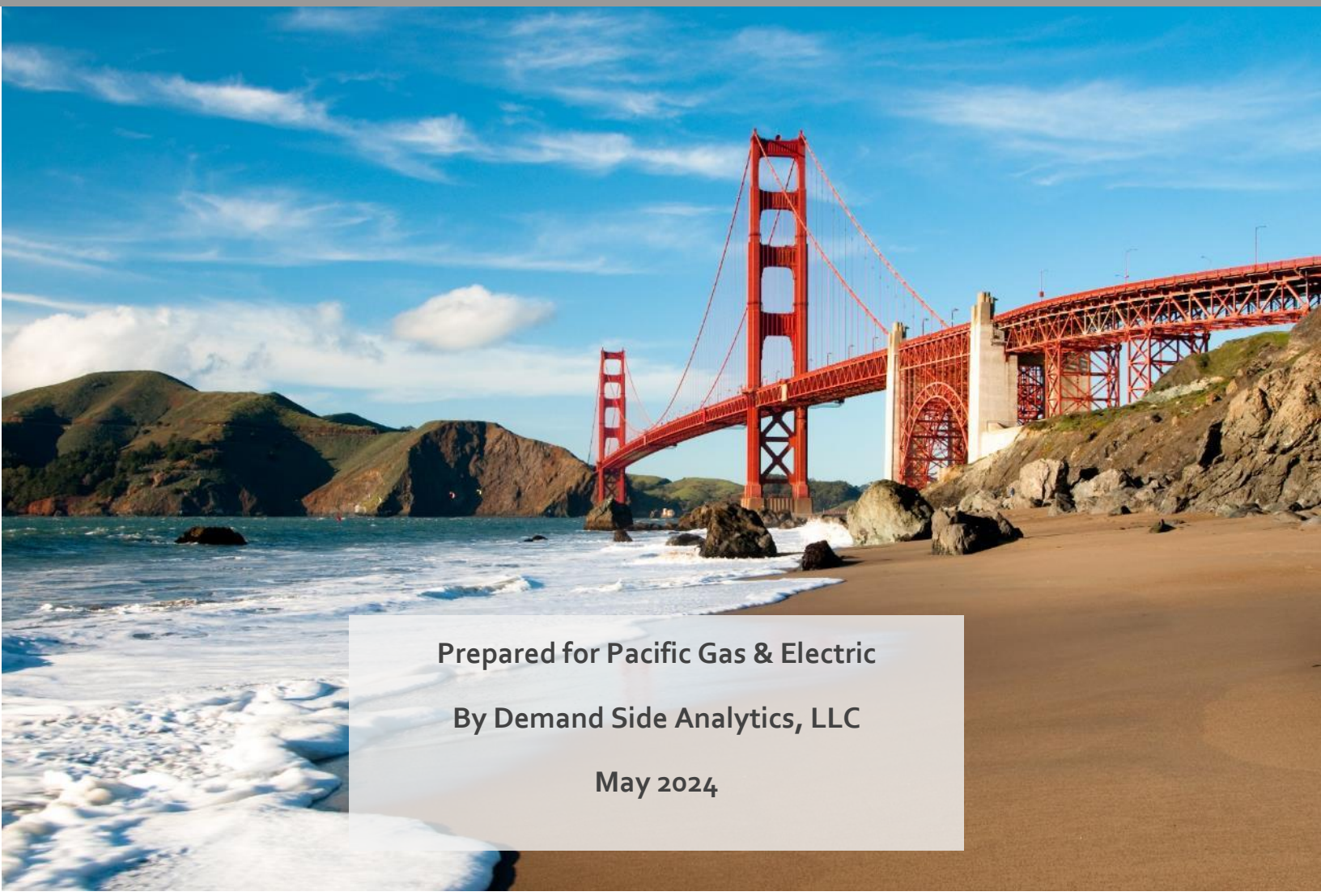
Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

DRAFT REPORT
CALMAC ID: PGE0498.01

2022-2023 Load Impact Evaluation of Pacific Gas and Electric's Smart Thermostat Control Pilot



Prepared for Pacific Gas & Electric

By Demand Side Analytics, LLC

May 2024

ACKNOWLEDGEMENTS

Demand Side Analytics Team

- Josh Bode
- Parker Gauthier
- Patrik Karlovic
- Hal Gordon, Ph.D.

