DRAFT REPORT

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2022 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 2022 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.

Ten testing events were conducted in October and November of 2022 for varying windows between 4 and 9 pm. In PY2022, only one event produced statistically significant demand reductions, so impacts can generally be interpreted as statistical noise. The average PY 2022 weekday 6pm to 9pm event produced 0 MW of load reduction.

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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, regression evaluation methodologies are used for evaluation purposes, as described in this report.

In PY 2022, one residential aggregator was enrolled in the pilot. This aggregator, Swell, controlled Tesla Powerwall batteries for 99 residential sites during ten test events in October and November. 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. 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 2022 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?

Ten test events were called for the Residential CBP pilot in October and November, with varying start times and lengths. The ten event dates and their respective start and end times are presented in Table 1-1.

Table 1-1: Residential CBP Events in 2022

Event date	Day of week	Event start	Event end	Event avg temp (F)	Max SDG&E system load (MW)
10/12/2022	Wednesday	7:00 pm	9:00 pm	66.9	2,879
10/13/2022	Thursday	8:00 pm	9:00 pm	65.0	2,746
10/14/2022	Friday	6:00 pm	9:00 pm	63.7	2,717
10/19/2022	Wednesday	4:00 pm	8:00 pm	80.9	3,530
10/20/2022	Thursday	7:00 pm	9:00 pm	65.1	3,124
11/9/2022	Wednesday	6:00 pm	9:00 pm	50.7	2,645
11/15/2022	Tuesday	4:00 pm	8:00 pm	56.5	2,666
11/17/2022	Thursday	7:00 pm	9:00 pm	52.1	2,658
11/22/2022	Tuesday	6:00 pm	9:00 pm	49.0	2,608
11/30/2022	Wednesday	4:00 pm	6:00 pm	52.3	2,744

Table 1-2 summarizes the estimated ex post demand reductions for the average weekday Residential CBP event. The evaluation yielded a negative reduction estimate but the results were not statistically significant. Because the result cannot be distinguished from statistical noise and it should be interpreted as being essentially zero. There appear to have been dispatch issues in PY 2022 resulting in no response to the dispatch signals sent.

Table 1-2: Summary of Average 2022 Ex Post Demand Reductions

Intervention	Sites	Load without DR (MW)	Load reduction (MW)	% Reduction
Residential CBP (Avg weekday 6-9pm event)	99	0.05	0.00	-5.2%

Table 1-3 summarizes the Residential CBP dispatchable ex ante reductions under August monthly peaking conditions for a 1-in-2 weather year. A positive reduction is assumed despite the impact of zero estimated for the ex post analysis because a clear impact was observed in PY 2021. The PY 2022 ex ante estimates are based on the load response observed in PY 2021 plus a derating factor to reflect the dispatch issues observed in PY 2022. 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. For both CAISO and SDG&E weather conditions, demand reductions are expected to increase with the substantial increase in site enrollments expected over the next three years. As enrollment forecasts flatten after 2028, reductions also flatten.

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

Year	Residential CBP		
	Sites	MW (CAISO)	MW (SDG&E)
2022	99	0.06	0.06
2023	1,050	0.60	0.64
2024	2,776	1.58	1.69
2025	4,280	2.43	2.61
2026	5,243	2.98	3.20
2027	5,938	3.37	3.63
2028	6,648	3.77	4.06
2029	6,648	3.77	4.06
2030	6,648	3.77	4.06
2031	6,648	3.77	4.06
2032	6,648	3.77	4.06
2033	6,648	3.77	4.06

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.

2.1 PROGRAM BACKGROUND

Program participation is open to aggregators of dispatchable residential resources. In PY 2021 and PY 2022 one residential battery storage aggregator enrolled. Swell enrolled 10 residential sites in PY 2021 and 99 residential sites in PY 2022. In PY 2022 enrolled sites had one to three 5-kW Tesla Powerwall battery systems per site and the average site had 6.96 kW of interconnected battery storage.

PY2022 was the second year of the residential pilot and thus the pilot's cost-effectiveness, load reduction capability, and feasibility as a full-scale residential program are still being assessed. In order to assess the pilot's load reduction capability under varying weather conditions and hours, ten 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 99 enrolled sites. PY2021 saw delivered load per site being dropped to 0 kW upon dispatch of the storage resources, but due to dispatch issues, PY2022 events on average did not see significant load reductions at the site level or in aggregate.

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 2022 – for each event day and hour?
2	How does weather influence the magnitude of demand response?
3	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?
4	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

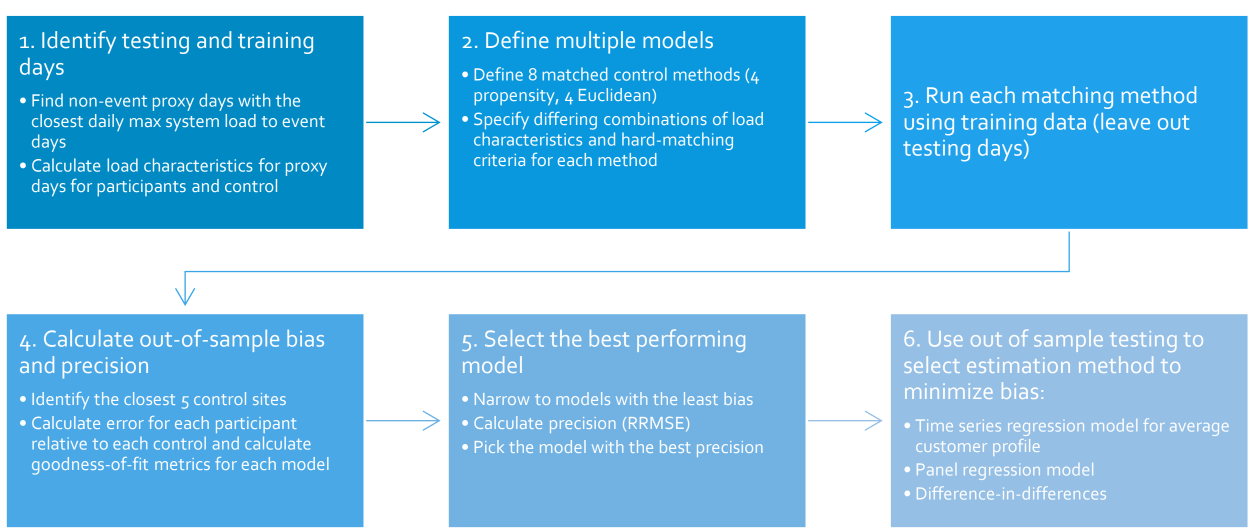


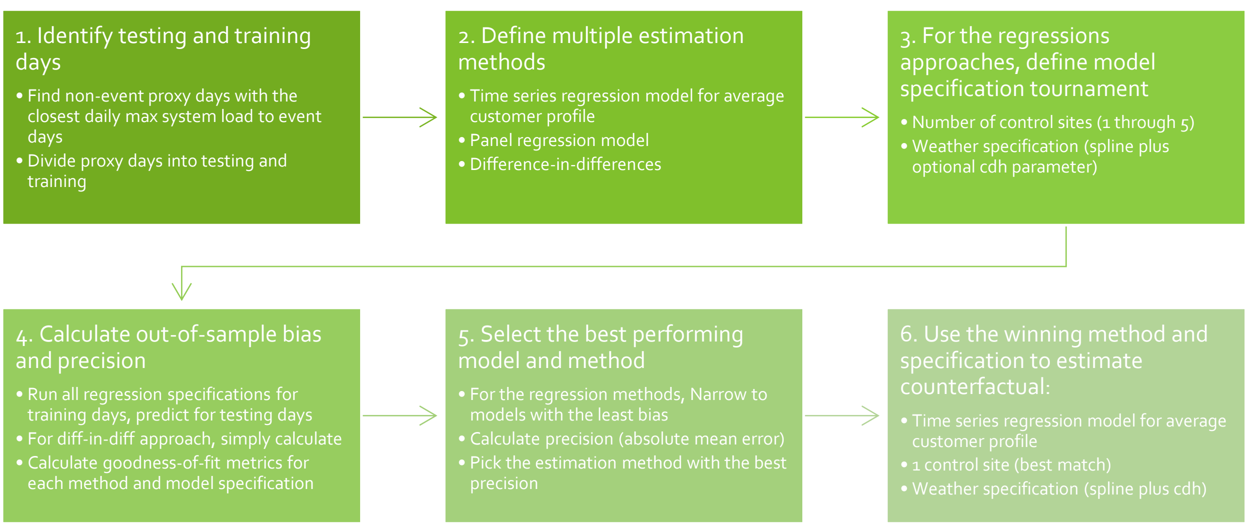
Figure 2-2 summarizes the robust model selection process used to select an estimation method using a two round out of sample tournament approach. This was particularly important given the challenge of estimating load reductions for a small sample of 99 sites. Three methodologies were explored and compared 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[1]
- Weather specification[2]

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

[1] As a first step, matches were selected for each of the 10 participants from a pool of about 2,600 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.

[2] 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

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 time series models (+0.6% to +5.5% bias) far out performed the panel models (+5% to +17% bias) and the simple difference in difference (+4% to +14% bias) which is why a panel model approach was selected for ex post impact estimation. 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.

