Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

FINAL REPORT

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2023 Load Impact Evaluation for San Diego Gas and Electric's Residential Capacity Bidding Pilot

Prepared for SD&GE
By Demand Side Analytics, LLC
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ABSTRACT

This study quantifies the demand impacts of San Diego Gas & Electric's Residential CBP pilot. The study focuses on two primary research questions: What were the 2023 demand reductions due to dispatch operations? What is the magnitude of dispatchable load reduction capability for 1-in-2 and 1-in-10 weather planning conditions?

The Residential CBP pilot was rolled out to facilitate residential participation in an analogous program to SDG&E's Capacity Bidding Program for commercial customers. Residential customers with storage resources are able to enroll with a participating residential aggregator and receive performance payments for dispatching their storage resources at the request of SDG&E. Participant settlements are calculated using an adjusted day-matching baseline, but this report uses regression methodology to evaluate event impacts.

Twenty events were conducted from July through October of 2023 for varying windows between 5 and 9 pm and included both reduction only and export events. The average PY 2023 export event produced 9 kWh of net load reductions, or 3 kW per hour over 3 hours. The average PY 2023 reduction event produced reductions roughly one fourth of those from export events.

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1 EXECUTIVE SUMMARY

The Residential Capacity Bidding Pilot (CBP) began in PY 2021 in an effort to extend participation in the established non-residential CBP to aggregators of residential customers. As its name implies, CBP is a capacity based market program which compensates participants for monthly capacity nominations plus energy based performance payments at market based rates established in the CBP tariff. Participants commit to producing load reductions during events (which may be called day ahead or day of) and performance payments are calculated using a day matching baseline approach. However, control group based evaluation methodologies are used for evaluation purposes, as described in this report.

Program participation is open to aggregators of dispatchable residential resources. In PY 2021, PY 2022, and PY 2023 one residential battery storage aggregator, Swell, was enrolled. Swell enrolled 10 residential sites in PY 2021, 99 residential sites in PY 2022, and 214 unique sites in PY2023[1]. In PY 2023 enrolled sites had one to three 5-kW Tesla Powerwall battery systems per site with an average of 7.5 kW of storage and the average site had 8.7 kW of interconnected battery storage.

In prior years, enrollments occurred late in the year and events were called in October and November, which did not provide a clear picture of hoe the pilot could perform during the summer months. PY 2023 was the first year of the pilot where enrollments were completed early enough to enable calling events during the summer and 20 were dispatched events in July through October. The events were called at various start times and durations. The events were used to assess the ability of the aggregator to control loads in response to an event signal, both to reduce loads and to export load to the grid. For the first 9 events, the batteries were operated to only produce reductions in delivered load. For the following 11 events, the batteries were operated to export energy to the grid. Due to the small size of the pilot, each participant was provided with a $200 participation incentive in lieu of capacity or performance payments.

This study analyzes two primary research questions:

- What were the 2023 demand reductions due to dispatch operations?
- What is the magnitude of dispatchable load reduction capability for 1-in-2 and 1-in-10 weather planning conditions?

Table 1-1 summarizes the 20 events called for the Residential CBP pilot in from July to October, with varying start times and lengths. Export events began on September 20, 2023 and are highlighted in grey. Number of participating sites increased throughout the summer as sites were enrolled and validated for dispatch.

[1] Though a total of 214 participants enrolled in PY 2023, due to mid-season disenrollments the maximum sites participating in any single event was 196

Table 1-1: Residential CBP Events in 2023

Event date	Day of week	Event start	Event end	Event avg temp (F)	Number of Participating Sites[2]*	SDG&E System Max MW
7/25/2023	Tuesday	6:00 pm	9:00 pm	74.6	66	3,521
7/28/2023	Friday	6:00 pm	9:00 pm	72.4	66	3,141
8/7/2023	Monday	5:00 pm	9:00 pm	76.1	80	3,288
8/11/2023	Friday	5:00 pm	9:00 pm	70.0	80	2,978
8/15/2023	Tuesday	5:00 pm	7:00 pm	75.4	80	3,309
8/16/2023	Wednesday	6:00 pm	8:00 pm	74.4	80	3,636
8/18/2023	Friday	6:00 pm	8:00 pm	73.0	191	3,180
8/29/2023	Tuesday	6:00 pm	9:00 pm	77.3	191	4,016
9/8/2023	Friday	5:00 pm	9:00 pm	77.3	195	3,783
9/20/2023	Wednesday	5:00 pm	9:00 pm	65.6	181	2,795
9/21/2023	Thursday	6:00 pm	8:00 pm	64.7	181	2,832
9/25/2023	Monday	5:00 pm	9:00 pm	65.5	181	2,805
9/26/2023	Tuesday	6:00 pm	8:00 pm	66.4	181	2,840
9/28/2023	Thursday	6:00 pm	9:00 pm	64.3	180	2,699
10/4/2023	Wednesday	5:00 pm	9:00 pm	70.8	180	2,954
10/5/2023	Thursday	6:00 pm	8:00 pm	70.3	180	3,273
10/6/2023	Friday	6:00 pm	9:00 pm	67.5	180	3,176
10/12/2023	Thursday	5:00 pm	9:00 pm	64.9	180	2,804
10/16/2023	Monday	6:00 pm	8:00 pm	64.9	193	3,055
10/20/2023	Friday	6:00 pm	8:00 pm	69.5	196	3,144

Export events highlighted in grey

*Though a total of 214 participants enrolled in PY 2023, due to mid-season disenrollments the maximum sites participating in any single event was 196

Table 1-2 summarizes the estimated ex post demand reductions for four average weekday Residential CBP event day types: reduction versus export events with 6 to 8pm and 5 to 9pm windows, respectively[3]. Delivered and net load results are shown to highlight differences between the two. When using delivered load, reductions of 0.2 to 0.6 were achieved, which event duration being the greatest factor. When using net load reduction events produce about 0.6 to 1.1 kW, depending on event duration, and 2.1 to 4.7 kW depending on event duration.

[2] Though a total of 214 participants enrolled in PY 2023, due to mid-season disenrollments the maximum sites participating in any single event was 196

[3] Three hour reduction events beginning at 6pm we analyzed as two hour 6 to 8pm events because there is no difference in reduction event dispatch for these two

Table 1-2: Summary of Average 2023 Ex Post Demand Reductions

Event Type	Avg Site Count	Delivered Load			Net Load		
		Load without DR (Avg kW)	Load reduction (Avg kW)	% Reduction	Load without DR (Avg kW)	Load reduction (Avg kW)	% Reduction
Avg reduction 6-8pm	101	1.18	0.65	55.3%	1.01	1.08	107.5%
Avg reduction 5-9pm	118	0.77	0.18	24.1%	0.46	0.57	125.4%
Avg export 6-8pm	186	0.61	0.41	66.9%	0.48	4.72	984.2%
Avg export 5-9pm	181	0.48	0.15	31.3%	0.02	2.12	10591.2%

Table 1-3 summarizes the Residential CBP dispatchable ex ante reductions under August monthly peaking conditions for a 1-in-2 weather year. Again, impacts are shown for both delivered load and net load and for reduction versus export events. The PY 2023 ex ante reduction event estimates are based on the hourly kW reductions observed during reduction events. The export event estimates are based on kWh load reductions observed during the PY 2023 export events[4]. The results are shown under both CAISO and SDG&E peaking conditions and reflect the reduction capability from 4-9 pm, which aligns with resource adequacy requirements. Because PY 2023 was the last year approved for the pilot, results are shown for future program planning purposes and are normalized to 100 sites.

