a narrow range.

Figure A-5: Minimum (left), median (center) and maximum (right) real-time market prices by month and hour.



Further, although the pattern for maximum prices was not strong (Figure 5, right), the number of hours with prices greater than $100/MW showed a strong pattern (Figure 6, right). This suggests the magnitude of a positive spike in prices is less dependent on time (i.e., the month and hour) than the frequency of the spike events.

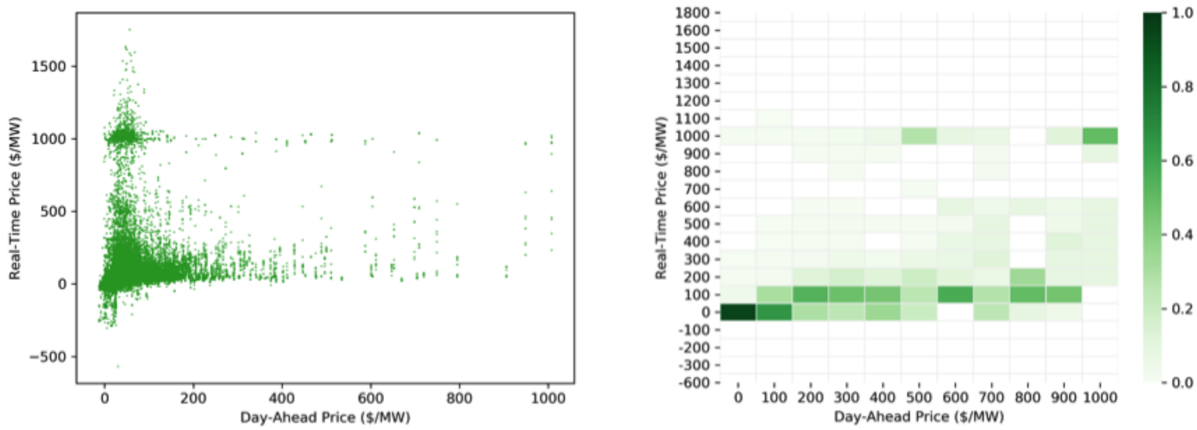
Figure A-6: Standard deviation by month and hour (left) and the frequency of >$100/MW prices (right) in the real-time market.



Day-Ahead Versus Real-Time Wholesale Market Prices

There is a relationship between day-ahead and real-time prices, although it is complex. The left plot of Figure A-7 is a scatter plot that shows a majority of price-pairs between $0-200/MW. There was also a cluster of real-time prices near $1,000/MW that correspond to day-ahead prices <$100/MW. And there was a relative paucity of real-time prices in the $500 to $900/MW range leading up to the cluster near $1,000/MW, suggesting that there was a systematic economic process (i.e., a high-price generator ramping up) that causes large price spikes to settle around $1,000/MW*.* The figure is also deceiving because it looks like a real-time price of $1,000/MW was most likely to occur when the day-ahead price was between $0-75/MW, but this was a result of the vastly greater number of samples that occurred at these prices.

Figure A-7: The day-ahead prices versus the corresponding real-time prices (left) and a heatmap showing the probability of a real-time price by the corresponding day-ahead price (right).

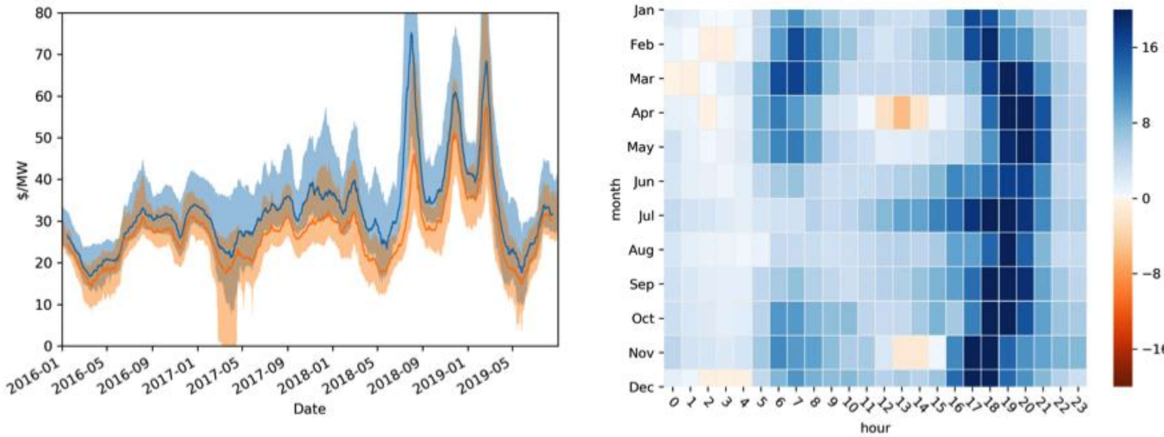


Indeed, when we examine the probability of a real-time price–given the day-ahead price–we see that higher day-ahead prices had a greater probability of higher real-time prices (right plot in Figure A-7). For example, the heatmap shows that when the day-ahead price was near $0/MW, the probability that the real-time price was in the same range was nearly 100%; whereas, if the day-ahead price was near $700/MW, the probability that the real-time price was near $50 was only about 20%. All said, despite a significant relationship between the day-ahead and real-time price, the range of real-time prices is relatively constant across all day-ahead prices.

Day-ahead prices are greater than real-time prices a majority of the time (Figure A-8, left). This time-series plot shows a 30-day moving median price with 50% prediction intervals (i.e., 50% of all prices during the corresponding month would fall within the interval). This pattern is relatively consistent across all hours and months, although the difference between the day-ahead and real-time prices is greatest during the afternoon/evening peak period (Figure 8, right). And median real-time prices approach–and sometimes surpass–median day-ahead prices in some early morning and midday hours during the spring and early winter (orange cells).

Overall, this analysis suggests consumers in the wholesale markets will pay more in the day-ahead market a majority of the time, but consumers in the real-time market are exposed to large, detrimental or beneficial swings in price.

Figure A-8: Time-series plot showing the 30-day moving median prices for day-ahead and real-time prices (left) and the difference between the median day-ahead and real-time prices by month and hour (right).



Findings Summary

Day-Ahead Market

- The median price was $32/MW, but there have been significant fluctuations in prices since the summer of 2018
- The largest prices occur in the afternoon/evening peak during the summer, and the lowest prices occur midday during the spring
- Prices in the afternoon/evening hours of the summer are characterized by significant variability and prices occasionally approach $1000/MW
- Although the midday hours during the spring typically have the lowest prices, the early morning hours in the spring and fall have the most consistent prices.

Real-Time Market

- The median real-time price was $27/MW but, like the day-ahead prices, there have been significant fluctuations since the summer of 2018
- The largest prices occur in the afternoon/evening peak during the summer (median price near $90/MW), and the lowest prices occur midday during the spring (median price near $10/MW)
- The real-time market is substantially more volatile than the day-ahead market, with a maximum price of $1750/MW and minimum price of -$570/MW
- Although higher prices tend to occur in the summer, price spikes can occur throughout the year, especially in the afternoon/evening hours

Day-Ahead Versus Real-Time Market Prices

- Day-ahead prices are typically greater than real-time prices
- The relationship between day-ahead and real-time prices is complex, but high day-ahead price are associated with higher real-time prices
- Overall, consumers in the wholesale markets will typically pay more in the day-ahead market, but consumers in the real-time face more uncertainty and are exposed to more frequent price spikes.