PG&E Team

- Wendy Brummer
- Katrina Wu
- Alex Bruck
- Aaron Kendall
- Ezana Kemmer
- Dillon Pan

ABSTRACT

This report presents the outcomes of Pacific Gas and Electric's (PG&E) Smart Thermostat Control Pilot conducted during the summers of 2022 and 2023. The Pilot comprised two components: demand response (DR) events and daily automated time-of-use (TOU) rate plan optimization. A key focus of this Pilot was the enrollment and effectiveness of various smart thermostat brands and the impact of temperature-based demand reduction strategies. At the close of 2023, the Pilot observed a significant market dominance of Nest thermostats (72.4%), followed by ecobee (26.0%), Emerson (1.6%), and newly introduced Honeywell Home thermostats (0.4%).Because ecobee thermostats offered the most effective functionality for TOU automation, the Pilot focused on the effects on those thermostats. The Pilot revealed that around 58% of ecobee users utilized TOU automation consistently in 2022 and 47% by the end of 2023. On high-load days, the smart thermostats demonstrated an average demand reduction of 0.13 kW per site during TOU control hours, with the effect diminishing over longer periods, especially during the net load peak hours (7–9 PM).

The Pilot underscores the variance in impacts due to geographic dispatch and temperature conditions. In 2022, the highest demand reduction was observed on September 6, a day of extreme heat and high system load, highlighting the correlation between temperature and DR effectiveness. The 2023 data further reinforced this, showing the most substantial impacts in hot regions such as the Central Valley and Sierras. The Pilot concluded that 90% of the variation in dispatchable demand reduction can be attributed to weather conditions, the duration of the event, and the time of day.

TABLE OF CONTENTS

FIGURES

TABLES

1 EXECUTIVE SUMMARY

This report presents the results of PG&E's Smart Thermostat Control Pilot for the 2022 and 2023 DR seasons. The Pilot was branded under the "SmartAC" trademark name and provided incentives to residential customers who allowed PG&E to reduce or shift their electricity use during peak hours (4:00 PM – 9:00 PM) by communicating with WiFi-enabled smart thermostats. PG&E worked with four types of connected thermostats – Nest, ecobee, Emerson, and Honeywell Home – that reduce or shift electricity load during demand response (DR) events. Additionally, two thermostat manufacturers – ecobee and Emerson – offered automated daily shifting in response to time-of-use (TOU) rates, shedding customer load daily during peak hours. Notably, most customers were already on TOU rates, and the automated daily shifting was over and above the customer behavioral response to time-of-use prices.

The primary objectives of this Pilot were to:

- Understand how enrollment rates vary by thermostat brand and what share of customers elect the daily TOU automation option.
- Quantify the magnitude of thermostat-enabled daily TOU demand reduction over and above customer behavioral response to the rates.
- Quantify the magnitude of dispatchable demand reduction for each DR event called including the incremental value for ecobee customers who elected daily TOU automation.
- Quantify how dispatchable reductions vary as a function of weather, event start, hours into the event, and daily TOU automation.
- Understand how demand reductions vary across customers by geography, income status, solar, and thermostat brand.
- Assess demand reduction persistence across the event hours.
- Assess the ability of the Pilot to deliver locational dispatch.

The Pilot was preceded by a DR Emerging Technology study which was initially launched in the middle of the 2021 summer. The purpose of the study was to assess the incremental value of DR events for customers on TOU rate plans. Only 14,000 customers on TOU rate plans were allowed onto the Pilot. As part of Rulemaking 20-11-003,, PG&E's proposal for a follow-on Pilot was authorized to further study smart thermostats in PG&E service territory.[1] At the beginning of the 2022 season, almost 13,000

[1] Rulemaking 20-11-003, Phase 2 Decision 21-12-015, Directing Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company to Take Actions to Prepare for Potential Extreme Weather in the Summers of 2022 and 2023

controllable thermostats were enrolled, which then grew to 109,802 devices by the end of the 2023 season.

In 2022, PG&E intentionally called events over a wide range of weather conditions, event start times, and event durations in order to fully understand device performance under different conditions. PG&E executed 19 territory-wide events in 2022, six in response to emergency notices from the California Independent System Operator (CAISO). In 2023, the CPUC authorized PG&E to integrate the Pilot into the CAISO wholesale market and the focus shifted to market integration. PG&E pilot resources were dispatched in response to market operator instructions by grid areas knows as Sub-Load Aggregation Points (SubLAPs). In total, the market operator called events on nine days in 2023, with 16 unique dispatch periods, but none were territory-wide.