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

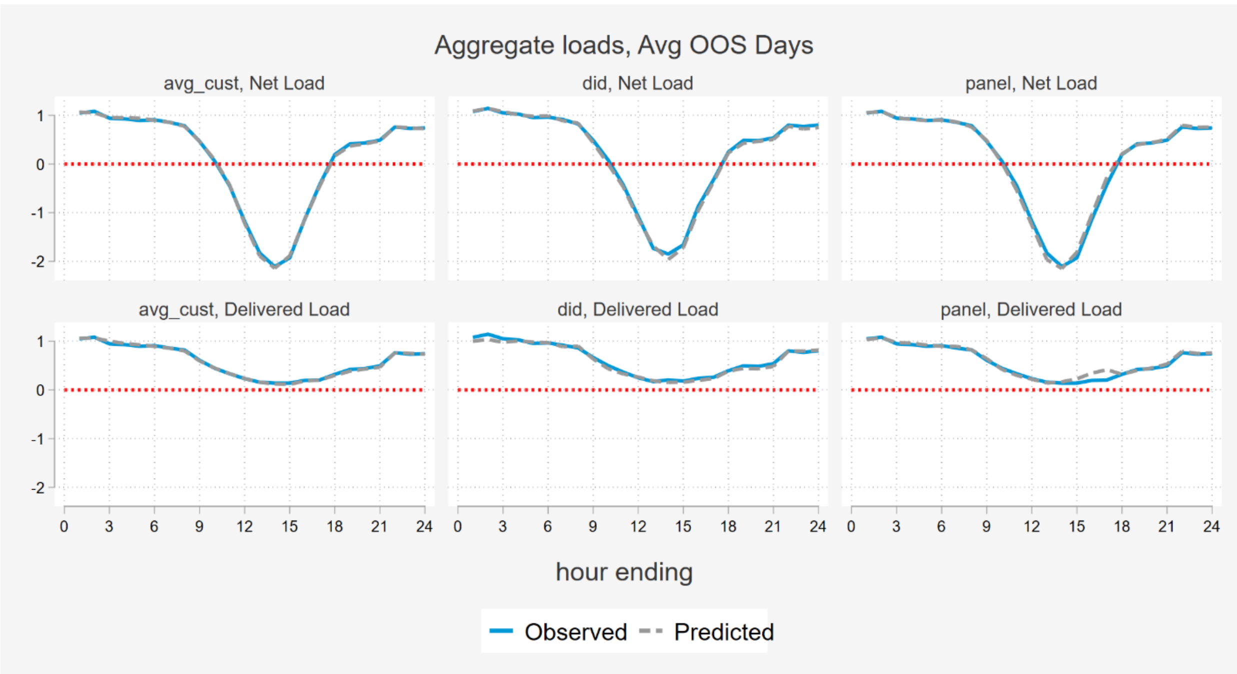


Table 2-2 summarizes the data sources, segmentation, and estimation methods used for each program. The segmentation was defined in advance of the analysis and is of particular importance because the evaluation used a bottom up approach to estimate impacts and to ensure that aggregate impacts across segments 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 primary segmentation variable was eligibility group, given the substantial difference in impact expected for default versus opt-in enrollment. In addition, the segmentation differentiated customers who were expected to deliver greater demand reductions– such as customers in the inland climate zone where cooling loads are higher– from customers who were expected to deliver lower demand reductions. Segmentation also included solar/net metering status. 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 99 participant sites ✓ a control pool of 5k non participants with battery storage
Segmentation	▪ None
Estimation method: Ex-post	▪ Average customer time series with out of sample model selection for the average customer
Estimation method: Ex-ante	▪ Weather normalized customer regressions by climate zone for reference loads ▪ Consideration of PY 2021 and PY 2022 performance for percent reductions

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 99 residential participant sites during 10 test events in October and November.

3.1 EVENT CHARACTERISTICS

Residential event impacts were assessed by site (premise and service point combination). Table 3-1, summarizes key characteristics for the 99 participating sites. Notably, nearly all sites (98%) also had PV collocated with their storage systems and 17% 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 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	99	99	98.0%	17.2%	8.05	6.96

Table 3-2 shows the 10 PY 2022 Residential CBP test event days dispatched in October and November. Due to the aggregator and participant enrollment timeline the test events were not dispatched during the hotter summer months typical of demand response programs. However, the goal was a technical test of the ability of storage systems to respond to dispatch signals. The ability of battery storage to respond to signals is not weather sensitive so this was a valid test. A variety of event windows were called, all on weekday. The most common windows were 6 pm to 9 pm (three events) and 7 pm to 9 pm (three events). The 6 pm to 9pm events have been used for average event reporting.

Table 3-2: Residential CBP Events in 2022

Event date	Day of week	Event start	Event end	Event avg temp (F)	Max SDG&E system load (MW)
10/12/2022	Wednesday	7:00 pm	9:00 pm	66.9	2,879
10/13/2022	Thursday	8:00 pm	9:00 pm	65.0	2,746
10/14/2022	Friday	6:00 pm	9:00 pm	63.7	2,717
10/19/2022	Wednesday	4:00 pm	8:00 pm	80.9	3,530
10/20/2022	Thursday	7:00 pm	9:00 pm	65.1	3,124

Event date	Day of week	Event start	Event end	Event avg temp (F)	Max SDG&E system load (MW)
11/9/2022	Wednesday	6:00 pm	9:00 pm	50.7	2,645
11/15/2022	Tuesday	4:00 pm	8:00 pm	56.5	2,666
11/17/2022	Thursday	7:00 pm	9:00 pm	52.1	2,658
11/22/2022	Tuesday	6:00 pm	9:00 pm	49.0	2,608
11/30/2022	Wednesday	4:00 pm	6:00 pm	52.3	2,744

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 2022 ▪ All analysis done by site (premise id-service point id pair)
Outage information	▪ PSPS and emergency outage data details which customers and what timeframes were impacted by outages
Customer characteristics	▪ Treatment: Sample of 99 residential CBP participants ▪ Control: Sample of 5k residential sites with battery storage ▪ Climate zones used in matched control selection
SDG&E hourly system loads	▪ Summer and Fall 2022 ▪ 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 5,000 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 10 test events called during PY 2022, all from 4 pm to 9pm. Table 3-4 summarizes the load reductions for Residential CBP sites for the 10 events and for the average 6 to 9 pm weekday event. Reductions were not significant for the average weekday event or for all but one event, which can be attributed to statistical noise. In the tables, the orange bars show a visual comparison of the reductions that are numerically labeled on the left of the bars. Directionally, reductions were negative for 7 of the 10 events, but given that results were not statistically significant for all but one event this can also be disregarded as statistical noise.

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

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Reductions (Ex Post)			Significant (90% CI)	Significant (95% CI)	Reductions (Baseline)	
				Aggregate (MW)	% Reduction	Average Site (kW)			Aggregate (MW)	Average Site (kW)
10/12/2022	7 to 9 pm	66.9	98	0.01	13.4%	0.05	No	No	-0.01	-0.09
10/13/2022	8 to 9 pm	65.0	98	-0.01	-19.0%	-0.10	No	No	-0.02	-0.16
10/14/2022	6 to 9 pm	63.7	98	-0.01	-17.8%	-0.10	No	No	-0.03	-0.35
10/19/2022	4 to 8 pm	80.9	98	0.01	26.0%	0.12	No	No	-0.01	-0.13
10/20/2022	7 to 9 pm	65.1	98	-0.02	-45.8%	-0.18	No	No	-0.02	-0.25
11/9/2022	6 to 9 pm	50.7	99	0.00	-7.4%	-0.04	No	No	-0.01	-0.11
11/15/2022	4 to 8 pm	56.5	99	-0.03	-45.8%	-0.26	Yes	Yes	-0.03	-0.30
11/17/2022	7 to 9 pm	52.1	99	-0.01	-23.1%	-0.11	No	No	0.00	-0.04
11/22/2022	6 to 9 pm	49.0	99	0.01	12.3%	0.06	No	No	0.00	0.01
11/30/2022	4 to 6 pm	52.3	99	0.00	-5.8%	-0.03	No	No	0.00	-0.05
Avg weekday event	**6 to 9 pm**	**54.5**	**99**	**0.00**	**-5.2%**	**-0.03**	**No**	**No**	**-0.01**	**-0.15**

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 program level. The baseline methodology produces estimates that track fairly well with ex post estimates in magnitude, but that are often different in direction. However, this effect can simply be interpreted as noise due to the small sample size of the program. 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 3-6: Comparison of Settlement Baseline and Load Impact Evaluation Methodologies.

Figure 3-1 shows the load shape for the average customer site for the average 6 to 9 pm weekday event. No meaningful or statistically significant load impacts (increase or reduction) are observed.