Table 1-3: Summary of Ex ante Dispatchable Demand Reductions, 1-in-2 Weather Conditions

Type of load and Event Dispatch	Residential CBP		
	Sites	kW (CAISO)	kW (SDG&E)
Net Load - Export Event	100	303.58	303.58
Delivered Load - Export Event	100	12.97	12.97
Net Load - Reduction Event	100	28.55	28.55
Delivered Load - Reduction Event	100	14.84	14.84

[4] The total site kWh for the event window was averaged across events of varying durations and then divided by 3, reflecting an assumption that the resource would be required to provide

2 INTRODUCTION

The Residential Capacity Bidding Program is a pilot rolled out in PY2021 to facilitate residential participation in a similar program to SDG&E's commercial Capacity Bidding Program. Commercial CBP is a capacity based market program which compensates participants for monthly capacity nominations plus energy based performance payments at market based rates established in the CBP tariff. The goal of Residential CBP is to enable aggregators of residential customers with dispatchable resources to bid their resources into a capacity market in a similar manner.

In accordance with Decision (D.) 22-12-009, SDG&E 's Residential CBP Pilot was approved for the 2023 Bridge Year. Therefore, the ex-ante section was not included in this report.

2.1 PROGRAM BACKGROUND

Program participation is open to aggregators of dispatchable residential resources. In PY 2021, PY 2022, and PY 2023 one residential battery storage aggregator enrolled. Swell enrolled 10 residential sites in PY 2021, 99 residential sites in PY 2022, and 214 unique sites in PY2023[5]. In PY 2023 enrolled sites had one to three 5-kW Tesla Powerwall battery systems per site with an average of 7.5 kW of storage and the average site had 8.7 kW of interconnected battery storage.

Current CBP rules only allow for use of delivered loads for settlement purposes to avoid the risk of double payment for generation already compensated through net metering. Therefore, delivered load was used as the primary metric for program reporting in prior years and dispatch has been designed to reduce delivered load. However, all participation in Residential CBP pilot has been from sites with battery storage which has the unique capability to provide dispachable energy exports when relief is needed on the grid. In the PY 2023, the pilot evaluation was structured to also inform key questions regarding the impact potential of reduction versus export events.

PY2023 was the third year of the residential pilot designed to assess the pilot's cost-effectiveness, load reduction capability, and feasibility as a full-scale residential program. In order to assess the pilot's load reduction capability under varying weather conditions and hours, twenty events were called for differing evening hours (anywhere from 4 to 9 pm) and on differing days of the week. During the events, Swell dispatched the energy storage resources of the sites enrolled and set up for event participation during each event. PY2021 saw delivered load per site being dropped to 0 kW upon dispatch of the storage resources. Due to dispatch issues, PY2022 events on average did not see significant load reductions at the site level or in aggregate. PY 2023 events demonstrated statistically significant reductions for most events. Export events produced similar impacts as reduction events when analyzing delivered load only and substantially greater impacts when analyzing net loads.

[5] The maximum sites participating in any single event was 196

2.2 STUDY RESEARCH QUESTIONS

Table 2-1 summarizes the key research questions for each intervention. Battery storage is a dispatchable resource that also can lead to daily changes in energy use.

Table 2-1: Key Research Questions

	Research Question
1	What were the demand reductions due to program operations and interventions in 2023 – for each event day and hour?
2	What control algorithm is being used for reduction versus export events and how do impacts vary for reduction versus export events?
3	How does weather, start time, and duration influence the magnitude of demand response?
4	How do ex post impacts compare for AMI delivered loads, AMI net loads, and end use telemetry provided by the aggregator?
5	What are the ex ante load reduction capabilities for 1-in-2 and 1-in-10 weather conditions? And how well does it align with ex post results?
6	What concrete steps or experimental tests can be undertaken to improve program performance?

2.3 OVERVIEW OF METHODS

The primary challenge of impact evaluation is the need to accurately detect changes in energy consumption while systematically eliminating plausible alternative explanations for those changes, including random chance. Did the introduction of the program cause a change in critical peak period demand? Or can the differences be explained by other factors? To estimate energy savings, it is necessary to estimate what energy consumption would have been in the absence of the intervention—the counterfactual or reference load.

The change in energy use patterns was estimated using difference-in-differences with a control site matched to each participant. In order to identify the control pool sites that best matched each participant's energy use patterns on event-like proxy days (similar in weather and system conditions to event days), several matching methods were tested. These methods included different matching algorithms (e.g. Euclidean and propensity matching) and different site characteristics to be used in the matching. Matching methods included different combinations of proxy day load characteristics such as load factor, load shape, and site weather sensitivity. Control candidates were also "hard-matched" on climate zone.

Figure 2-1 summarizes the out of sample testing process used to select the matched controls to be used for modeling. Essentially, the out of sample process is an iterative approach whereby data is systematically left out of the matching model then used to assess matching method performance—a well performing model should produce matches for loads on days which were not used for the model. The final model is identified based on least bias (% Bias) and best fit (Relative RMSE) metrics.

