Portland General Electric
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November 21, 2022

Via Electronic Filing

Public Utility Commission of Oregon
201 High Street, S.E., Suite 100
P.O. Box 1088
Salem, OR 97308-1088

Re: UM 2141: Cadmus' Evaluation of PGE's Smart Thermostat Program Winter 2020/2021, Summer 2021, and Winter 2021/2022 Seasons for the BYOT and Direct Installation Channels

Enclosed is the evaluation of Portland General Electric Company's (PGE's) Direct Load Control Thermostat Pilot (DLCT) for the Winter 2020/2021, Summer 2021, and Winter 2021/2022 seasons. PGE contracted with a third-party evaluator, Cadmus, to evaluate the load impacts and customer experience[1] of both the Bring-Your-Own-Thermostat (BYOT) and Direct Install (DI) delivery channels of the DLCT Pilot. These offerings are tariffed in PGE's Schedule 5. Previous DLCT and BYOT evaluations were filed in UM 1708.

Key findings:

Cadmus's evaluation found that by April 2022, PGE had acquired approximately 4.2 MW of winter demand response capacity and 23.83 MW of summer demand response capacity[2] from the combined DI and BYOT channels.

When comparing the evaluated seasons to prior seasons, Cadmus found the pilot's recent savings performance was lower and noted several contributing factors, including an Intelligent Demand Response (IDR) dispatch experiment and the heat dome event in summer 2021 and warmer event temperatures in winter 2020/2021 and 2021/2022.

PGE's DLCT Pilot customer satisfaction rating was high but decreased by eight percentage points in summer 2021 over the previous summer. Cadmus attributed this drop to fewer customers feeling comfortable during events.

The evaluation also contains the results of the Pilot's test of pre-event email notifications in summer 2021. Although Cadmus found pre-event notifications reduced event overriding by two to six percentage points, they did not affect demand savings because avoided overrides occurred during the second half of events when demand savings are smaller. Ninety-eight percent of respondents found the notifications useful and wanted to continue receiving them.

[1] Customer experience was evaluated for summer 2021 season only.
[2] Based on per participant kW impacts for seasons evaluated in this report multiplied by participants enrolled in each season as of April 2022.

In response to program evaluation report requests #7 and #8 in Order 15-203, the Pilot undertook the following activities:

- In summer 2021, the Pilot ran an experiment to determine if a more consistent load reduction across event hours could be achieved using an IDR dispatch strategy that staggered event start times between customer groups. Cadmus found IDR did achieve a more consistent load reduction, but also reduced the average savings across event hours. No significant difference was found in satisfaction and comfort between IDR and standard treatment.
- Cadmus analyzed event overriding behavior and rates among pilot participants in summer 2021. The report finds override rates averaged between 15 and 21 percent in winter and 22 and 31 percent in summer and most overriding occurs in the first event hour. Cadmus reports customer characteristics and changes in thermal comfort were strong predictors, but much overriding behavior remains unexplained.

Key recommendations from the Cadmus evaluation and Pilot team updates:

- Provide customers with tips to stay comfortable during demand response events. **Update:** The Pilot is working to integrate tips into its communications.
- Work with DRMS provider to improve customer comfort and increase savings during events. **Update:** The Pilot is exploring dispatch strategies that increase comfort.
- Consider running another pre-event notification experiment with varying messaging options. **Update:** The pilot rolled out pre-event notifications to all participants in summer 2022 and will evaluate the results as part of the next evaluation.
- Consider evaluating demand savings among more customer segments and marketing the pilot more to those with the highest savings potential. **Update:** The Pilot is exploring pilot specific segmentation.

If you have any questions or require further information, please contact Megan Stratman at megan.stratman@pgn.com. Please direct all formal correspondence or requests to the following e-mail address pge.opuc.filings@pgn.com.