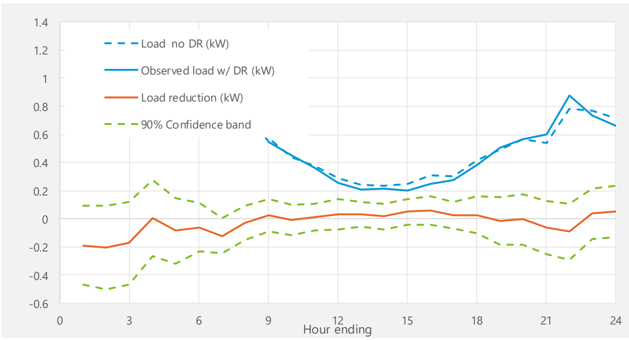
Figure 3-1: Residential CBP Summary for Average Event, Average Customer

Table 1: Menu options

Type of results	Average Customer
Category	All RESCBP
Type of Load	Delivered Load
Event date	Avg weekday event

Table 2: Event day information

RESCBP Event start	6:00 PM
RESCBP Event end	9:00 PM
Total enrolled accounts	99
Avg load reduction (Event Window)	-0.03
% Load reduction (Event Window)	-5.2%



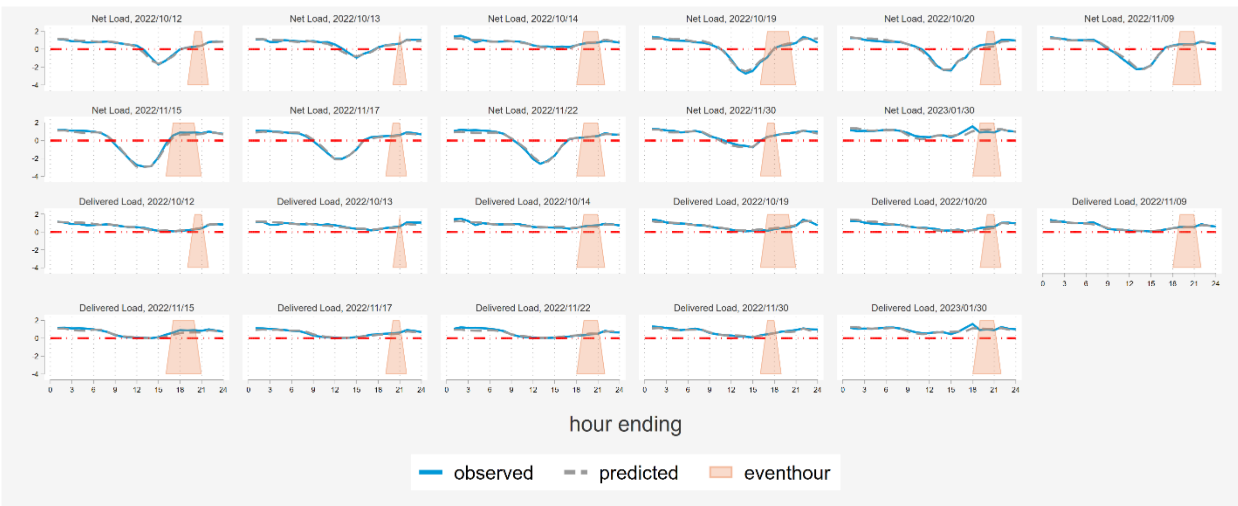
Hour ending	Load no DR (kW)	Observed load w/ DR (kW)	Load reduction (kW)	% Load reduction	Avg temp (F, site weighted)	Uncertainty adjusted impact - Percentiles: 5th	10th	30th	50th	70th	90th	95th	Std. error	T-statistic
1	1.08	1.27	-0.19	-17.5%	55.2	0.09	0.03	-0.10	-0.19	-0.28	-0.41	-0.47	0.171	-1.11
2	1.10	1.31	-0.20	-18.5%	54.8	0.09	0.03	-0.11	-0.20	-0.30	-0.44	-0.50	0.181	-1.13
3	0.99	1.16	-0.17	-17.5%	54.2	0.12	0.06	-0.08	-0.17	-0.27	-0.40	-0.47	0.179	-0.97
4	0.98	0.97	0.01	0.6%	54.4	0.28	0.22	0.09	0.01	-0.08	-0.20	-0.26	0.164	0.03
5	0.96	1.04	-0.08	-8.8%	53.8	0.15	0.10	-0.01	-0.08	-0.16	-0.27	-0.32	0.142	-0.59
6	0.92	0.98	-0.06	-6.4%	53.4	0.11	0.08	0.00	-0.06	-0.11	-0.19	-0.23	0.105	-0.56
7	0.83	0.95	-0.12	-14.4%	54.1	0.01	-0.02	-0.08	-0.12	-0.16	-0.22	-0.25	0.077	-1.56
8	0.76	0.79	-0.03	-3.7%	57.7	0.09	0.06	0.01	-0.03	-0.07	-0.12	-0.15	0.072	-0.39
9	0.57	0.55	0.03	4.4%	61.4	0.14	0.12	0.06	0.03	-0.01	-0.07	-0.09	0.071	0.35
10	0.44	0.45	-0.01	-2.5%	63.5	0.10	0.07	0.02	-0.01	-0.05	-0.10	-0.12	0.066	-0.17
11	0.38	0.36	0.01	3.4%	65.1	0.11	0.09	0.04	0.01	-0.02	-0.06	-0.08	0.057	0.22
12	0.29	0.25	0.03	11.6%	65.8	0.14	0.12	0.07	0.03	0.00	-0.05	-0.07	0.065	0.51
13	0.24	0.21	0.03	13.6%	65.7	0.12	0.10	0.06	0.03	0.00	-0.04	-0.06	0.055	0.59
14	0.23	0.22	0.02	7.5%	65.8	0.11	0.09	0.05	0.02	-0.01	-0.05	-0.07	0.055	0.32
15	0.25	0.20	0.05	20.0%	64.9	0.14	0.12	0.08	0.05	0.02	-0.02	-0.04	0.056	0.90
16	0.31	0.25	0.06	19.2%	63.1	0.16	0.14	0.09	0.06	0.03	-0.02	-0.04	0.063	0.95
17	0.30	0.28	0.02	8.2%	59.8	0.12	0.10	0.05	0.02	0.00	-0.05	-0.07	0.057	0.44
18	0.41	0.39	0.03	7.0%	57.9	0.16	0.13	0.07	0.03	-0.01	-0.07	-0.10	0.080	0.36
19	0.49	0.51	-0.02	-3.2%	55.8	0.15	0.11	0.04	-0.02	-0.07	-0.15	-0.18	0.101	-0.16
20	0.56	0.57	0.00	-0.6%	54.5	0.18	0.14	0.05	0.00	-0.06	-0.14	-0.18	0.109	-0.03
21	0.54	0.60	-0.06	-11.7%	53.1	0.13	0.09	0.00	-0.06	-0.12	-0.21	-0.25	0.116	-0.55
22	0.78	0.87	-0.09	-11.7%	52.3	0.11	0.06	-0.03	-0.09	-0.16	-0.25	-0.29	0.121	-0.76
23	0.77	0.74	0.04	4.7%	51.7	0.21	0.18	0.09	0.04	-0.02	-0.10	-0.14	0.109	0.33
24	0.71	0.66	0.05	7.4%	51.3	0.23	0.19	0.11	0.05	0.00	-0.09	-0.13	0.110	0.48

	Reference load (kW)	Estimated load w/ DR (kW)	Load reduction (kW)	% Load reduction	Weighted temp (F)	Uncertainty adjusted impact - Percentiles: 5th	10th	30th	50th	70th	90th	95th	Std. error	T-statistic
Event Window	0.53	0.56	-0.03	-5.2%	54.5	0.15	0.11	0.03	-0.03	-0.08	-0.17	-0.21	0.11	-0.25

3.3.2 Comparison of PY 2022 Impacts to PY 2021 Impacts

No statistically significant load reductions were observed for PY 2022. This is apparent when inspecting observed and predicted loads for each event day, as summarized in Figure 3-2 (the dotted red line simply indicated zero load). Figure 3-2 also includes a post season test event that was run on January 30, 2023 as investigation into the lack of reductions. Modest delivered load reductions of 13% (or 0.1 kW per site) were observed for the three hours of this supplementary test event. A load increase of over 40% (or over 0.4 kW) was observed in the two hours prior to the event, most likely due to battery charging. This lead to a usage increase of 0.8 kWh (0.4 kW over two hours) that was substantially larger than the 0.3 kWh (0.1 kW over three hours) of usage shifted away from the event window.