Figure 2-1: Out of Sample Process for Control Group Selection

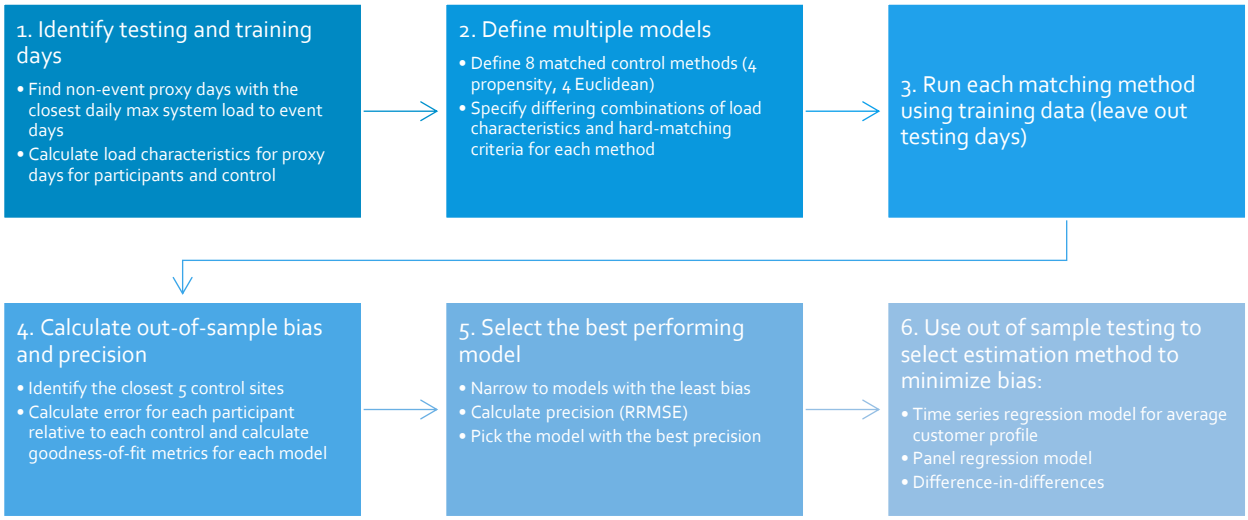


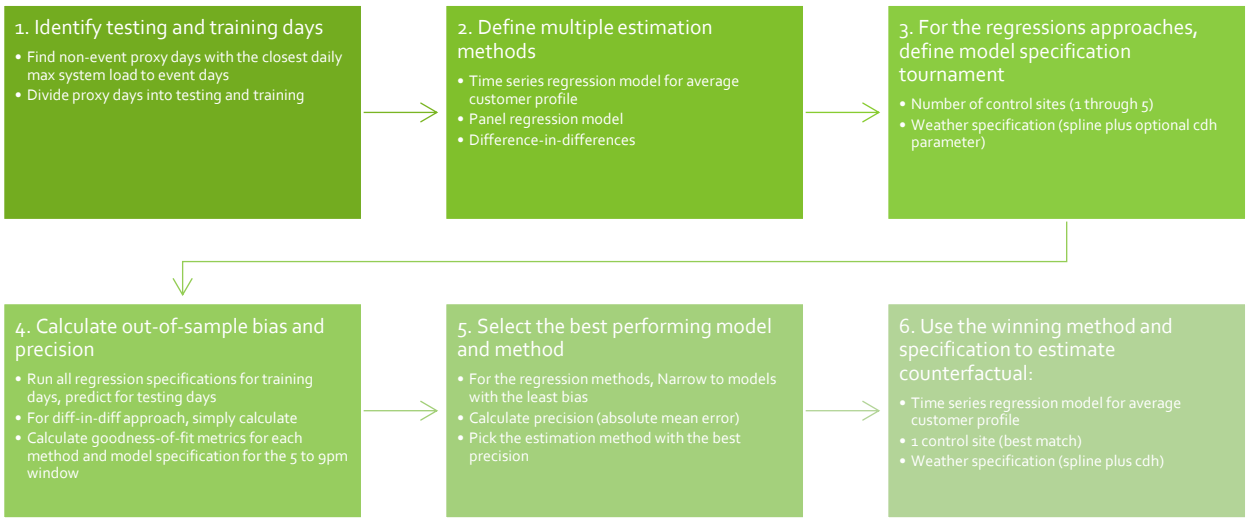
Figure 2-2 summarizes the robust model selection process used to select an estimation method using a two round out of sample tournament approach. This was particularly important given the challenge of estimating load reductions for a small sample of 214 sites. Three methodologies were explored and compared using out of sample (OOS) model selection for this impact evaluation:

- Average customer time series with out of sample model selection for the average customer
- Panel model with out of sample model selection for the panel
- Difference-in-in differences

Models considered for selection varied across the following parameters:

- Number of control sites[6]
- Weather specification[7]

Figure 2-2: Out of Sample Process for Estimation Method and Model Selection



In all cases leave one out cross validation was used for model selection. Essentially, counterfactual loads were predicted for a subset of event-like proxy days left out of the estimating sample, then used to calculate model bias and fit statistics. The best performing model for each methodology was selected to minimize bias. Observed and predicted load for the best model is shown in Figure 2-3. The model specification tournament summarized in Figure 2-2 has been conducted for the last three evaluations, since PY 2021, and PY 2023 is the first year in which difference-in-differences performed the best and was selected for ex post impact estimation. This indicates that the pilot has begun to reach the participant size at which pooling across participants meaningfully reduces noise. All analyses were done for both delivered and net loads, though for reporting purposes delivered loads were used due to CAISO rules which require loads in market based demand response programs to use exclude exports.

[6] As a first step, matches were selected for each of the 214 participants from a pool of about 16,000 non participant solar plus storage sites. Five matches with similar load profiles on event-like proxy days were selected for each site using Euclidean distance matching, weighting 4 to 9pm loads more heavily. Loads for control sites were used as predictor variables.

[7] Two specifications were tested: a two knot weather spline model on 18 hour moving average temperature, and this weather spline plus a parameter for cooling degree hours above a 65F base

Figure 2-3: Observed and Predicted Loads for Best Performing Model on Out of Sample Days

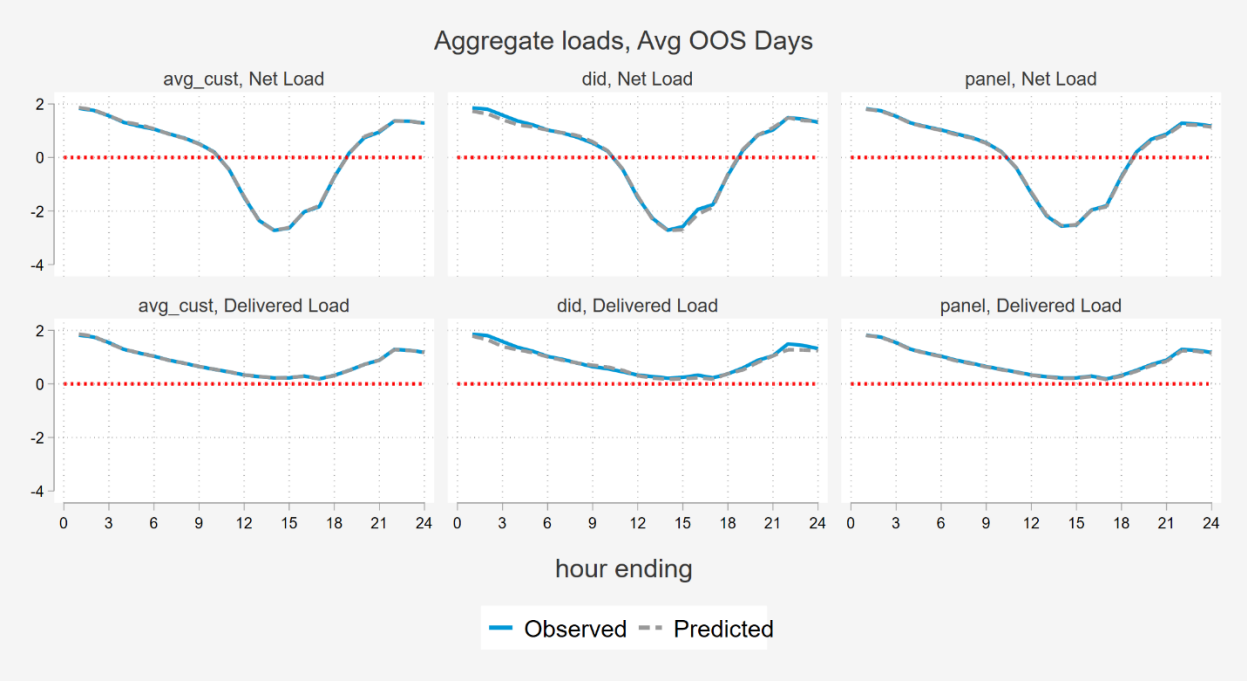


Table 2-2 summarizes the data sources, segmentation, and estimation methods used for each program. The segmentation was defined in advance of the analysis and is of particular importance because the evaluation used a bottom up approach to estimate impacts and to ensure that aggregate impacts across segments equaled the sum of the parts. Because impacts for each segment were added together, the segmentation was structured to be mutually exclusive and completely exhaustive. In other words, every customer was assigned to exactly one segment. The segmentation variable was climate zone, given the small size of the population and the expected potential to greater demand reductions from customers in the inland climate zone where cooling loads are higher. Additional segments were analyzed, after the fact, as part of exploratory analysis, but the core results presented are based on the segmentation detailed below.