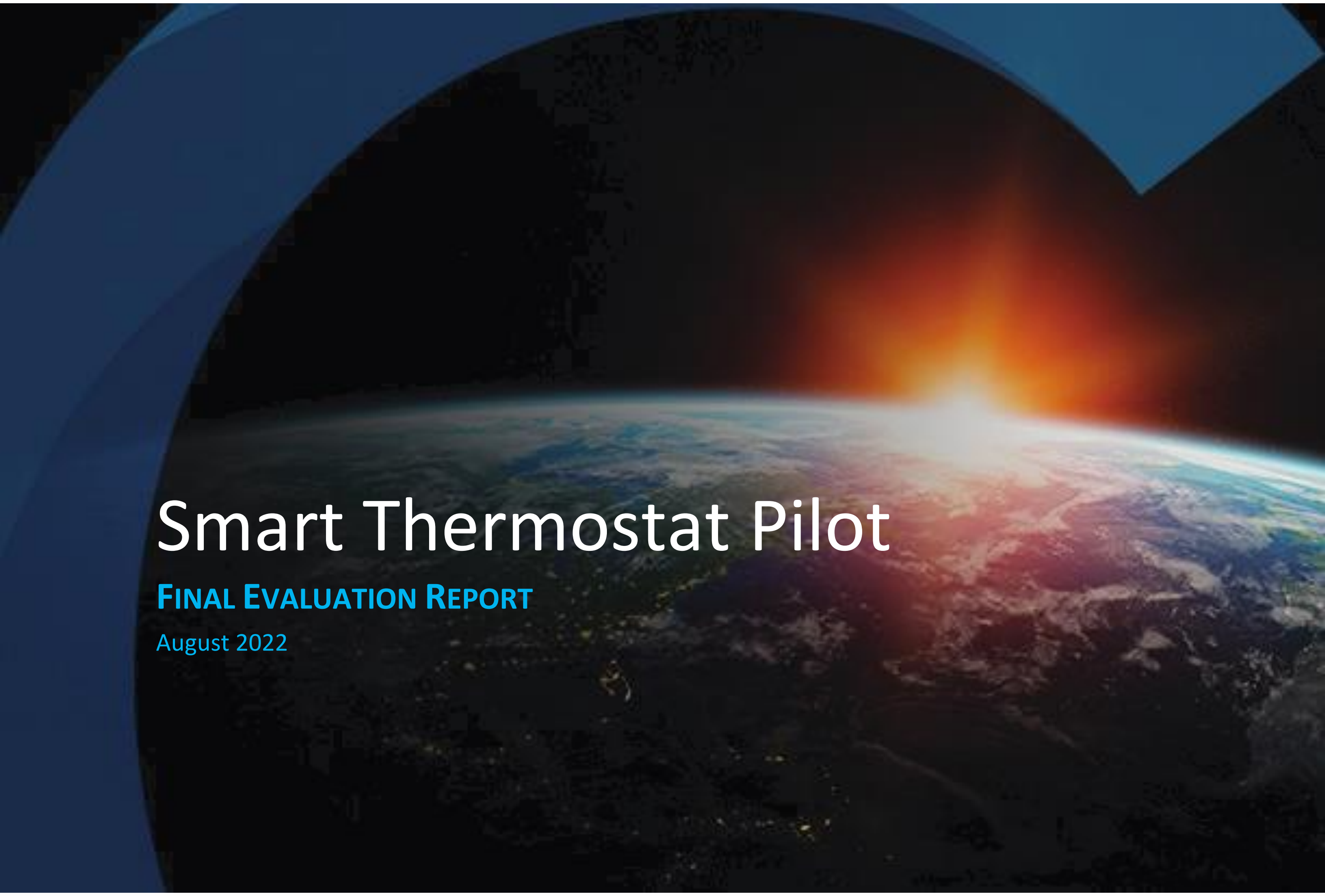
Sincerely,

/s/ *Jaki Ferchland*
Jaki Ferchland
Manager, Revenue Requirement

Enclosure

cc: UM 1708 and UM 2141 Service Lists
Nick Sayen, OPUC

CADMUS



Smart Thermostat Pilot

FINAL EVALUATION REPORT

August 2022

Prepared for:

Portland General Electric

121 Southwest Salmon Street

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Acronyms, Terms, and Definitions

Acronym/Term	Definition
AMI	Advanced metering infrastructure
BYOT	Bring-Your-Own Thermostat
Event Override	Occurs when a customer overrides the control of the thermostat by the demand response management service provider by adjusting the thermostat settings. PGE loses the ability to control the HVAC equipment for the remainder of the event.
Heat dome	Extreme weather event between Friday, June 25, 2021 and Wednesday, June 30, 2021 affecting Portland, Oregon and the Pacific Northwest. Maximum daily temperatures in Portland, Oregon reached 108°F on Saturday, June 26, 112°F on Sunday, June 27, and 116°F on Monday, June 28. PGE called a Smart Thermostat event on Monday.
HVAC	Heating, ventilation, and air conditioning
IDR	Intelligent demand response. IDR is control strategies designed to achieve specific grid operations or customer experience objectives such as achieving delivery of a constant level of demand savings, maximizing greenhouse gas emissions reductions, or maximizing customer thermal comfort during events.
Indicative Temperature	A PGE-designated temperature threshold (which is at or above 90°F in the summer and at or below 32°F in the winter) that may trigger a demand response event.
ITT	Intent to treat treatment effect. The average kilowatt impact per enrolled customer (or other relevant outcome) for customers that the pilot intends to treat with thermostat demand response.
kW	Kilowatt
kWh	Kilowatt-hour
Matched comparison group	PGE customers with smart thermostats who have not enrolled in the Smart Thermostat pilot and were matched to participants with similar demand for electricity on non-event days. The electricity demand of the matched comparison group provided a baseline for measuring the demand response event impacts.
Micro-segment	Five PGE customer segments used to characterize residential customer peak time rebate demand response savings potential: Big Impactors, Fast Growers, Middle Movers, Borderliners, and Low Engagers. See *Appendix C* for additional descriptions.
MW	Megawatt
OEM	Original equipment manufacturer
OLS	Ordinary least squares
PGE	Portland General Electric
Participant group	Enrolled customers who received the thermostat control signals during demand response events.
THI	Temperature-humidity index
TOT	Treatment effect on the treated. This is the average impact per treated customer.