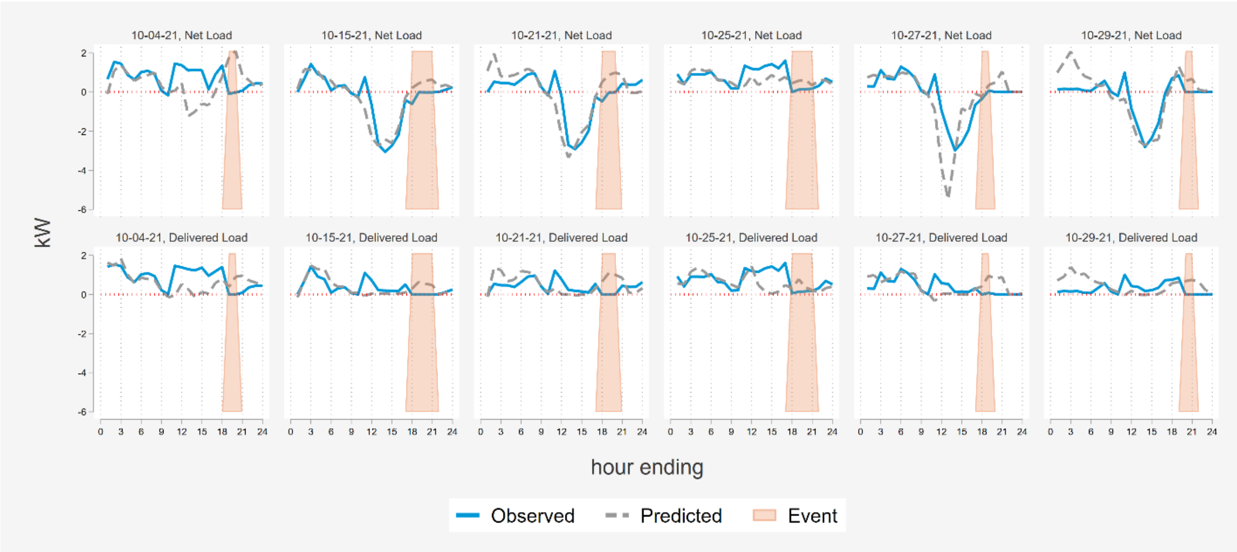
Figure 3-2: Observed and Predicted Loads, PY 2022 Residential CBP Event days



This contrasts with the observed and predicted loads from PY 2021, summarized in Figure 3-3.[3] The load shapes exhibit more noise because there were only 10 participants compared to 99 for PY 2022. Despite this noise, loads clearly dropped to essentially 0 kW consistently during the event window for each event. This was true whether using delivered loads or net loads. This is the dispatch behavior one would expect from a fully controllable resource like battery storage and has been observed in multiple other battery pilots. It is unknown why this was not the case for the PY 2022 Residential CBP. However, it seems reasonable to assume that the issue can be resolved. Therefore, for PY 2022 ex ante estimates load reductions are assumed to be a 50% reduction in whole building loads.

[3] PY 2021 impacts were evaluated using the same methodology tournament approach used in PY 2022. The panel model approach was selected to evaluate impacts for the 10 participants that year.

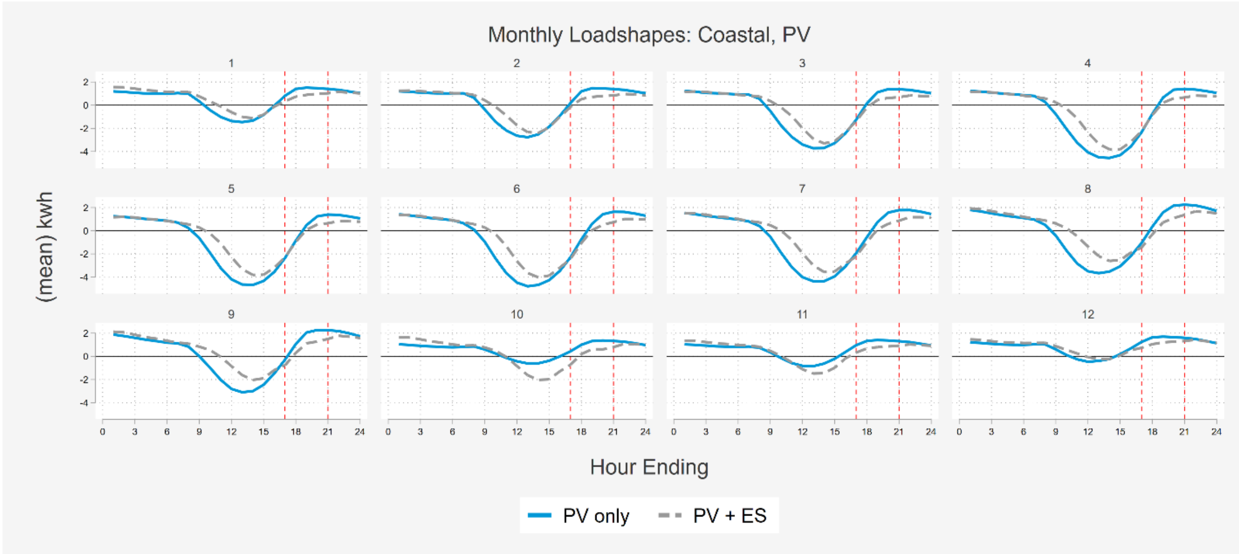
Figure 3-3: Observed and Predicted Loads, PY 2021 Residential CBP Event days



The PY 2021 and PY 2022 test events show a range of possible event dispatch outcomes, between eliminating delivered load entirely and producing minimal impacts. For Residential CBP the maximum reduction potential is limited to reducing delivered loads to zero, because exports are not compensated under market based programs like this. Figure 3-4 compares average net load daily profiles for each month of the year for PV customers with and without energy storage[4]. To ensure comparability only customers in the Coastal climate zone are shown, though the shapes are very similar for customers in the Inland climate zone. On average, customers with storage export less excess generation during the day and import less in the evening (the 4 to 9 pm peak window falls between the dotted red lines). Specifically, peak hour imports are reduced by roughly half from about 2 kW to about 1 kW. The remaining 1 kW of load corresponds to about 4 to 5 kWh of peak hour imports (across the 4 to 9 pm window, most concentrated in 5 to 9 pm). The average storage customer has 7 kW (and 19 kWh) of battery storage, indicating that there is ample capacity remaining to deliver further reductions for existing battery storage installations. This indicates that either customers are reserving a large portion of their capacity for back up or that more active management of battery operations is required to fully eliminate peak window imports. In practice, both likely limit the import reduction potential.

[4] Limited to customers with PV system sizes between 5 kW and 20 kW, to ensure size comparability. Participants in DR programs including Power Saver Rewards, Residential CBP, and AC Saver Day Ahead are excluded

Figure 3-4: Monthly Average Loadshapes, Coastal Customers with PV



Given how battery storage is currently operated, there are three potential use cases for capturing incremental value, including avoiding energy imports during peak hours (either through daily shifting or events) and exporting generation in peak hours. Table 3-5 summarizes the existing economic incentives, peak load potential and technical considerations for each.

Table 3-5: Incentives, Load Potential, and Considerations for Battery Storage Use Cases

Storage Operation Use Case	Economic Incentives	Peak Load Potential	Technical Considerations
Reduce delivered peak loads to zero on a daily basis	The TOU peak to super off peak differential for the DR-SES rate is $0.44 cents per kWh. About $140 to $160 per year in untapped value for the average PV+ES customer, after factoring in minimum bill limitations.	Average reduction potential is about 1 kW per customer in August and September, 0.5 kW in other months	Default battery settings reduce but do not eliminate peak usage. The capability of a battery to fully eliminate peak imports if a function of the battery size relative to home loads and PV system size and the portion of the battery the customer makes available for daily usage. More active management needed than currently available "off-the shelf".
Reduce delivered peak loads to zero on an event basis	Residential CBP is designed to capture this value (in the absence of daily shifting). Assuming average peak load is bid into the program (about 1 kW per customer in August and September,	Average reduction potential is about 1 kW per customer in August and September, 0.5 kW in other months. Reduction potential	If daily load shifting were more complete there would be no remaining "event" based value. The two are mutually exclusive.

Storage Operation Use Case	Economic Incentives	Peak Load Potential	Technical Considerations
	0.5 kW in other months), there is about $70 to $85 per in potential capacity payments to the average PV+ES customer.[5] This is about half the incentive potential for daily TOU shifting.	on the hottest days is about 2.4 kW (Coastal) to 2.9 kW (Inland) per customer in September (1.3 to 1.9 kW in August)	Dispatch algorithms need to incorporate more active management to consistently drop delivered loads to zero during an event. Also, in cases where battery capacity is insufficient to cover the full customer load, there is no incentive to or default capability to spread reductions over the event rather than exhausting the battery in the first hours of the event.
Export power during peak hours on an event basis	CAISO integrated programs do not compensate for battery exports and there is currently no program to capture peak capacity value for battery exports. ELRP group A4 (virtual power plant aggregators) is a load modifying program designed for battery exports (energy only), but SDG&E currently has no A4 aggregators[6]. Payments of $2 per kWh are determined using baseline settlements.	ELRP A4 forecasts assume 55% of battery capacity is available net of customer reserve and daily peak reduction. This corresponds to about 4 kW over two hours or 8 kWh per average customer with 7 kW of battery storage.	Export dispatch algorithms require active management. TOU price signals could provide an incentive but there are technical limitations which differ by battery provider / operator: some allow for exports, some do not. Exports are also limited by solar production since generally batteries only store on-site generation[7]

[5] Based on existing CBP capacity payments per kW-month for each month. Given event uncertainty and penalties, it is assumed that average load rather than peak load would be bid. Capacity payments make up the bulk of payment potential

[6] ELRP group A6 (Power Saver Rewards) does not limit exports but exports were not generally in PY 2022 and percent reductions were similar for customers with and without PV. A6 is behavioral only and does not include active dispatch or management of resources

[7] Powerwalls are an exception: they have a default option to charge from the grid ahead of extreme weather

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 3-6 compares the settlement baseline to the regression with synthetic controls approach used for the load impact evaluation and underscores why the latter is more methodologically robust.