Table 2-2: Evaluation Methods

Evaluation Element	Residential CBP
Data sources / samples	▪ All event season data for the past program year for ✓ All 214 participant sites ✓ a control pool of 16k non participants with battery storage

Evaluation Element	Residential CBP
Segmentation	▪ Climate zone
Estimation method: Ex-post	▪ Difference in difference with out of sample matched control selection ▪ Simple difference for supplemental analysis of telemetry data
Estimation method: Ex-ante	▪ Weather normalized customer regressions by climate zone for reference loads ▪ PY 2023 percent reductions for reduction events and kWh reductions for export events

3 RESIDENTIAL CBP EVENT DAY IMPACTS

Residential Capacity Bidding Pilot (CBP) participants' enrolled to allow aggregator control of their storage systems in response to event dispatch signals. The aggregator, Swell, sent control signals to Tesla Powerwall batteries at 214 residential participant sites during 20 events in July through October.

3.1 EVENT CHARACTERISTICS

Residential event impacts were assessed by site (premise and service point combination). Table 3-1, summarizes key characteristics for the 214 participating sites. Notably, nearly all sites (99.5%) also had PV collocated with their storage systems and 22.4% of sites were also on EV rates. Each Powerwall has a capacity of 5 kW and most participants had either one or two Powerwalls, for an average storage capacity of about 7.6 kW.

Table 3-1: Participant Characteristics

Program	Total sites	Sites in event analysis	% Sites with PV	% Sites with EV	Avg. PV system size (kW)	Avg. battery size (kW)
Residential CBP	214	214	99.5%	22.4%	8.68	7.56

Table 3-2 shows the 20 PY 2023 Residential CBP test event days dispatched from July through October. For the first 9 events, the batteries were operated to only produce reductions in delivered load. For the following 11 events (highlighted in grey), the batteries were operated to export energy to the grid. The dispatch schedule for events was designed to answer key questions regarding the effect on impacts of start time, duration, weather, and dispatch method (reduction versus export). The most common windows were 6 pm to 8 pm and 5 pm to 9 pm. Estimated ex post demand reductions are reported for four average weekday Residential CBP event day types: reduction versus export events with 6 to 8pm and 5 to 9pm windows, respectively[8].

[8] Three hour reduction events beginning at 6pm we analyzed as two hour 6 to 8pm events because there is no difference in reduction event dispatch for these two

Table 3-2: Residential CBP Events in 2023

Event date	Day of week	Event start	Event end	Event avg temp (F)	Number of Participating Sites	SDG&E System Max MW
7/25/2023	Tuesday	6:00 pm	9:00 pm	74.6	66	3,521
7/28/2023	Friday	6:00 pm	9:00 pm	72.4	66	3,141
8/7/2023	Monday	5:00 pm	9:00 pm	76.1	80	3,288
8/11/2023	Friday	5:00 pm	9:00 pm	70.0	80	2,978
8/15/2023	Tuesday	5:00 pm	7:00 pm	75.4	80	3,309
8/16/2023	Wednesday	6:00 pm	8:00 pm	74.4	80	3,636
8/18/2023	Friday	6:00 pm	8:00 pm	73.0	191	3,180
8/29/2023	Tuesday	6:00 pm	9:00 pm	77.3	191	4,016
9/8/2023	Friday	5:00 pm	9:00 pm	77.3	195	3,783
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9/25/2023	Monday	5:00 pm	9:00 pm	65.5	181	2,805
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10/4/2023	Wednesday	5:00 pm	9:00 pm	70.8	180	2,954
10/5/2023	Thursday	6:00 pm	8:00 pm	70.3	180	3,273
10/6/2023	Friday	6:00 pm	9:00 pm	67.5	180	3,176
10/12/2023	Thursday	5:00 pm	9:00 pm	64.9	180	2,804
10/16/2023	Monday	6:00 pm	8:00 pm	64.9	193	3,055
10/20/2023	Friday	6:00 pm	8:00 pm	69.5	196	3,144

Export events highlighted in grey

3.2 DATA SOURCES AND ANALYSIS METHOD

Table 3-3 summarizes the five data sources used to conduct the residential CBP event impact analysis. The analysis was done by site on hourly load data. Various data sources were used to classify sites into the study segments. While different segments were developed for the various analyses in this report, the characteristic definitions used to build segments were consistent across analyses.

Table 3-3: Residential CBP Event Impact Evaluation Data Sources

Source	Comments
Hourly interval data	▪ Summer and Fall 2023 ▪ All analysis done by site (premise id-service point id pair)
15 minute telemetry data	▪ July through October 2023 for all participants

Source	Comments
Outage information	▪ PSPS and emergency outage data details which customers and what timeframes were impacted by outages
Customer characteristics	▪ Treatment: Census of 214 residential CBP participants[9] ▪ Control: Sample of 16k residential sites with battery storage ▪ Climate zones used in matched control selection
SDG&E hourly system loads	▪ Summer and Fall 2023 ▪ Used to identify non-event days with similar system loads as event days
Ex post weather data by weather station	▪ Used to derive weather sensitivity for treatment and control pool sites, used as a matching criteria

The primary analysis method was time series regression for the average participant with synthetic controls. The winning matching approach selected one matched control site for each of the 99 residential CBP sites among a control candidate pool of roughly 16,000 sampled residential sites with battery storage who were not enrolled in CPP or other DR programs. The time series model included solar irradiance in addition to synthetic control to predict counterfactual loads for each event day.

3.3 EX POST LOAD IMPACTS

3.3.1 RESIDENTIAL CBP IMPACTS BY EVENT

There were 20 events called during PY 2023, all between 5 pm and 9 pm. Table 3-4 summarizes the delivered load reductions for Residential CBP sites for the 20 events and for the average event day types (export events are highlighted in grey). Reductions were significant for most individual events and for most average event definitions except for the average 5 to 9pm reduction event. Lack of statistical significance is more prevalent for lower impacts (especially reduction events) and events with fewer participating sites. This makes sense because both of these characteristics tend to reduce statistical power. In the tables, the orange bars show a visual comparison of the reductions that are numerically labeled on the left of the bars. There is little difference in delivered load reductions for export versus reduction events because delivered load excludes exports. Impacts for the 2 hour windows (6 to 8 pm) are about three fold the impacts estimated for the 4 hour window (5 to 9 pm).