The 2022 DR impact analysis relied on randomized control trials. As customers enrolled, DSA randomly assigned them to one of ten groups. Except for CAISO emergencies, a subset of the ten randomly assigned groups were dispatched for each event while the remaining groups were held back as control groups. As a result, while 19 events were called, individual customers experienced fewer than eight events each during the summer. The event impacts were estimated using whole-home hourly data and a difference-in-differences panel regression. In 2023, the DR analysis solely relied on a difference-in-differences calculation using a matched control group. The daily TOU automation analysis included over 11,000 sites and was analyzed using a matched control group and difference-in-differences for both years.

Table 1 and Table 2 summarize the event-based demand reductions from the 2022 and 2023 seasons, respectively. Table 3 summarizes the results from the analysis of the daily TOU automation. Finally, Table 4 summarizes the key findings from the Pilot.

Table 1: 2022 DR Events and Per Site Impacts (kW)

					Hourly Impacts (kW)				Event Average				
Date	Event Hours	Event hours Avg. Temp	Max Temp (Participant weighted)	Dispatched Sites	Hour 1	Hour 2	Hour 3	Hour 4	Reference Load (Baseline)	Impact	% Impact	se	t
06/22/2022	18:00 to 20:00	85.6	88.1	1,455	0.41	0.23	0.14		1.74	0.26	15.0%	0.038	6.84
06/27/2022	17:00 to 19:00	89.3	90.2	1,470	0.56	0.30	0.25		1.44	0.37	25.9%	0.036	10.45
07/11/2022	17:00 to 19:00	91.4	92.2	1,441	0.91	0.55	0.38		1.63	0.61	37.6%	0.041	14.99
07/16/2022	19:00 to 21:00	88.7	91.9	1,584	0.72	0.40	0.19		2.14	0.43	20.2%	0.038	11.31
07/18/2022	19:00 to 21:00	85.6	89.0	1,622	0.66	0.39	0.27		2.07	0.44	21.2%	0.036	12.37
07/21/2022	18:00 to 21:00	84.3	87.7	1,598	0.53	0.30	0.21	0.13	1.67	0.29	17.4%	0.032	9.17
07/28/2022	17:00 to 20:00	81.4	84.0	3,333	0.58	0.38	0.27	0.18	1.33	0.35	26.5%	0.023	15.37
08/03/2022	18:00 to 21:00	87.4	90.7	2,835	0.70	0.40	0.24	0.22	2.00	0.39	19.6%	0.030	13.13
08/04/2022	19:00 to 21:00	80.8	84.2	3,617	0.63	0.36	0.22		1.87	0.40	21.5%	0.025	15.90
08/15/2022	17:00 to 20:00	91.7	93.9	3,852	0.40	0.25	0.21	0.13	1.92	0.25	13.0%	0.026	9.61
08/16/2022	20:00 to 21:00	89.7	92.4	19,377	0.73	0.34			2.48	0.54	21.7%	0.008	64.96
08/17/2022	18:00 to 21:00	85.7	88.5	15,650	0.57	0.41	0.30	0.18	1.89	0.36	19.2%	0.024	15.26
08/21/2022	19:00 to 21:00	79.0	82.6	3,941	0.68	0.35	0.22		1.90	0.42	21.8%	0.026	15.94
09/04/2022	18:00 to 21:00	94.5	99.4	4,311	1.05	0.62	0.39	0.26	2.43	0.58	23.9%	0.026	22.28
09/05/2022	21:00 to 21:00	93.2	93.2	10,979	0.27				3.16	0.27	8.5%	0.018	14.90
09/06/2022	18:00 to 20:00	101.7	105.6	21,334	1.38	0.90	0.61		3.34	0.96	28.9%	0.014	66.69
09/07/2022	18:00 to 21:00	94.5	100.5	21,310	1.11	0.74	0.51	0.38	2.89	0.68	23.6%	0.012	57.68
09/08/2022	18:00 to 21:00	97.3	103.4	21,261	1.21	0.75	0.47	0.29	3.04	0.68	22.3%	0.013	53.26
09/09/2022	20:00 to 21:00	83.6	86.3	2,756	0.57	0.32			2.19	0.44	20.2%	0.030	14.75
Average		88.7	91.8	7,565	0.88	0.58	0.42	0.27	2.57	0.59	22.8%	0.028	21.15