Executive Summary

Through the Smart Thermostat pilot, Portland General Electric (PGE) manages residential customers' ducted space-conditioning electricity demand during summer and winter demand response events. PGE's demand response management service provider remotely adjusts the thermostat setpoints of thousands of participating customers to increase electricity demand during a pre-conditioning phase before the events begin and to reduce electricity demand during the events.[1]

PGE launched the Bring-Your-Own-Thermostat (BYOT) track of the Smart Thermostat pilot in 2015. Customers who already owned a smart thermostat were and remain eligible to participate in this track. In 2018, PGE expanded eligibility by launching Direct Install, offering customers a free or discounted smart thermostat device with complimentary installation from a technician to remove the barriers of the hardware cost, installation cost, and the difficulty of self-installation. In 2022, PGE ceased enrolling customers in Direct Install and plans to transition the pilot to a single-track, full-scale program within the next several years and to begin the process of integrating the program with grid operations.[2]

Cadmus evaluated the performance of the BYOT and Direct Install tracks during winter 2020/2021, summer 2021, and winter 2021/2022. This report provides results from the evaluation including demand savings performance metrics to give PGE grid operators confidence in the capabilities of this product as a capacity resource. PGE initiated three smart thermostat demand response events in winter 2020/2021, eight events in summer 2021, and three events in winter 2021/2022. All events lasted three hours. This evaluation is different than previous ones in that (1) it assesses some significant innovations in the pilot delivery intended to improve the customer experience and to accelerate the transition of the pilot to program status; and (2) it also seeks to gain insights about customer behaviors during events by analyzing thermostat telemetry data and participant survey data. In summer 2021, PGE tested the delivery of pre-event notifications with the objective of improving the customer experience, which will help with customer retention. PGE also tested an IDR dispatch strategy with the objective of achieving a constant level of demand savings, i.e., "flattening the savings shape," across event hours. In winter 2021/2022, PGE tested evening demand response. The IDR and winter evening tests were conducted to better understand the demand response grid services capabilities of smart thermostats, which will be necessary before PGE can integrate the pilot with its grid operations. PGE seeks insights about customer

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[1] PGE has demand response goals of 141 MW in the winter and 211 MW in the summer by 2025. Portland General Electric. July 19, 2019. *Integrated Resource Plan*. Filed with the Oregon Public Utility Commission. https://edocs.puc.state.or.us/efdocs/HAA/lc73haa162516.pdf

[2] To be eligible to participate, customers must have a central air conditioner, ducted heat pump, or electric forced-air furnace HVAC system; and have a working Wi-Fi network in the home. Customers with a ducted heat pump can participate in both the winter and summer seasons. Customers with an electric forced-air furnace and central air conditioner can also participate in both seasons. Customers with only a central air conditioner can only participate in the summer season, and customers with only an electric forced-air furnace can only participate in the winter season. For participating in at least 50% of the event hours during a season, BYOT customers receive a $25 bill credit at the end of the season. Direct Install customers do not receive a $25 bill credit.

behaviors from analysis of telemetry data that it can use to increase demand savings and improve the customer experience during events.

Through panel regression analysis of individual-customer hourly advanced metering infrastructure (AMI) meter data, interviews with pilot staff, and customer surveys, Cadmus assessed the BYOT and Direct Install load impacts before, during, and after the load control events; the pilot delivery; the customer experience, including customer thermal comfort, event overriding behaviors, and satisfaction; and the impacts of the pre-event notifications and IDR. In addition, Cadmus analyzed smart thermostat telemetry data to gain insights about customer overriding behaviors during demand response events.