Estimated load reductions using the baseline method for settlements are presented in the far right columns of Table 3-4 as a basis for comparison. Baseline load reductions are calculated at the

[9] Though a total of 214 participants enrolled in PY 2023, due to mid-season disenrollments the maximum sites participating in any single event was 196

aggregator level. To derive the baseline loads are summed across sites and the top 5 of the prior 10 non-event, non-holiday weekdays (or top 3 of 5 non-event weekend days) are selected. The unadjusted baseline is the average across these comparison days. Then a same day adjustment is applied to the baseline. Essentially the ratio of the observed load to the baseline load in pre-event hours is applied to the baseline to address remaining gaps. This adjustment ratio is capped at a 1.4 upward adjustment and a 1/1.4 downward adjustment.

The baseline methodology produces estimates that track fairly well with ex post delivered load estimates in magnitude and direction. However, the baseline appears to systematically underestimate reductions for reduction events, which produce smaller impacts and are therefore more difficult to distinguish from noise. While the aggregate program baseline does better filtering out statistical noise than an individual baseline, it is still susceptible to bias. Thus ex post impacts are considered to be a more precise and accurate estimate of the true load reduction that occurred. Further detail on the differences between the baseline and ex post methods is provided in Table 3-7: Comparison of Settlement Baseline and Load Impact Evaluation Methodologies.

Table 3-4: Residential CBP Event Reductions (Delivered Load)

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Reductions (Ex Post, Delivered Load)			Significant (90% CI)	Significant (95% CI)	Reductions (Baseline)	
				Aggregate (MW)	% Reduction	Average Site (kW)			Aggregate (MW)	Average Site (kW)
7/25/2023	6 to 9 pm	74.6	66	0.02	33.1%	0.29	No	No	0.00	-0.01
7/28/2023	6 to 9 pm	72.4	66	0.01	23.4%	0.12	No	No	0.01	0.21
8/7/2023	5 to 9 pm	76.1	80	0.02	37.8%	0.20	Yes	Yes	0.00	0.03
8/11/2023	5 to 9 pm	70.0	80	0.00	17.2%	0.05	No	No	0.01	0.12
8/15/2023	5 to 7 pm	75.4	80	0.03	68.2%	0.32	Yes	Yes	0.02	0.26
8/16/2023	6 to 8 pm	74.4	80	0.04	67.1%	0.51	Yes	Yes	0.03	0.34
8/18/2023	6 to 8 pm	73.0	191	0.20	83.2%	1.04	Yes	Yes	0.12	0.61
8/29/2023	6 to 9 pm	77.3	191	0.12	44.9%	0.65	Yes	Yes	0.05	0.25
9/8/2023	5 to 9 pm	77.3	195	0.03	18.6%	0.15	No	No	0.01	0.06
9/20/2023	5 to 9 pm	65.6	181	-0.02	-32.7%	-0.13	Yes	Yes	-0.02	-0.12
9/21/2023	6 to 8 pm	64.7	181	0.02	27.3%	0.10	No	No	0.04	0.21
9/25/2023	5 to 9 pm	65.5	181	0.03	34.5%	0.14	Yes	Yes	0.02	0.10
9/26/2023	6 to 8 pm	66.4	181	0.10	86.3%	0.54	Yes	Yes	0.06	0.35
9/28/2023	6 to 9 pm	64.3	180	0.05	64.3%	0.30	Yes	Yes	0.07	0.37
10/4/2023	5 to 9 pm	70.8	180	0.05	50.0%	0.30	Yes	Yes	0.05	0.26
10/5/2023	6 to 8 pm	70.3	180	0.06	56.8%	0.32	Yes	Yes	0.10	0.55
10/6/2023	6 to 9 pm	67.5	180	0.03	32.0%	0.19	Yes	No	0.08	0.46
10/12/2023	5 to 9 pm	64.9	180	0.06	60.5%	0.31	Yes	Yes	0.08	0.47
10/16/2023	6 to 8 pm	64.9	193	0.12	78.6%	0.61	Yes	Yes	0.12	0.62
10/20/2023	6 to 8 pm	69.5	196	0.10	70.0%	0.52	Yes	Yes	0.15	0.76
Avg reduction 6-8pm	6 to 8 pm	77.7	101	0.07	55.3%	0.65	Yes	Yes	0.02	0.22
Avg reduction 5-9pm	5 to 9 pm	76.2	118	0.02	24.1%	0.18	Yes	No	0.01	0.07
Avg export 6-8pm	6 to 8 pm	67.2	186	0.08	66.9%	0.41	Yes	Yes	0.09	0.50
Avg export 5-9pm	5 to 9 pm	66.7	181	0.03	31.3%	0.15	Yes	Yes	0.03	0.18

Export events highlighted in grey
Average 6-8pm reduction events include 6-9pm reduction events (no difference in dispatch)

Table 3-5 summarizes the net load reductions for Residential CBP sites for the 20 events and for the average event day types (export events are highlighted in grey). Reductions were significant for all individual events and for all average event definitions. In the tables, the orange bars show a visual

comparison of the reductions that are numerically labeled on the left of the bars. Because they include exports, net load reductions are substantially higher for export events than for reduction events. Specifically, export events produce about four times the reductions as do reduction only events. Impacts for the 2 hour windows (6 to 8 pm) are about twice the impacts estimated for the 4 hour window (5 to 9 pm).

Estimated load reductions using telemetry data are presented in the far right columns of Table 3-5 as a basis for comparison. Because telemetry data is only available for participants, telemetry based load reductions are calculated using a simple difference which subtracts average telemetry load on event like proxy days from the telemetry load on event days. The same proxy days are used for both the net ex post and the telemetry analyses. Notably, the telemetry results are within plus or minus 2% of the ex post net load results for the average export events. Telemetry results are within 11% and 33% of the ex post net load results for 2 and 4 hour reduction events, respectively. The implication is that telemetry data is a robust alternative to AMI net loads when assessing battery response to events, especially export events.