Table 3-6: Comparison of Settlement Baseline and Load Impact Evaluation Methodologies

	Settlement Baseline	Load Impact Evaluation
Approach	Within-subjects baseline	Time series regression for the average customer with synthetic controls
Does the approach control for exogenous factors?	No. A pre-post within subjects approach only compares participant load before and	Yes. Any changes in load not due to the event will be

	Settlement Baseline	Load Impact Evaluation
	during the event. There is no way to identify changes in loads that may not be due to the event.	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 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 3-5 compares the settlement baseline (left panel) averaged across the average weekday event to the ex post results (right panel) for the average weekday event. The baseline loads shown are calculated at the aggregate level. As described above the baseline (dotted 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 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 9 pm event window. Both methods show a negative reduction, or a load increase. The load impact evaluation errors showed that increase is not to be statistically significant. In contrast, the baseline produces a larger increase and no errors are available for a baseline.

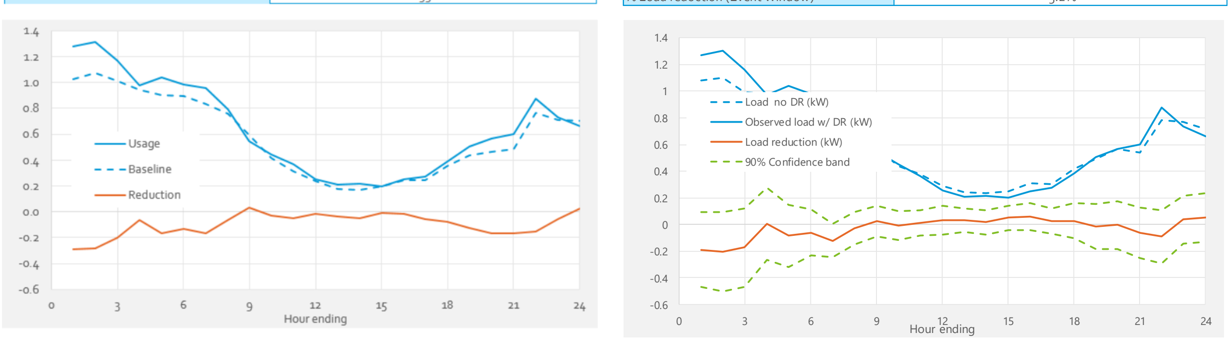
Figure 3-5: Residential CBP Average Weekday Event Load Impact Compared to Baseline

Settlement Baseline - Average (kW)

Event load reduction (kW)	-0.15
Event % load reduction	-33.2%

Load Impact Evaluation - Average (kW)

Avg load reduction (Event Window)	-0.03
% Load reduction (Event Window)	-5.2%



3.4 EX ANTE LOAD IMPACTS

A key objective of the 2022 evaluation is to quantify the relationship between demand reductions, temperature, and hour of day. However, load reductions did not exhibit clear patterns by these parameters. Further, most participating sites have dispatchable generating interconnected and reductions appear to be directly driven by dispatchable generation capacity rather than curtailment of weather sensitive loads. As such, historical load patterns were not used to derive the ex ante forecast and the forecast is not differentiated by weather conditions. Rather, capacity enrollments were forecast as a portion of total interconnected dispatchable generation that can feasibly be enrolled. Enrollments are derated for performance during actual events, relative to nominated reductions specified by enrollees at the time of enrollment.

3.4.1 EX ANTE ENROLLMENT FORECAST

As summarized in Figure 3-6, the ex ante forecast model uses historical interconnection data to derive the ex ante estimates. Essentially, historical interconnected capacity and growth rates are used to project future interconnected capacity. In terms of customer sites, the technical potential for the pilot is simply all sites corresponding to this capacity.[8] The feasible potential incorporates expected limits on enrollment. Given the nascent stage of the Residential CBP pilot, external reference points were used. Specifically, DSA is currently supporting a residential battery pilot in PG&E territory which produced enrollment rates of 6% to 7% across thousands of residential sites over a two month period. This was then doubled, to allow for the potential for additional enrollment were to continue for another year. Essentially, an enrollment ceiling of 12% of potential would yield a 6% annual enrollment rate, assuming that 50% of total potential would be enrolled annually. The feasible load potential for the pilot is assumed to be the entire load during the 4 to 9pm planning window for these interconnections as observed in PY 2021, derated by 50% for the dispatch issues observed in PY 2022.

[8] Average interconnected capacity was 7.0 kW per SDG&E residential customer site in 2022

Figure 3-6: Residential CBP Ex Ante Model Architecture

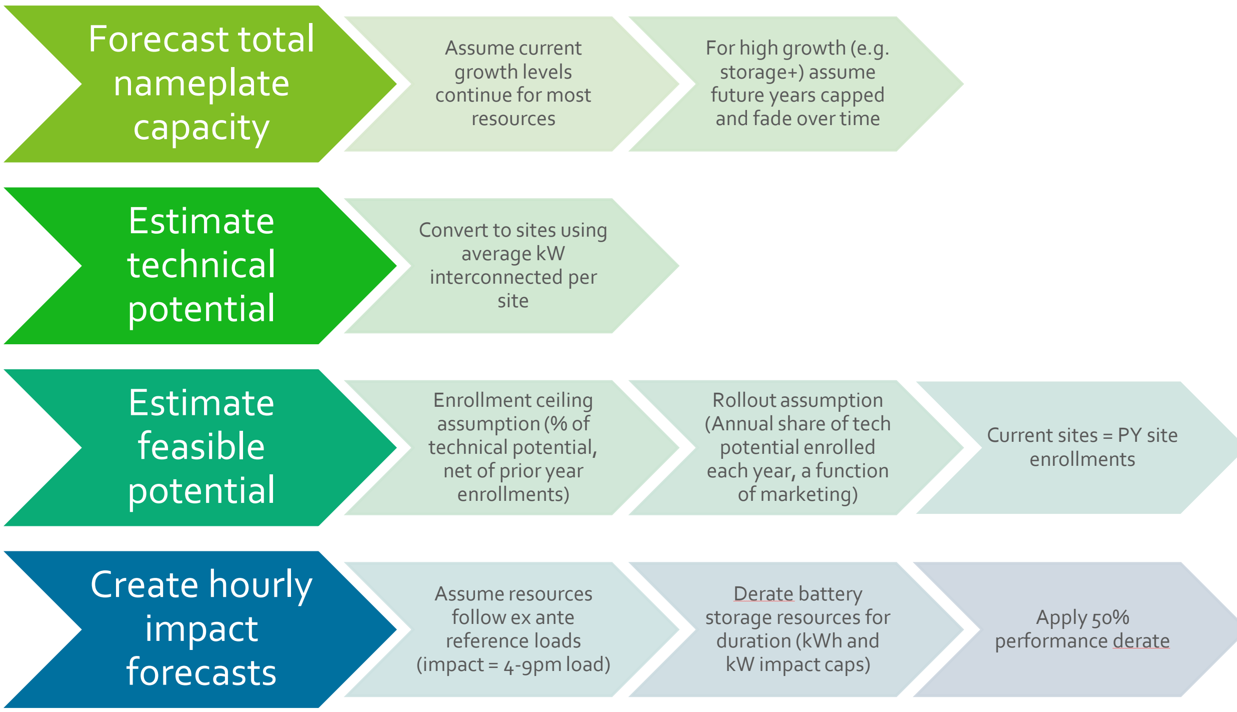


Figure 3-7 shows the cumulative historical generation capacity for residential and non-residential dispatchable generation sources including storage in SDG&E territory. For Residential CBP the enrollment forecast focused on residential storage which exhibited a historical annualized growth rate of 58% across 2021 and 2022.

Figure 3-7: Historical Cumulative Interconnection Capacity

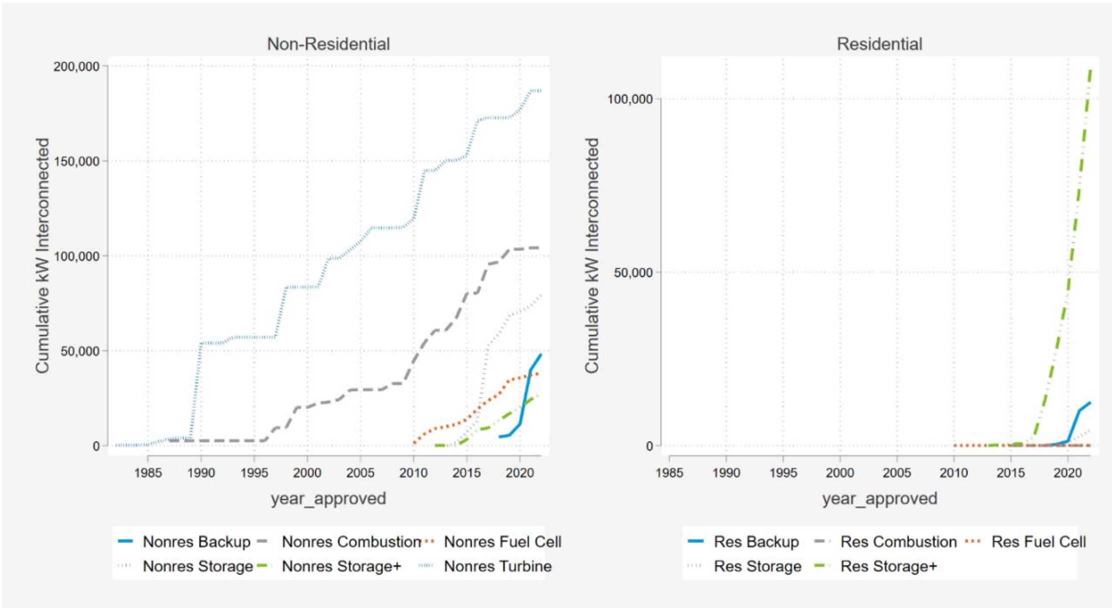


Table 3-7 summarizes annualized growth rates of the past two years, from January 2021 to December 2022. To further smooth likely unsustainably large capacity increases for residential stand-alone solar, all modeled growth rates were capped at 100% (annual doubling) and assumed to decrease by 25% each year. As an example, year over year growth rate of 100% in 2023 would decrease to 18% year over year growth by 2028.