Savings Performance

Table 1 presents demand response event savings for winter 2020/2021, summer 2021, and winter 2021/2022 and the customer satisfaction findings from summer 2021.[3] In winter, the hourly demand savings per participant home averaged 0.69 kW and 0.51 kW for the 2020/2021 and 2021/2022 seasons, respectively. In summer, the pilot achieved average demand savings per participant of 0.63 kW, and 78% of customers were satisfied with the pilot. Since some participants in the summer 2021 season were randomly assigned to participate in the pre-event notification and IDR experiments, Table 1 also displays average demand savings for customers who did not participate in those experiments and received the standard demand response event dispatch treatment (0.68 kW).

Table 1. Demand Savings and Satisfaction Results

	Winter 2020/2021	Summer 2021	Winter 2021/2022
Savings [a]			
Planned savings (kW)	1.2	1.0	1.1
Evaluated savings (kW)	**0.69**	**0.63**	**0.51**
Evaluated savings for participants who did not participate in IDR or pre-event notification experiments (kW)	N/A	**0.68**	N/A
Evaluated savings for events meeting indicative temperature threshold (kW) [b]	N/A	**0.70**	N/A
Evaluated savings for events meeting indicative temperature threshold (kW) for participants who did not participate in IDR or pre-event notification experiments (kW) [c]	N/A	**0.76**	N/A
Satisfaction [d]			
Satisfied (rating of 6 through 10)	N/A	78%	N/A
Delighted (rating of 9 or 10)	N/A	36%	N/A

[a] Savings values equal the average kilowatt demand reduction per participant home during events; **blue** font indicates significance at the 5% level.

[b] This row excludes the June 28, 2021 extreme heat dome event and includes all summer 2021 participants.

[c] This row excludes the June 28, 2021 extreme heat dome event.

[d] Satisfaction values are based on respondents' post-event program satisfaction rating on a 0- to 10-point rating scale.

[3] Cadmus and PGE did not administer participant surveys in the winter 2020/2021 or winter 2021/2022 seasons.

Table 1 also shows the average demand savings per participant home for demand response events with weather conditions that met the indicative temperature thresholds. Indicative temperature thresholds refer to PGE-designated temperatures that may trigger a demand response event. These were a minimum of 90°F in summer and a maximum of 32°F in winter. In summer 2021, all except one event were temperature indicative. In winter 2020/2021 and winter 2021/2022, no events were temperature indicative.

Table 2 shows key pilot savings performance metrics by event hour for winter 2020/2021, summer 2021, and winter 2021/2022. Winter metrics are based on all winter events because none met the temperature threshold (32°F or below). Summer metrics only include events that met the temperature indicative threshold (90°F or above) except the June 28 extreme heat dome event. Cadmus calculated the average savings per participant based on impact estimates for participants who received standard demand response and did not receive pre-event notifications. We calculated the pilot megawatt savings based on total enrolled participants. Load impacts as a percentage of metered baseline demand are shown in parentheses.

Table 2. Smart Thermostat Performance Metrics

Key Metrics		Winter 2020/2021	Summer 2021	Winter 2021/2022	
				Morning Events	Evening Events
Number of Events Used in Calculating the Metric		3	6	1	2
Average Savings per Participant (kW)	Event Hour 1	0.97 (29%)	1.11 (36%)	0.66 (25%)	0.54 (21%)
	Event Hour 2	0.66 (20%)	0.73 (23%)	0.48 (20%)	0.54 (18%)
	Event Hour 3	0.45 (15%)	0.44 (14%)	0.36 (16%)	0.47 (16%)
Pilot Savings (MW)	Event Hour 1	5.3	31.7	4.7	3.9
	Event Hour 2	3.6	20.9	3.4	3.8
	Event Hour 3	2.5	12.5	2.6	3.4

Notes: No winter 2020/2021 or winter 2021/2022 events were temperature indicative, but Cadmus calculated metrics based on impact estimates from all events in each season. Summer 2021 metrics exclude the September 9 event, which was not temperature indicative, and the June 28 extreme heat dome event, which Cadmus considers an outlier. Summer 2021 per-participant savings are based on impact estimates from participants who received standard demand response and did not receive pre-event notifications; however, Cadmus calculated pilot megawatt savings based on total enrolled participants, which indicates the savings the pilot would have delivered if all participants received standard demand response. Savings as a percentage of baseline demand are shown in parentheses.

Pilot Demand Response Capacity

As of April 2022, PGE had enrolled 32,289 total customers in the pilot, comprising approximately 933 winter-eligible, 25,178 summer-eligible customers, and 6,178 customers eligible to participate in both seasons.[4] Using this evaluation's estimates of per-participant demand savings for summer and winter, PGE possesses approximately 4.20 MW of winter demand response capacity and 23.83 MW of summer demand response capacity from the Smart Thermostat pilot. These capacity values reflect the average savings across all event hours and therefore include savings degradation after the first event hour.[5]

Conclusions

This evaluation of the Smart Thermostat pilot confirms many of the high-level take-aways from previous evaluations, including that the pilot is effective at reducing peak demand and that customers remain satisfied with the pilot. However, the evaluation also drew new conclusions related to the IDR and notifications experiments and the analysis of the thermostat telemetry data.