Table 3-5: Residential CBP Event Reductions (Net Load)

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Reductions (Ex Post)			Significant (90% CI)	Significant (95% CI)	Reductions (Telemetry)	
				Aggregate (MW)	% Reduction	Average Site (kW)			Aggregate (MW)	Average Site (kW)
7/25/2023	6 to 9 pm	74.6	66	0.03	75.8%	0.46	Yes	Yes	0.05	0.72
7/28/2023	6 to 9 pm	72.4	66	0.03	132.7%	0.49	Yes	Yes	0.05	0.71
8/7/2023	5 to 9 pm	76.1	80	0.06	630.2%	0.69	Yes	Yes	0.06	0.70
8/11/2023	5 to 9 pm	70.0	80	0.06	438.5%	0.70	Yes	Yes	0.03	0.33
8/15/2023	5 to 7 pm	75.4	80	0.10	-3326.1%	1.26	Yes	Yes	0.08	1.00
8/16/2023	6 to 8 pm	74.4	80	0.07	155.7%	0.87	Yes	Yes	0.06	0.71
8/18/2023	6 to 8 pm	73.0	191	0.31	161.4%	1.60	Yes	Yes	0.19	1.00
8/29/2023	6 to 9 pm	77.3	191	0.16	67.1%	0.86	Yes	Yes	0.20	1.03
9/8/2023	5 to 9 pm	77.3	195	0.10	93.4%	0.51	Yes	Yes	0.16	0.83
9/20/2023	5 to 9 pm	65.6	181	0.39	-2884.8%	2.18	Yes	Yes	0.38	2.12
9/21/2023	6 to 8 pm	64.7	181	0.79	1222.7%	4.35	Yes	Yes	0.79	4.37
9/25/2023	5 to 9 pm	65.5	181	0.38	-4063.0%	2.09	Yes	Yes	0.38	2.11
9/26/2023	6 to 8 pm	66.4	181	0.92	986.7%	5.06	Yes	Yes	0.94	5.18
9/28/2023	6 to 9 pm	64.3	180	0.63	738.1%	3.48	Yes	Yes	0.61	3.40
10/4/2023	5 to 9 pm	70.8	180	0.36	1684.6%	2.01	Yes	Yes	0.36	2.00
10/5/2023	6 to 8 pm	70.3	180	0.84	893.2%	4.67	Yes	Yes	0.85	4.74
10/6/2023	6 to 9 pm	67.5	180	0.52	421.4%	2.91	Yes	Yes	0.48	2.68
10/12/2023	5 to 9 pm	64.9	180	0.40	2317.5%	2.23	Yes	Yes	0.38	2.09
10/16/2023	6 to 8 pm	64.9	193	0.94	886.1%	4.86	Yes	Yes	0.96	4.97
10/20/2023	6 to 8 pm	69.5	196	0.89	841.8%	4.55	Yes	Yes	0.92	4.68
Avg reduction 6-8pm	6 to 8 pm	77.7	101	0.11	107.5%	1.08	Yes	Yes	0.12	1.20
Avg reduction 5-9pm	5 to 9 pm	76.2	118	0.07	125.4%	0.57	Yes	Yes	0.09	0.76
Avg export 6-8pm	6 to 8 pm	67.2	186	0.88	984.2%	4.72	Yes	Yes	0.90	4.81
Avg export 5-9pm	5 to 9 pm	66.7	181	0.38	10591.2%	2.12	Yes	Yes	0.37	2.07

Export events highlighted in grey
Average 6-8pm reduction events include 6-9pm reduction events (no difference in dispatch)

Figure 3-1 shows the delivered and net load hourly shapes for the average customer site for the average 6 to 8 pm weekday reduction event. Figure 3-2 shows the same for the average 6 to 8 pm weekday export event. The scale is the same across all four panels to highlight the difference in magnitude for the net load results for the export event compared to the other load and dispatch types.

Figure 3-1: Residential CBP Summary for Average 6-8pm Reduction Event, Average Customer

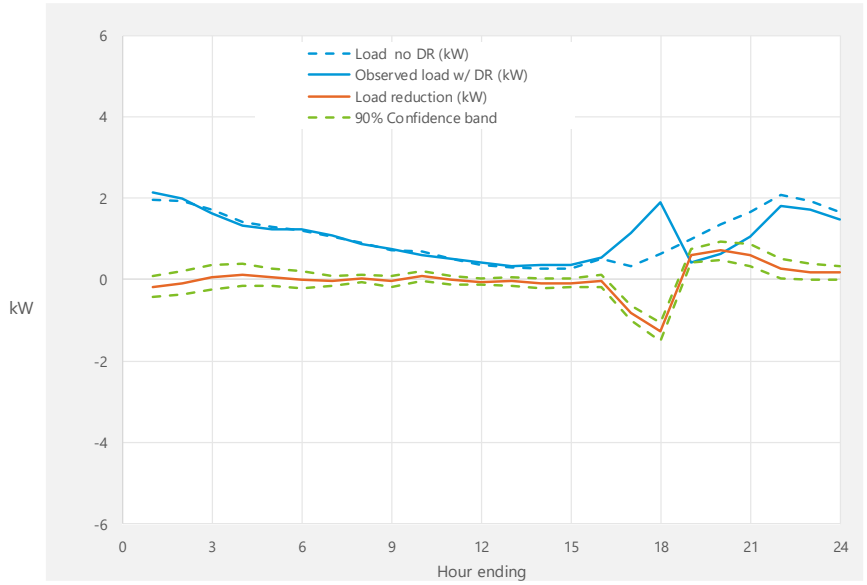
Delivered Load

Table 1: Menu options

Type of results	Average Customer
Category	All
Subcategory	All study segments
Event date	Avg reduction 6-8pm
Load	Delivered Load

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total enrolled accounts	101
Avg load reduction (Event Window)	0.65
% Load reduction (Event Window)	55.3%



Net Load

Table 1: Menu options

Type of results	Average Customer
Category	All
Subcategory	All study segments
Event date	Avg reduction 6-8pm
Load	Net Load

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total enrolled accounts	101
Avg load reduction (Event Window)	1.08
% Load reduction (Event Window)	107.5%

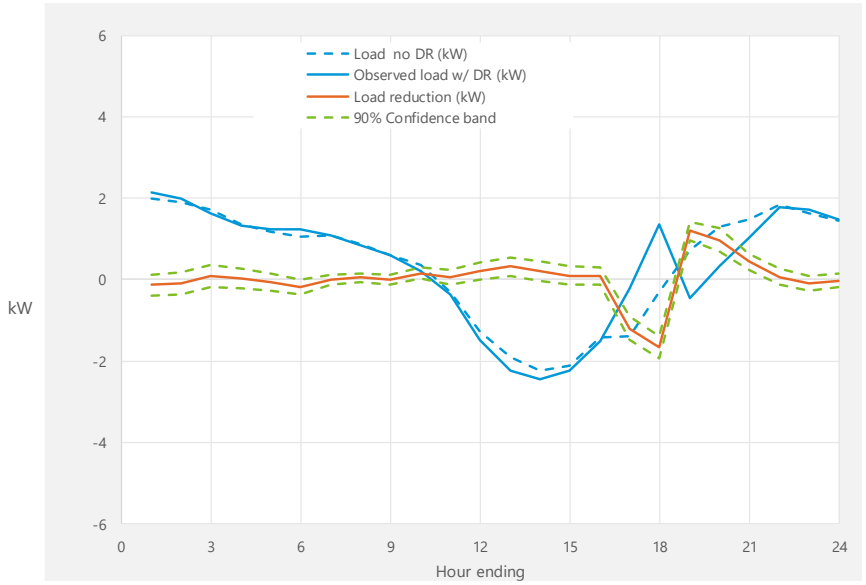


Figure 3-2: Residential CBP Summary for Average 6-8pm Export Event, Average Customer