Table 3-7: Recent Residential Storage Growth Rates

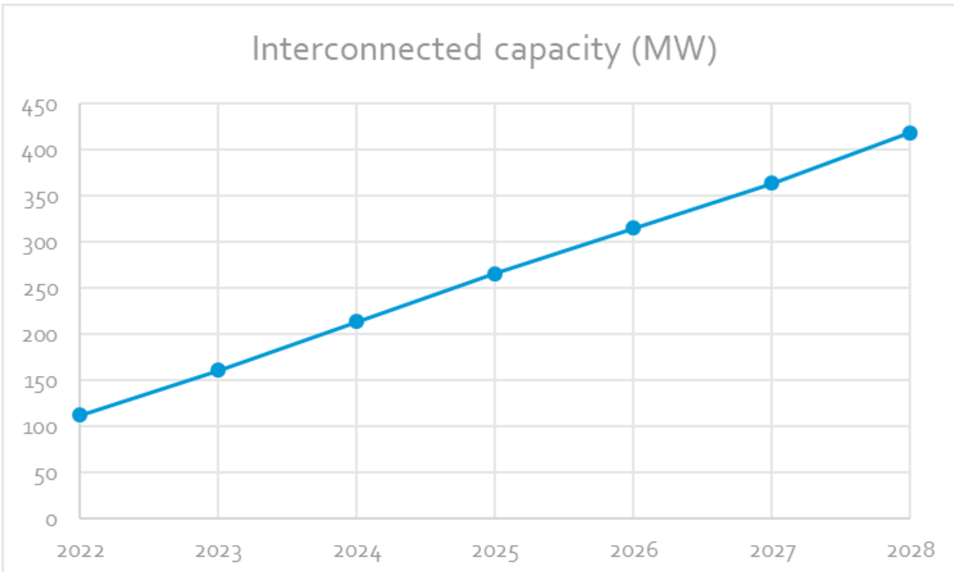
Class	Dispatchable Generation Category	Annualized growth (2021 to 2022)	Annualized growth (2020 to 2022)
Residential	Storage	66%	100%
	Storage+ (collocated)	48%	57%
	All storage	***48%***	***58%***

Figure 3-8 shows the capacity forecast for residential storage by extrapolating this growth rate into the future, tapering to 50% growth over time and producing a forecast of about 360 MW in 2027. This same approach was undertaken for all battery storage[9] for the non-residential ELRP evaluation and produced

[9] Residential and non-residential, collocated and non-collocated

a forecast of about 540 MW by 2027. As an external check for forecasted growth assumptions, the aggregate storage forecast was compared to a more sophisticated bass diffusion model executed for a separate behind the meter ETCC study, cited in Figure 3-9. The ETCC study forecast of between 450 MW and 500 MW for 2027 aligns reasonably well with the 540 MW forecast using the methodology for this evaluation using the simple growth model, after factoring in recent strong growth in storage and the vintage of the ETCC study[10].

Figure 3-8: Forecasted Cumulative Residential Collocated Storage Capacity



[10] https://www.etcc-ca.com/reports/behind-meter-battery-market-study. Based on interconnection data through 2019

Figure 3-9: SDG&E Forecast of Total Behind the Meter Battery Capacity[11]

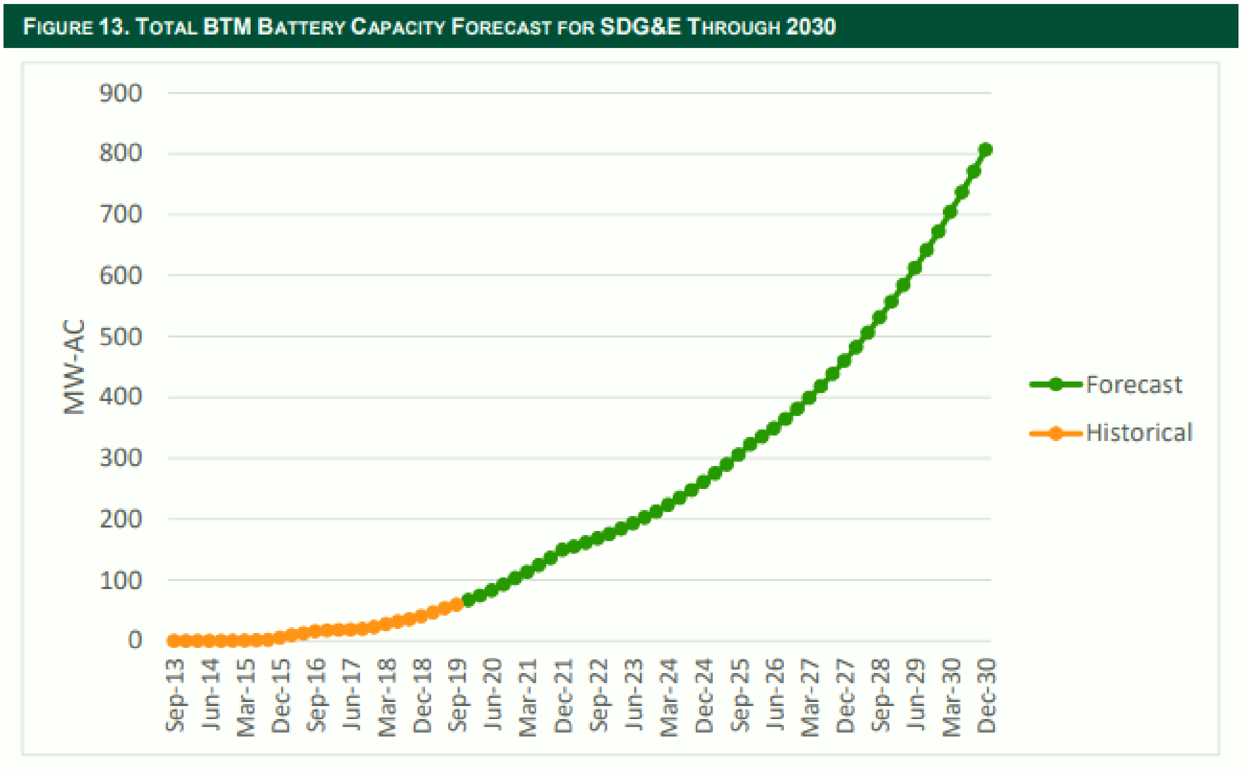


Table 3-8 summarizes the additional assumptions made for each step in the model. As noted above, historical growth rates were extrapolated but capped. In terms of customer sites, the technical potential for the pilot is simply all sites corresponding to this capacity.[12] Feasible potential was capped at 50% of technical potential and ramped annually so that total feasible potential is close to being reached by 2028. Hourly impacts assume flat generation shapes, given the dispatchable nature of these resources. Impacts for battery storage are derated to reflect duration limitations.

Table 3-8: Forecast Model Assumptions

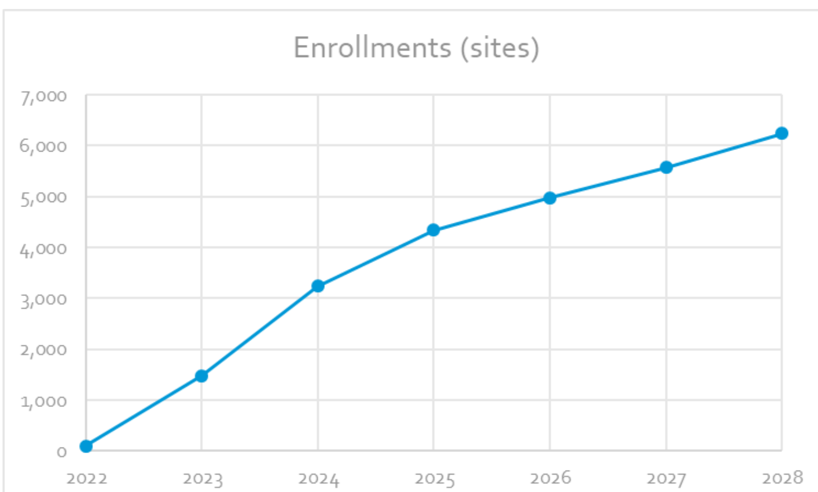
Analysis Step	Assumption	Definition
Capacity Forecast	Annualized growth rates	Growth from 2020 to 2022 based on DSA analysis of SDG&E historical interconnections provided by SDG&E. Growth rates were capped at 100% and rates above 15% were decreased annually by 25% until they reached 15%.