Table 2: 2023 DR Events and Per Site Impacts (kW)

Date	Event Hours	Event hours Avg. Temp	Max Temp (Participant weighted)	Dispatched Sites	Hourly Impacts (kW)				Event Average				
					Hour 1	Hour 2	Hour 3	Hour 4	Reference Load (Baseline)	Impact	% Impact	se	t
06/30/2023	16:00 to 17:00	99.6	99.6	14,119	0.73				2.03	0.73	35.9%	0.018	40.96
06/30/2023	17:00 to 18:00	82.0	82.0	26,708	0.44				1.44	0.44	30.9%	0.012	37.28
06/30/2023	18:00 to 19:00	92.4	92.4	6,075	0.70				2.32	0.70	30.3%	0.032	21.85
06/30/2023	19:00 to 20:00	82.7	82.7	24,224	0.69				2.23	0.69	31.1%	0.016	43.21
07/15/2023	16:00 to 19:00	99.5	100.7	43,000	0.82	0.59	0.41		2.50	0.61	24.3%	0.011	53.21
07/17/2023	17:00 to 19:00	101.3	102.1	11,817	1.10	0.65			3.28	0.87	26.6%	0.022	39.51
08/15/2023	16:00 to 18:00	100.5	100.8	14,472	1.09	0.76			2.87	0.92	32.1%	0.019	48.84
08/15/2023	17:00 to 19:00	104.2	104.7	7,694	1.15	0.60			3.40	0.88	25.8%	0.025	34.84
08/16/2023	16:00 to 20:00	98.8	101.4	5,615	0.96	0.59	0.39	0.29	2.94	0.56	19.0%	0.028	19.97
08/16/2023	17:00 to 20:00	100.7	102.6	13,878	1.24	0.79	0.43		3.30	0.82	24.8%	0.020	41.23
08/16/2023	18:00 to 20:00	80.5	82.4	54,248	0.67	0.37			2.13	0.52	24.4%	0.009	57.95
08/16/2023	19:00 to 20:00	102.0	102.0	2,936	1.11				3.23	1.11	34.2%	0.037	29.56
08/23/2023	17:00 to 19:00	91.6	93.4	2,326	0.59	0.29			2.27	0.44	19.4%	0.046	9.62
10/05/2023	17:00 to 19:00	81.5	82.7	32,035	0.45	0.28			1.52	0.36	24.0%	0.011	34.27
10/06/2023	17:00 to 19:00	81.7	83.1	29,747	0.55	0.36			1.73	0.46	26.4%	0.012	38.41
10/19/2023	17:00 to 19:00	78.0	79.5	30,420	0.36	0.25			1.36	0.30	22.2%	0.009	32.64
Average		**92.3**	**93.3**	**19,957**	**0.69**	**0.45**	**0.41**	**0.29**	**2.23**	**0.57**	**25.5%**	**0.023**	**24.74**

Table 3: TOU per Site Impacts (kW)

System	Day Type	Accounts (Average)	4:00-5:00 PM	5:00-6:00 PM	6:00-7:00 PM	7:00-8:00 PM	Average 4-8 PM
ALL	AVERAGE DAY JULY	3,557	0.14	0.08	0.05	0.03	0.07
	AVERAGE DAY AUGUST	3,766	0.14	0.11	0.08	0.06	0.10
	AVERAGE DAY SEPTEMBER	3,735	0.09	0.08	0.05	0.06	0.07
PG&E	PEAK DAY JULY	2,971	0.14	0.12	0.10	0.01	0.09
	PEAK DAY AUGUST	3,575	0.10	0.05	0.04	-0.02	0.04
	PEAK DAY SEPTEMBER	3,552	0.10	0.07	0.04	0.05	0.06
	TOP 20 DAYS	3,659	0.13	0.10	0.04	-0.03	0.06
CAISO	PEAK DAY JULY	2,935	0.05	0.10	0.08	0.01	0.06
	PEAK DAY AUGUST	3,596	0.18	0.18	0.15	0.03	0.13
	PEAK DAY SEPTEMBER	3,562	0.13	0.08	0.03	0.02	0.07
	TOP 20 DAYS	3,710	0.12	0.09	0.08	0.03	0.08
CAISO Net Loads	PEAK DAY JULY	2,935	0.05	0.10	0.08	0.01	0.06
	PEAK DAY AUGUST	3,617	0.18	0.18	0.19	0.09	0.16
	PEAK DAY SEPTEMBER	3,568	0.07	0.04	0.03	0.07	0.05
	TOP 20 DAYS	3,904	0.13	0.09	0.05	-0.02	0.06