PGE's Smart Thermostat pilot reduced residential heating and cooling loads, though the pilot's recent savings performance was lower than in previous seasons due to IDR testing in summer 2021 and warmer event temperatures in winter 2021/2022. The pilot averaged demand savings per participant of 0.69 kW in winter 2020/2021, 0.63 kW in summer 2021, and 0.51 kW in winter 2021/2022. The lower savings in winter 2021/2022 was likely due to warmer event temperatures than in the previous winter and the calling of evening instead of morning events as in previous winters. The lower savings in summer 2021 than summer 2020 (0.85 kW) were attributable to the extreme heat dome event on June 28, 2021 and the implementation of IDR among some participants. When the summer 2021 impact analysis was limited to temperature-indicative events and participants who received the standard demand response control strategy, demand savings averaged 0.76 kW per participant. This savings estimate is closer to but remains statistically different from the savings estimate for temperature indicative events in summer 2020 (0.86 kW).

IDR flattened smart thermostat savings and pre-event notifications reduced overrides, but more testing and refinement of these strategies are needed. During summer 2021, PGE tested the impacts of an IDR control strategy and pre-event notifications on overriding, demand savings, and satisfaction. Pre-event notifications reduced overriding but did not increase savings because avoided overrides tended to

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[4] Enrollments reflect the number of actively enrolled customers as of April 2022. We excluded customers who had unenrolled from the program in these counts.

[5] To calculate demand response system capacity, Cadmus used the average demand savings per enrolled thermostat across all event hours for each season (0.59 kW averaged across winter 2020/2021 and winter 2021/2022 and 0.76 kW in summer 2021, the evaluated savings during temperature indicative events for participants who did not participate in the IDR or pre-event notification experiments). Though we used this straightforward average, demand response resources have many potential uses and capacity can be calculated for events that are triggered for specific outside temperatures, PGE system load, or market condition thresholds, or for subpopulations or at different durations and dispatch times. PGE's demand response capacity depends on how it plans to use the resource.

occur toward the end of events. Cadmus did not detect any statistically significant differences in savings between participants who received a pre-event notification and those who did not, including during the last event hour. IDR flattened the event savings, but also reduced the average savings across event hours. During the experiment (events 3 through 8), IDR savings per participant averaged 0.56 kW while standard demand response savings per participant averaged 0.75 kW. Respondents who received IDR were just as satisfied and comfortable as those who did not receive the IDR treatment. Most respondents liked receiving the pre-event notification emails and would like to continue receiving those emails, but the notifications did not make a statistically significant difference in their program satisfaction.

Smart thermostats provided less demand response savings at extreme temperatures in summer 2021. PGE achieved smaller demand savings during the extreme heat dome event (0.43 kW per participant) on June 28, 2021 than other summer 2021 events. Possible explanations for the smaller savings during the extreme heat event are that some home cooling systems could not cool the home enough to bring the interior temperature to the thermostat setpoint and continued to run or that home cooling systems could maintain the temperature setpoint but the interior temperature of the home drifted rapidly upward after the setpoint adjustment.[6] Because there was only one extreme heat event, it is not possible to know if the lower savings were attributable to the extreme heat or another factor. Nonetheless, PGE grid operators should be mindful of the risk that this resource may provide less capacity at extreme temperatures. PGE also plans to review its expectations around load shifting during extreme heat events and will prioritize customer health and safety.

Customer satisfaction with the program remained high but decreased in summer 2021 due to fewer customers feeling comfortable during events. Program satisfaction decreased significantly from 86% in summer 2020 to 78% in summer 2021.[7] While the majority of respondents said they felt comfortable during a summer 2021 event, the season saw the biggest degradation in comfort to date. Respondents'

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6 Cadmus's analysis of participant thermostat telemetry data supports this hypothesis, showing there were only very small differences in thermostat temperature set points between the extreme heat dome event on June 28 and other events but that HVAC systems ran for longer during the extreme heat dome event. Also, despite the greater average run time, the average interior temperature of homes during the June 28 event remained two to three degrees above the average event-adjusted thermostat setpoint. In contrast, the 101°F event called on August 11, 2021, behaved more similarly to other events in terms of HVAC run time, and the average interior of the home was within one degree of the average target setpoint throughout most of the event. This suggests that during the extreme heat dome event the HVAC units of some participants could not provide enough cooling to bring the home interior temperature down to the adjusted set point, ran more than usual, and did not provide the expected demand savings.