[11] https://www.etcc-ca.com/reports/behind-meter-battery-market-study
[12] Average interconnected capacity was 7.0 kW per SDG&E residential customer site in 2022

Analysis Step	Assumption	Definition
Technical Potential	kW interconnected capacity per site	Average battery capacity interconnected at SDG&E residential customer sites with storage. Assumed to be 7.0 kW per site based on analysis of all SDG&E interconnected residential sites as of 2022.
Feasible Potential	Enrollment ceiling	Maximum attainable share of technical potential, analogous to program share of the market. Assumed to be 12%, or annual enrollment of 6%[13], reaching maximum enrollment after two years of marketing.
	New annual enrollment cap	Share of attainable enrollment that can be enrolled in a single year. Assumed to be 50%, so assuming an enrollment ceiling of 12% of technical potential, 6% (=12% * 50%) of technical potential can be enrolled in a given year
	Attrition	Portion of enrolled capacity that leaves the program each year. Assumed to be 5%, based on experience with residential thermostat programs
Hourly Impacts	Impacts by month and hour	Impacts are assumed to be equal to 4-9pm reference load for all ex ante specifications and zero outside of the 4-9pm planning window. This is based on PY 2021 performance.
	Battery duration	Caps based on battery duration and total capacity were assessed but none limited actual forecast impacts given that 4 to 9pm loads are typically only about 10% of capacity.
	Performance derate	All ex ante impacts are derated by 50 percent to reflect the dispatch uncertainty observed in PY 2022.

Figure 3-10 summarizes the resulting site enrollment forecast.

Figure 3-10: Residential CBP Enrollment Forecast

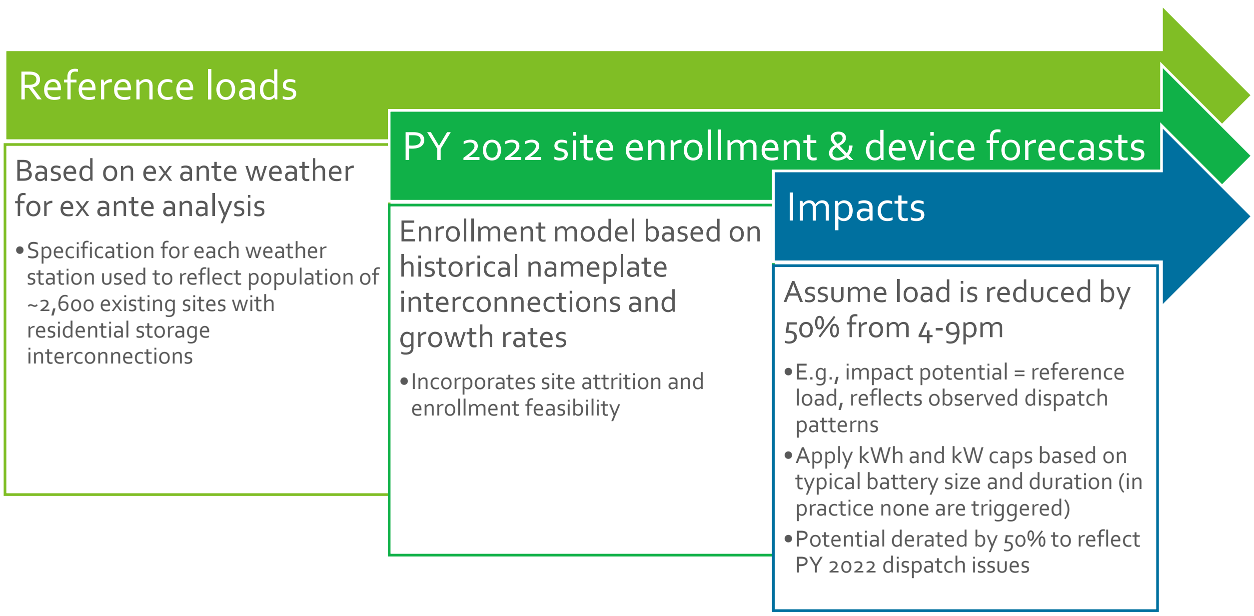


[13] This puts annual enrollment in line with the 6 to 7% enrollment rate observed in a recent PG&E residential battery pilot

3.4.2 Ex Ante Reference Loads and Load Reduction Model

The ex ante capacity forecast for Residential CBP was derived by combining the three key inputs shown in Figure 3-11. Essentially, reference loads were developed using 2022 loads for about the roughly 2,600 residential sites with storage. Average impacts were derived by applying impact assumptions from the PY 2021 ex post evaluation, which essentially showed that loads are dropped to 0 kW during events. Aggregate impacts were developed by applying an enrollment forecast based on historical battery storage growth and other key assumptions discussed below.

Figure 3-11: Ex Ante Inputs and Assumptions



As described in the methodology section the ex ante load forecast is derived by combining

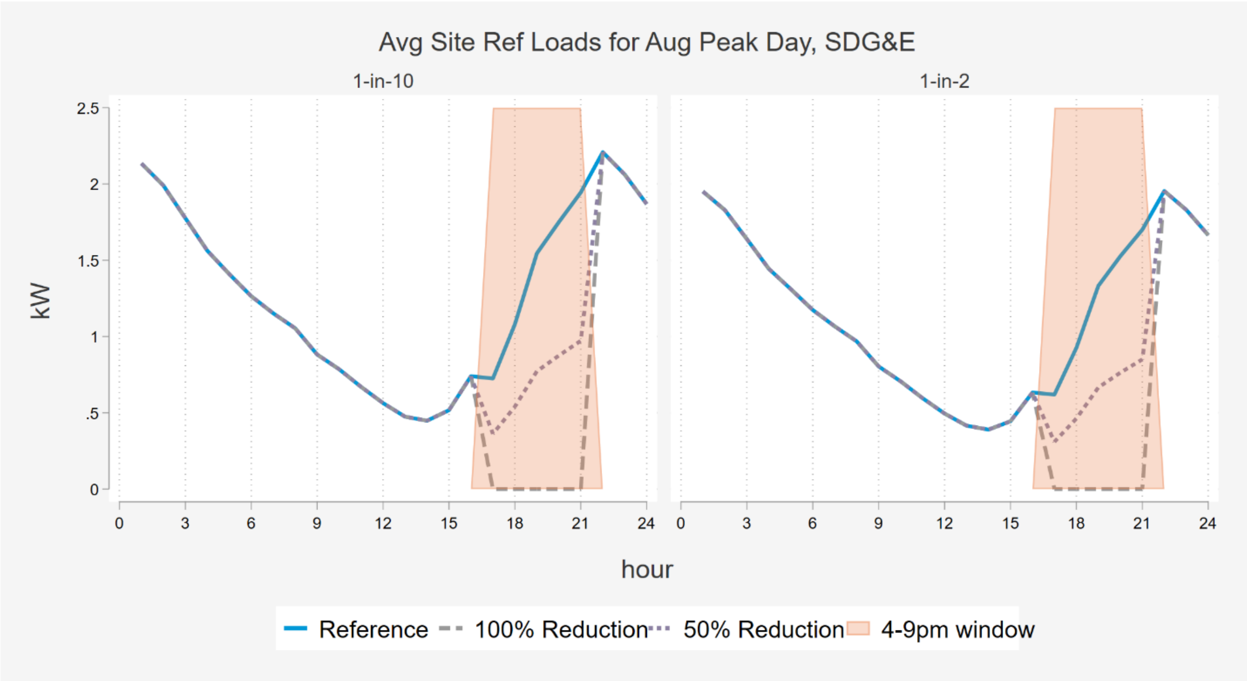
- reference loads, developed using a sample of 2,600 residential sites with solar and storage, weighted to the full territory population[14] of storage interconnections
- impact assumptions based on PY 2021 ex post conclusions that battery storage is dispatched to keep whole building loads at 0 kW during events
- the enrollment forecast based on historical growth in interconnections and assumptions regarding enrollment rate, described above

[14] Including distribution by climate zone and weather station

Figure 3-12 shows the resulting average reference loads for the August peak day, based on the analysis of delivered loads. As expected, these loads exhibit the very low daytime loads, and steep evening ramp common to premises with solar generation. Reference loads and forecasted load impacts were developed for all ex ante specifications.

The dashed grey line shows what load would be if fully curtailed by battery storage, essentially kept at 0 kW by the battery storage thereby producing load reductions of about 1.4 kW per site under 1-in-2 conditions. The dotted grey line shows what load would be if 50% of these reductions are achieved, essentially derating the full reduction assumption by 50% in light of the PY 2022 dispatch uncertainty and producing load reductions of about 0.7 kW per site under 1-in-2 conditions. This 50% reduction was assumed for PY 2022 ex ante impacts.