Table 4: Key Findings Summary

Key Finding	Additional Detail
Of the 108,190 devices enrolled at the end of the 2023 season, 72.4% were Nest thermostats, 26.0% were ecobee thermostats, 1.6% were Emerson, and 0.4% were Honeywell Home thermostats.	Nest devices were the most popular by the end of the 2023 season. However, in the 2022 Nest and ecobee had similar enrollment numbers. Marketing for ecobee devices occurred throughout the 2022 spring and fall periods, explaining their surge in enrollment. In 2023, most of the new enrollment was from Nest devices, which coincided with the marketing efforts. While the manufacturers did not share all the details about their marketing efforts, ecobee devices allowed in-app enrollment, while Nest customers could enroll on the Nest website. Emerson and Honeywell Home devices routed potential enrollees to the implementation vendor's enrollment web page.
Approximately 58% of ecobee participants utilized TOU automation at the beginning of the 2022 season, which declined to approximately 47% by the end of the 2023 season.	There were two device brands – Emerson and ecobee – that offered automated TOU response in 2022 and 2023, with ecobee customers making up the majority of enrollees. While Emerson offered automated TOU response, the number of participants was small and were therefore excluded from the analysis.
The thermostats enabled automated daily shifting that delivered daily demand reductions over and above customer response to TOU rates.	Thermostats reduced demand by 0.13 kW per site, on average, on the non-event days when PG&E loads were highest (Top 20 Load Days). The load impacts were measured using smart meter data and vary by hour, with larger results in the first hour and decreasing demand reduction in later hours. The device demand reduction was limited to four hours despite the five-hour peak. The thermostats did not deliver demand reduction for the 8:00 - 9:00 PM hour. Because thermostat demand reductions decay with longer durations, the demand reduction for net load peak hours (7:00 -9:00 PM) was substantially smaller than for the 4:00 – 7:00 PM period.
The algorithms automated the DR around the correct peak hours	Most participants were on rates with a 4-9 PM peak. For those sites, the data shows pre-cooling from 3-4 PM and snapback after 9 PM. However, the TOU-D rate had a shorter 5-8 PM peak. For TOU-D, the data shows re-cooling from 4-5 PM and snapback after 8 PM.
2022 events intentionally introduced wide variation in temperatures, event start time, and event duration, allowing us to quantify how performance varies as function of those factors fully	On September 6, 2022, one of the hottest and highest PG&E load days, the thermostats delivered an average impact of 0.96 kW over the DR event window, with the largest impacts, 1.38 kW per site, occurring in the first event hour. These impacts were much higher than cooler event days. Generally, hotter days with high system loads experienced the greatest impacts.
2023 events focused on CAISO market integration and locational dispatch. There was wide geographic variation in the event dispatch from CAISO, with most events called in hotter parts of the service territory.	Due to CAISO wholesale market integration, impacts were mostly driven by the temperature within the CAISO sub-LAPs in which participants were dispatched. While there was significant participation throughout the PG&E service territory, the largest concentration of participants resided in South Bay area. Those who delivered the largest impacts resided in the Central Valley and Sierras areas.

Key Finding	Additional Detail
The demand reduction is largest when temperatures are hottest, but the magnitude of the reduction decays across the event period	Over 90% of the variation in dispatchable demand reduction is explained by weather, the number of hours into the event, and the hour of the day. The biggest driver is the number of hours into the event. No matter the weather conditions or the event start time, we observed decay in the reduction over the event duration. The second-largest driver is the weather. The thermostats deliver larger demand reduction when temperatures are hotter.
For sites with automated daily shifting, the overall demand reduction is split into two distinct components – the daily shifting – and the event-based load reduction over and above the daily response.	Both the automated daily shifting and the event-based response are due to thermostat control. The combined total of the two components – daily shifting and incremental event-based response – is equivalent to the event impacts for sites without automated daily shifting. However, neither vendor nor PG&E receive capacity credits for technology enabled daily shifting.
The daily shifting algorithms effectively automated the response around the correct TOU peak hours	The thermostats correctly automated the daily load shifting for sites with 4-9 pm and 5-8 pm peak periods.