7 These results were calculated using all smart thermostat participant survey responses. The 2018 results are for BYOT customers, the 2019 results are for BYOT and DI, the 2020 results are for DI customers, and the 2021 results are for BYOT and DI customers. When we restrict the analysis sample to DI customers, the same trends in customer satisfaction and comfort are evident. The percentages of DI customers satisfied were 92% in 2019, 86% in 2020, and 79% in 2021. The percentages of DI customers comfortable were 79% in 2019, 73% in 2020, and 62% in 2021.

self-reported thermal comfort before an event and during an event showed a statistically significant decrease of 27 percentage points. Results from a regression analysis show that customer satisfaction with the program depends strongly on comfort during the event. Summer 2021 was the hottest event season to date and the high temperatures could have contributed to lower comfort during the event, thus leading to lower program satisfaction. Another explanation could be customer fatigue with the program: PGE began the pilot in 2015 and most enrolled customers have experienced multiple event seasons. It is not known whether customer satisfaction changes the longer a customer is in the program and this could be a topic to explore in future evaluations.

Smart thermostat demand response savings varied by home size and HVAC equipment type. Customers with larger homes achieved higher demand response savings in both seasons. In summer, homes in the top size quartile delivered demand savings approximately twice as much as homes in the bottom quartile. Also, in summer, participants with central air conditioning delivered more savings than participants with heat pumps. In winter, there was no difference in savings between electric forced-air furnace homes and heat pump homes, but homes with heat pumps and electric back-up heat saved more than those with natural gas back-up heat. PGE could use information about differences in participant savings to market the program with more focus on the largest potential savers or to shape savings across demand response event hours.

Customer characteristics and changes in thermal comfort were strong predictors of overriding, but much overriding behavior is unexplained. During summer, adverse changes in thermal comfort during events (deviations in home interior temperature from normal setpoint by 3°F +) increased the probability of overriding by about 40 percent. Also, customer characteristics such as preferences for lower thermostat temperature set points increased the probability of overriding an event. But these factors only explain a small share of the variation between customers and across events in overriding behaviors.

Pre-event notifications did not affect smart thermostat demand savings but participants liked receiving the notifications. Based on analysis of AMI meter demand data and customer survey data from a randomized experiment, Cadmus found pre-event notifications issued the day of the event reduced the rate of overriding by between two and six percentage points depending on the event. Nevertheless, because overrides avoided by the notifications tended to occur toward the end rather than beginning of events, the notifications did not increase demand savings. Also, almost all survey respondents reported finding the pre-event notifications useful or very useful (98%) and wanted to continue receiving them (98%), though receiving the notifications did not increase their program satisfaction. These results suggest that there is no to little risk to PGE from continuing to send pre-event notifications to participants.

Recommendations

Based on the evaluation findings and conclusions, Cadmus has several recommendations.

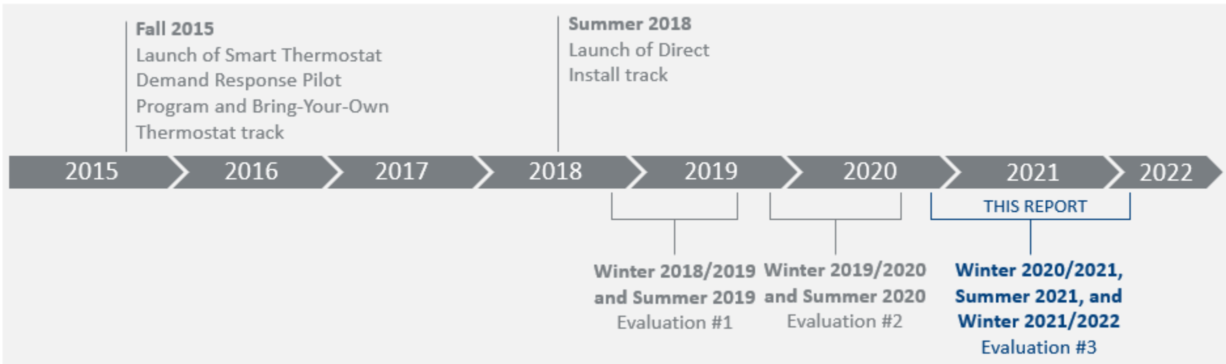
- **Provide customers with tips on ways to stay comfortable during demand response events.** PGE can use relevant tips from Peak Time Rebates and can embed these tips in the pre-event notifications and program welcome materials that customers receive after enrollment. This may reduce the incidence of overriding.
- **Work with Resideo on strategies to help improve customer comfort and increase savings during events.** PGE and Resideo could test different setback strategies, including customizing the event temperature setback for each home based on the efficiency of the home's thermal envelope, the customer's preference for comfort, and the customer's history of overriding events. For example, PGE could perform more aggressive pre-conditioning or less aggressive setback on high-frequency overriders.
- **Consider running another pre-event notification experiment with varying messaging options.** The pre-event notification randomized field experiment yielded several positive findings, including customers liked the notifications and the notifications reduced overriding, and several null findings, including pre-notifications did not affect savings or customer satisfaction. PGE could run another pre-event notification experiment with a larger population, testing the robustness of the findings from the first experiment or applying the messaging insights gained from the Smart Grid Test Bed evaluation to draft different notification messages or to vary the timing of the delivery of the messages.[8]
- **Consider evaluating demand savings among more customer segments and marketing the pilot more aggressively to those with the highest savings**. PGE can evaluate savings by additional customer characteristics (such as home age, household size, and geographic location) to gain a better understanding of customers with the highest savings potential. Targeting these groups for enrollment could improve the pilot's cost-effectiveness.