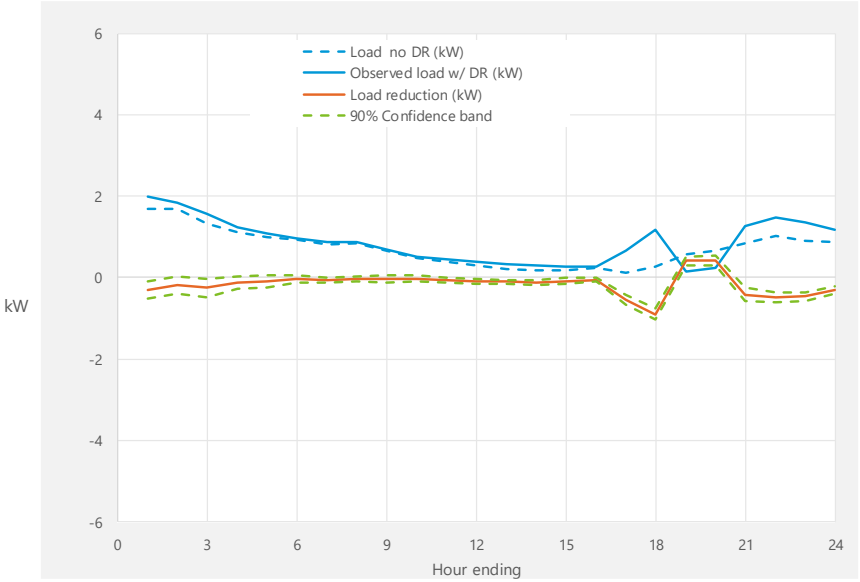
Delivered Load

Table 1: Menu options

Type of results	Average Customer
Category	All
Subcategory	All study segments
Event date	Avg export 6-8pm
Load	Delivered Load

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total enrolled accounts	186
Avg load reduction (Event Window)	0.41
% Load reduction (Event Window)	66.9%



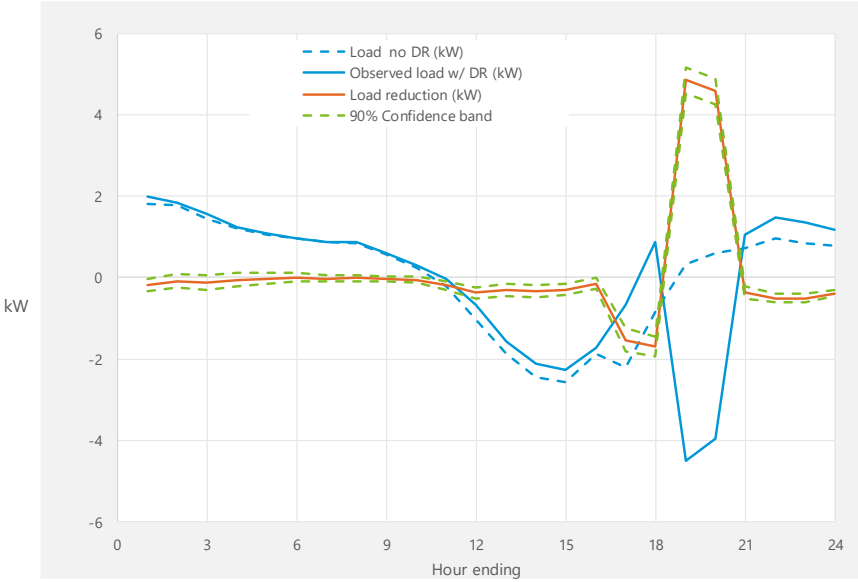
Net Load

Table 1: Menu options

Type of results	Average Customer
Category	All
Subcategory	All study segments
Event date	Avg export 6-8pm
Load	Net Load

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total enrolled accounts	186
Avg load reduction (Event Window)	4.72
% Load reduction (Event Window)	984.2%



3.3.2 Residential CBP Impacts by Climate Zone

About 60% of the Residential CBP participants are located in the inland climate zone with the remainder in the coastal climate zone. For air conditioning load control demand response applications, load response potential is usually often a function of cooling load, which tends to be higher in warmer, inland climates. This should not be the case for battery storage export events, but it may be the case for reduction only events which are limited to reducing delivered load. Table 3-6 compares ex post results using net loads for participants located in the inland versus coastal climate zone. Net loads are shown instead in delivered loads because net loads are a more complete representation of actual reductions. As expected average reference loads do tend to be higher for inland participants. Also as expected, kW reductions for reduction events tend to be meaningfully higher for the average inland participants, despite percent reductions being somewhat higher for coastal participants. This indicates that reduction events are a function of the delivered load available for curtailment. In contrast, there is little difference in average kW reductions for export events by climate zone.

Table 3-6: Residential CBP Event Reductions by Climate Zone (Net Load)

Type of Event	Climate Zone	Temp	Sites	Aggregate (MW)				Average Site (kw)			t-stat
				Ref Load	Reduction	% Reduction	Std Error	Ref Load	Reduction	Std Error	
Avg export 5-9pm	Coastal	68.1	71	0.01	0.39	2724.0%	0.03	0.08	2.15	0.19	11.54
	Inland	65.8	110	0.00	0.38	-11753.8%	0.02	-0.02	2.11	0.12	16.92
Avg export 6-8pm	Coastal	68.0	75	0.07	0.87	1234.6%	0.06	0.38	4.65	0.35	13.38
	Inland	66.7	122	0.10	0.89	877.5%	0.04	0.54	4.76	0.22	21.62
Avg reduction 5-9pm	Coastal	75.0	75	0.04	0.06	153.2%	0.02	0.31	0.47	0.14	3.35
	Inland	77.0	119	0.06	0.07	115.5%	0.02	0.55	0.63	0.17	3.82
Avg reduction 6-8pm	Coastal	75.6	72	0.06	0.08	122.4%	0.01	0.61	0.75	0.15	5.09
	Inland	79.0	119	0.13	0.13	103.1%	0.02	1.25	1.29	0.21	6.22

3.3.3 Comparison of Evaluation Load Reductions to Baseline Approach

If scaled to a program, Residential CBP will capacity and performance payments will be determined using baseline settlement rules. The baseline rules are applied at the aggregate program level and differ for weekday and weekend events only in the baseline eligible days and are summarized below:

- All events:
  - Calculate the average event-period load for the prior 10 eligible days
    - Weekday events: non-event weekdays (excluding holidays)
    - Weekend events: non-event weekend days (including holidays)
  - Identify the 5 days with the top load.
  - Take the average hour loads across these top 5 days to compute the unadjusted baseline.

- Calculate average load over the two hour pre-event period before and two hour post-event period after the event (with a two-hour pre-event buffer before and a two-hour post-event buffer after)
- Calculate average load during the pre-event and post-event adjustment hours for the selected baseline days
- Calculate the adjustment ratio by dividing pre-event load for the event day by the average pre-event loads for the selected baseline days. Cap the adjustment ratio at 1.4 upwards and 1/1.4 downwards. Apply the capped adjustment ratio to the unadjusted baseline to compute the adjusted baseline.
- Subtract observed load from the adjusted baseline. This is the load reduction.
- Payments are calculated from event performance relative to capacity nominations. Load increases (negative reductions) can result in penalties.