Figure 3-12: Ex Ante Reference Loads



3.4.3 Ex Ante Load Impacts

Table 3-9 summarizes the ex ante demand reduction capability by forecast year for different planning conditions. The tables reflect dispatchable demand reductions available from 4 pm to 9 pm on August monthly peaking conditions for 1-in-2 and 1-in-10 weather conditions. They align with the planning conditions used for resource adequacy attribution. They incorporate an enrollment forecast for sites described above. All ex ante impacts are derated by 50% to reflect the dispatch uncertainty observed in the PY 2022 test events. Aggregate impacts are expected to grow with enrolled residential storage capacity until flattening after 2028.

Table 3-9: Portfolio Impacts for August Monthly Peak Day

Year	Sites	Avg. reference load (kW)	CAISO		SDG&E	
			1-in-2	1-in-10	1-in-2	1-in-10
2022	99	1.27	0.06	0.07	0.06	0.07
2023	1,050	1.27	0.60	0.69	0.64	0.74
2024	2,776	1.27	1.58	1.83	1.69	1.96
2025	4,280	1.27	2.43	2.82	2.61	3.02
2026	5,243	1.27	2.98	3.46	3.20	3.69
2027	5,938	1.27	3.37	3.92	3.63	4.18
2028	6,648	1.27	3.77	4.38	4.06	4.68
2029	6,648	1.27	3.77	4.38	4.06	4.68
2030	6,648	1.27	3.77	4.38	4.06	4.68
2031	6,648	1.27	3.77	4.38	4.06	4.68
2032	6,648	1.27	3.77	4.38	4.06	4.68
2033	6,648	1.27	3.77	4.38	4.06	4.68

3.4.4 Comparison of Ex Post And Ex Ante Load Impacts

Table 3-10 compares the demand reductions from 2022 events to the PY 2022 reductions expected for the 1-in-2 weather conditions used for planning. Results are shown for the 4 to 9 pm resource adequacy window and compared to the average PY 2022 weekday 6 to 9 pm event.

In 2022, residential CBP customers delivered 0.00 MW during the during the 6 to 9 pm event window. Any ex post impacts for PY 2022 can be interpreted as statistical noise. A positive ex ante reduction is assumed despite the impact of zero estimated for the ex post analysis because a clear impact was observed in PY 2021. The PY 2022 ex ante estimates are based on the load response observed in PY 2021 plus a derating factor to reflect the dispatch issues observed in PY 2022. Ex ante weather conditions are much higher than ex post average temperatures because ex post events were conducted during the cooler months of October and November. Battery storage can be dispatched at any time of year, but because load reductions are limited by the delivered load available to be curtailed, load reductions are expected to be the highest in summer months.

Table 3-10: Residential CBP Comparison of Ex Post and Ex Ante Load Impacts for 2022

Result Type	Day Type and Period	Sites	Load without DR (MW)	Load Reduction (MW)	% Reduction	Daily Max Temp (F)	Event Avg Temp (F)
Ex Post Avg. Weekday	Event Period (6 to 9 pm)	99	0.05	0.00	-5.2%	65.8	54.5
Baseline Avg. Weekday	Event Period (6 to 9 pm)	99*	0.04	-0.01	-37.7%	65.8	54.5
Ex ante SDG&E	1-in-2 Weather August Peak (4 to 9pm)	99	0.12	0.06	50.0%	90.4	83.5
Ex ante CAISO	1-in-2 Weather August Peak (4 to 9 pm)	99	0.11	0.06	50.0%	87.4	81.3

*96 sites were included in the aggregate baseline analysis after excluding sites with outages

3.4.5 Ex Ante Load Impact Slice-of-Day Tables

Table 3-11 and Table 3-12 show the 2022 ex ante aggregate hourly impacts for each month under CAISO and SDG&E monthly peaking conditions, respectively. The tables are designed to enable the CPUC's Slice-of-Day Resource Adequacy requirements. The estimated reductions are greatest in August and September as there is the most amount of cooling load available to be curtailed. Response to an event begins in hour ending 17 and increases slightly over the event hours until hour ending 21.

Table 3-11: Slice of Day Table for CAISO 1-in-2 Weather Year Monthly Peak Day (Aggregate Impacts (MW))

Hour Ending	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.02	0.00
18	0.00	0.00	0.00	0.02	0.02	0.03	0.04	0.04	0.04	0.04	0.03	0.00
19	0.00	0.00	0.00	0.03	0.03	0.04	0.05	0.06	0.06	0.06	0.04	0.00
20	0.01	0.01	0.01	0.04	0.03	0.05	0.06	0.07	0.07	0.07	0.05	0.01
21	0.01	0.01	0.01	0.05	0.04	0.06	0.07	0.08	0.08	0.08	0.05	0.01
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3-12: Slice of Day Table for SDG&E 1-in-2 Weather Year Monthly Peak Day (Aggregate Impacts (MW))

Hour Ending	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.02	0.01	0.02	0.03	0.03	0.04	0.03	0.02	0.00
18	0.00	0.00	0.00	0.03	0.02	0.03	0.04	0.05	0.05	0.04	0.03	0.00
19	0.00	0.00	0.00	0.04	0.03	0.04	0.06	0.07	0.08	0.06	0.04	0.00
20	0.01	0.01	0.01	0.05	0.04	0.05	0.07	0.08	0.09	0.06	0.05	0.01
21	0.01	0.01	0.01	0.05	0.05	0.06	0.08	0.08	0.10	0.07	0.05	0.01
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4 CONCLUSIONS AND RECOMMENDATIONS

The residential CBP program did not deliver statistically significant demand reductions in PY 2022 but should be able to deliver reductions in the future provided key issues are addressed. 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 the CBP pilot, test an 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 7 kW, it is only compensated for offsetting whole building load (e.g., 2 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 will may 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.

- **Recruit aggregators and participants ahead of the summer demand response season.** For PY 2021 and PY 2022 enrollment delays resulted in test events only occurring in the fall (October and November). Resource potential for Residential CBP is the highest in the summer months and the pilot is expected to yield the greatest benefits in these months. It is also important to test load reduction performance in the summer.

- **Encourage aggregators to dispatch algorithms designed to fully eliminate imports during the event window.** Battery storage systems are not currently operated to fully eliminate peak hour imports. Despite the absence of more active management of daily shifting, about half of the economic value to the customer and to the grid can be achieved by fully eliminating imports during CBP events. Residential CBP dispatch that does not achieve this provides minimal value to the customer and to the grid.

- **Thoroughly test and validate load dispatch ahead of the event season**. Test 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 test events so load reductions or lack thereof can be clearly identified. Test events should be evaluated soon after dispatch to identify and correct any issues. This should help avoid the dispatch issues observed in PY 2022.

APPENDIX

A. TIME SERIES REGRESSION MODEL WITH SYNTHETIC CONTROLS

A time series regression with synthetic controls were used as the primary method for estimating load impacts for PY 2022 impacts for Residential CBP. The approach is implemented on a time series of average customer loads. It relies on control sites that did not experience the intervention (one matched to each participant site), solar irradiance, plus weather and month characteristics, to estimate the counterfactual. The time series model estimates a counterfactual load using weather and loads for the matched control sites. A separate model is estimated for each hour of day and all modeling excludes event days. Reductions are the difference between the observed participant and predicted counterfactual loads. With a time series model with synthetic controls, one should observe:

- Very similar energy use patterns for participant and counterfactual loads when the intervention is not in place.
- A change in demand patterns for customers who are dispatched or subject to time varying prices, but no similar change for the counterfactual load.
- The timing of the change should coincide with the introduction of intervention.

The use of a time series model allows for incorporation of multiple control sites and does not rely on finding a single ideal match. Inclusion of multiple matches was testing in the model selection tournament but the winning model only included a single matched control (the closest match for each participant). The equation for the model is presented below in Equation A 0-1 and Table A 0-1. A separate model was estimated for each hour of the day.

Equation A 0-1: Ex Post Regression Model for Residential CBP

$$kW_t = \mathrm{a} + \mathrm{b} \cdot kW_{0_t} + \sum_{n=1}^{max} \mathrm{c}_n \cdot month_n + \mathrm{d} \cdot solar_t + \mathrm{e} \cdot CDH_t + \sum_{n=1}^{max} \mathrm{f}_{n,t} \cdot spline_{n,t} + \delta_t + \varepsilon_{i,t}$$

Where:

Table A 0-1: Ex Post Regression Elements for Residential CBP

$\mathrm{kW_t}$	Is the average usage across participants for each time period.
$\mathrm{kW\_0_t}$	Is the average synthetic control usage across matched controls for each time period. Synthetic controls were selected based on Euclidean distance matching (the winning matching method in a tournament of 8 methods). They did not experience the treatment.
a	Is the model intercept.
b	Coefficient for the synthetic control load.
c	Coefficients for each month .
d	Coefficient for average solar irradiance across participants for each time period.
e	Coefficient for weather sensitivity of loads, based on CDH above 65F.

f	Coefficients for weather sensitivity of loads, based on a 2 knot spline of 18 hour moving average of temperature, averaged across participants for each time period.
δ_t	Represents time effects for each time period. This accounts for observed and unobserved factors that vary by time but affect all customers equally.
$\varepsilon_{i,t}$	Represents the error term for each individual customer and time period.