[8] Portland General Electric. March 31, 2022. "Smart grid Test Bed Project Final Evaluation Report." Filing to The Public Utility Commission of Oregon. https://edocs.puc.state.or.us/efdocs/HAE/um1976hae155256.pdf

Evaluation Objectives and Approach

As Figure 1 shows, this Smart Thermostat pilot evaluation covers the BYOT and Direct Install tracks during the winter 2020/2021, summer 2021, and winter 2021/2022 seasons.

Figure 1. Timeline of Smart Thermostat Pilot and Evaluation



PGE specified six objectives for the evaluation:

1. Estimate the average kilowatt impact per participant home before, during, and after the load control events
2. Identify the determinants of demand response savings such as weather conditions and customer characteristics
3. Assess the impacts of participation on customer satisfaction with the program and with PGE
4. Assess the impacts of pre-event notifications and IDR on demand savings, overriding behavior, and customer experience
5. Identify factors influencing event overriding behavior
6. Identify opportunities to improve pilot delivery, pilot performance, cost-effectiveness, and customer experience

Table 3 shows the schedule of load control events that PGE initiated during the previous three seasons. PGE called three events both winter 2020/2021 and winter 2021/2022 and eight events in summer 2021. Each event lasted three consecutive hours and occurred on a weekday (non-holiday) afternoon or morning, typically when PGE system electricity demand was high due to customer heating or cooling. Event days tended to occur on the coldest days in winter and hottest days in summer.

Table 3. Load Control Events

Season	Event	Date	Average Outdoor Temperature (°F) [a]	Start Time	Duration (hours)	Met Indicative Temperature Threshold [b]
Winter 2020/2021	1	1/26/2021	35	7:00 a.m.	3	N
	2	2/3/2021	38	7:00 a.m.	3	N
	3	2/10/2021	34	7:00 a.m.	3	N
Summer 2021	1	6/21/2021	93	5:00 p.m.	3	Y
	2	6/28/2021	109	5:00 p.m.	3	Y
	3	7/29/2021	96	5:00 p.m.	3	Y
	4	7/30/2021	91	5:00 p.m.	3	Y
	5	8/4/2021	95	5:00 p.m.	3	Y
	6	8/11/2021	101	5:00 p.m.	3	Y
	7	8/13/2021	94	5:00 p.m.	3	Y
	8	9/9/2021	82	5:00 p.m.	3	N
Winter 2021/2022	1	1/27/2022	40	5:00 p.m.	3	N
	2	2/2/2022	40	7:00 a.m.	3	N
	3	2/23/2022	35	5:00 p.m.	3	N

[a] The average outdoor temperature is based on the temperature recorded at the National Oceanic and Atmospheric Administration weather station nearest to participants' homes.

[b] The term "indicative temperature" refers to a PGE criterion to designate temperature thresholds that may trigger demand response events. These are set at or above 90°F in the summer and at or below 32°F in the winter.

Each demand response event has two phases: (1) a pre-conditioning phase, when the smart thermostat initiates extra space heating or cooling during the one hour leading up to the event; and (2) an event temperature setback phase, during which the temperature setting on the thermostat is adjusted by one to three degrees to reduce electricity demand for space heating and cooling during the event. Customers can opt out of an event at any time by adjusting the thermostat settings or hitting the event cancel button.

Table 4 lists the evaluation activities and how they mapped to the research objectives. *Appendix A* presents more details about the matched comparison group selection, the panel regression analysis, telemetry data analysis, and process evaluation activities including the staff interviews, and customer surveys.