The baseline approach is used to determine settlements for participants because it is simple to calculate and simple to explain to customers. Notably, because CBP is a market based program, it follow CAISO baseline rules which require evaluating the baseline in aggregate. With aggregate baselines loads are summed across participating sites before calculating the baseline, allowing noise observable at the individual level to cancel out. The more participants there are, the more noise will be canceled out. However, the Residential CBP baseline is a within subjects method that does not include a comparison group and therefore does not control for exogenous influences on loads unrelated to the pilot. Table 3-7 compares the settlement baseline to the difference in differences with matched controls approach used for the load impact evaluation and underscores why the latter is more methodologically robust.

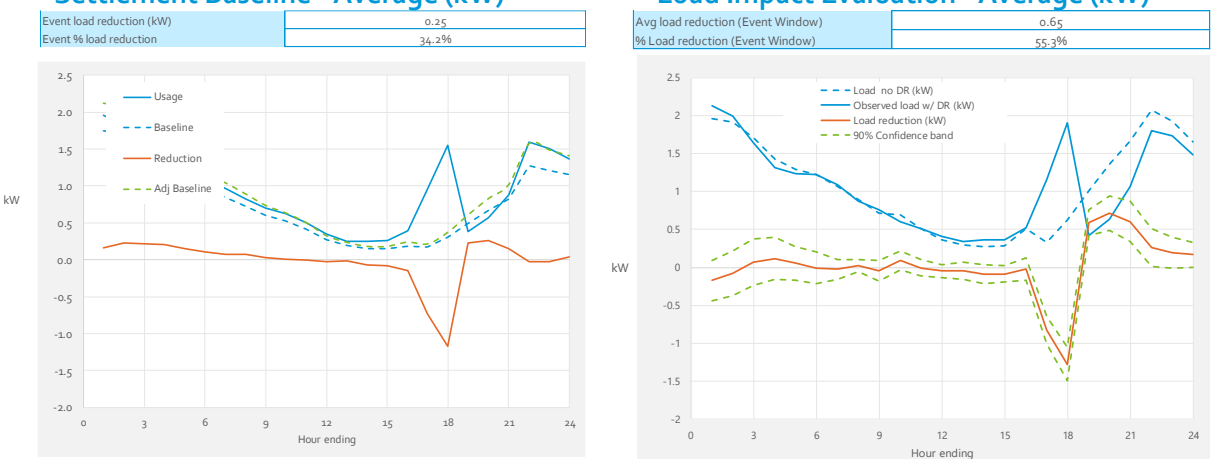
Table 3-7: Comparison of Settlement Baseline and Load Impact Evaluation Methodologies

	Settlement Baseline	Load Impact Evaluation
Approach	Within-subjects baseline. Top 5 of 10 prior weekdays, Top 3 of 5 prior weekends, same day adjustment capped at 1.4 up, 1/1.4 down	Difference in differences with matched controls
Does the approach control for exogenous factors?	No. A pre-post within subjects approach only compares participant load before and during the event. There is no way to identify changes in loads that may not be due to the event.	Yes. Any changes in load not due to the event will be apparent in the loads of the synthetic controls.
Does the approach minimize statistical noise?	Yes. The baseline is computed at the aggregate level in order to smooth the noise inherent in individual customer loads.	Yes. Tournaments are used to select controls and regression models which minimize error and bias. Then results are aggregated across participating sites. Noise that is apparent at

	Settlement Baseline	Load Impact Evaluation
		the individual level is thereby averaged out.
Is the approach symmetrical?	Yes. Customers are compensated for positive event reductions but receive a penalty for reductions which are negative.	Yes. Load increases are treated no differently than load reductions.

Figure 3-3 compares the settlement baseline (left panel) averaged across the average weekday event to the ex post results (right panel) for the average 6 to 8 pm event, each using delivered load. The baseline loads shown are calculated at the aggregate level. As described above the baseline (dotted green line in the left panel) is the average of the five highest days among the prior ten for each participant. These days are selected for aggregate participant loads and are the same days for all participants. The load impact counterfactual (dotted blue line in the right panel) is the counterfactual load predicted using the time series regression with synthetic controls. Both the baseline and the load impact counterfactual follow the shape of the observed event day participant load shape relatively well, though the load impact counterfactual follows more closely both before and after the 6 to 8 pm event window. Both methods show a positive reduction in load. The load impact evaluation errors showed that the reduction is statistically significant. In contrast, the baseline produces a smaller reduction. No errors are available for a baseline.

Figure 3-3: Residential CBP Average Weekday Event Load Impact Compared to Baseline



4 CONCLUSIONS AND RECOMMENDATIONS

The residential CBP program substantially delivered statistically significant demand reductions in PY 2023 and a future program providing access to CBP for residential battery storage should be able to deliver reductions in the future. The recommendations below may not be currently funded, and costs need to be considered alongside other research and pilot priorities.

4.1 RESIDENTIAL CBP RECOMMENDATIONS

- **For performance-based settlements, consider using net load or telemetry data.** Settlements based on delivered load are problematic for two reasons in the context of battery storage. First, settlement baselines perform best with large impacts but censoring net loads diminishes the signal to noise ratio. This results in noise being mistaken for impacts, and effectively compensating noise. This is especially the case for reduction only events which reduce loads less than export events and which delivered load settlements tend to systematically underestimate. Second, the greatest load reduction potential for battery storage systems lies in leveraging available capacity to export energy to the grid. Delivered load ignores exports, making it impossible to measure and compensate this value.

- **For maximal benefit, design a program which compensates for exports**. The load reduction potential for battery storage in the Residential CBP pilot was about 9 kWh per event, or 3 kW per hour for a 3-hour event, for sites averaging 7.5 kW of battery storage. This is about ten-fold the reduction potential for a reduction only event. The cost of recruiting, enrolling, connecting, and administering participant sites is a relatively fixed per site cost. Therefore, maximizing the benefit per participant, especially increase by ten-fold, will substantially improve cost-effectiveness and may be the difference between a cost-effective and a cost-ineffective program.

- **Thoroughly test and validate load dispatch ahead of the event season**. Events with clear validation protocols should be run ahead of each season to confirm that load control is being effectively dispatched. Evaluation methodology criteria for validating effective load reductions should be defined ahead of the events so load reductions or lack thereof can be clearly identified. Events should be evaluated soon after dispatch to identify and correct any issues.

- **As an alternative to compensating energy exports, consider a program design option that counts exports as demand reductions but only includes capacity payments (i.e., does not include energy payments).** The batteries in Residential CBP do not receive compensation for exports due to CAISO rules. As a result, there is untapped potential. While a battery may have the capability to deliver 3 kW, it is only compensated for offsetting part of whole building load (e.g., 0.3 kW). The CAISO reasoning for excluding imports is that battery storage customers may get double payment, once from the DR payment and once through NEM credits. By only

paying for capacity, SDG&E can incentivize additional, untapped peaking capacity, while avoiding double-payment for energy. Further, energy only programs such as ELRP could have unpredictable aggregator payments from year to year. The alternative is to create a load modifying DR product, explicitly for battery storage, that allows batteries to receive compensation for export capacity. This may still include a performance based element to ensure that nominated reductions are reflective of capacity actually delivered.