Table 4. Evaluation Activities

Activity	Description	Corresponding Evaluation Objective(s)	Outcome
Research Design	Quasi-experimental (all enrolled customers received event treatments). Matched comparison customers were selected from nonparticipants with smart thermostats and eligible HVAC equipment.	1, 2, 4	Accurate and precise estimates of impacts
Data Collection and Preparation	Collect and prepare analysis of individual customer AMI meter interval consumption data.	1, 2, 4	Final analysis sample for estimation of load impacts
Load Impact Analysis	Regression analysis of individual customer AMI meter interval consumption data.	1, 2, 4	Estimates of event demand impacts
Overriding Analysis	Summary statistics and regression analysis of participant-level thermostat telemetry data.	5	Understanding of overriding frequency and characteristics of participants who override
Staff Interviews	Interviews with PGE and implementation pilot staff to understand pilot implementation processes, successes, and challenges.	6	Thorough understanding and documentation of the pilot design and implementation
Customer Surveys	Summer 2021 event surveys with customers.	3, 4, 5	Findings on customer event awareness, thermal comfort, override behavior, and satisfaction

Evaluation Findings

This section presents evaluation findings from the Smart Thermostat pilot and is organized according to the following topics:

- Pilot delivery
- Load impacts
- Implementation experiments
- Overriding analysis
- Customer experience
- Future changes and consideration

Pilot Delivery

Using information gathered from the staff interviews and pilot tracking data, Cadmus assessed the Smart Thermostat pilot's delivery. Several key findings emerged.

From a pilot management perspective, the pilot operated as expected and quickly resolved issues. PGE called three events during winter 2020/2021, eight events during summer 2021, and three events during winter 2021/2022. PGE reported that Resideo and CLEAResult met their implementation expectations for all three seasons, and that it was satisfied with both implementation contractors' management. PGE and Resideo reported only one issue with the first summer event, when customers with a heat pump accidentally did not receive an event dispatch on their smart thermostat; this was corrected in time for the second event. CLEAResult reported a supply chain issue with an original equipment manufacturer (OEM), which was resolved by gap-filling with a different OEM's thermostats.

PGE implemented abundant marketing activities and nearly met its 2021 enrollment goal. In 2021 alone, PGE enrolled approximately 13,578 new thermostats, the most ever in a single year. By the end of 2021, PGE had enrolled 34,102 total thermostats, almost meeting its 2021 enrollment goal of 34,714 thermostats.[9] Three percent of participants were winter-only customers, 78% were summer-only customers, and 19% were dual-season customers.

The winter storm of February 2021, which caused widespread power outages throughout PGE's service territory, halted all marketing activities for six weeks. PGE resumed in-person direct installs during the middle of 2021 as cases of the COVID-19 Delta variant began to spike.[10] These two unexpected challenges did not impact recruitment, as PGE employed multiple marketing efforts throughout the year (via OEMs' direct customer outreach, special promotions, an enrollment incentive increase, and KGW news segments) and had virtual install as a backup for direct installs.

Throughout the year, PGE also leveraged enrollment at thermostat point-of-sale on its online Marketplace and leveraged OEM promotions to its customers in PGE territory for the BYOT track. PGE

9 Some participants enrolled multiple thermostats in the pilot. A total of 32,289 homes were enrolled in the pilot as of April 2022.

10 PGE implemented COVID-19 specific safety protocols for Direct Install to protect the health of customers and installers.

also cited the importance of the Energy Trust smart thermostat incentive in driving smart thermostat adoption and therefore increasing the population eligible to participate in the pilot.

Table 5 shows active enrollments during the winter 2020/2021, summer 2021, and winter 2021/2022 seasons. In particular, the increase in enrollments between winter seasons appears to have come from BYOT and the PGE's Marketplace.

Table 5. Enrollment by Season and Type of HVAC System

Category	BYOT	Marketplace	Direct Install	Virtual Install	Total
Winter 2020/2021 Enrollments					
Electric Forced Air	308	6	566	24	904
Heat Pump	2,314	38	2,142	76	4,570
Total	**2,622**	**44**	**2,708**	**100**	**5,474**
Summer 2021 Enrollments					
Air Conditioning	17,304	2,354	3,084	400	23,142
Heat Pump	2,827	276	2,148	127	5,378
Total	**20,131**	**2,630**	**5,232**	**527**	**28,520**
Winter 2021/2022 Enrollments					
Electric Forced Air	441	156	586	46	1,229
Heat Pump	3,228	401	2,161	106	5,896
Total	**3,669**	**557**	**2,747**	**152**	**7,125**

Notes: A participant is identified by the unique combination of Service Agreement ID and Service Premise ID. Enrollments reflect the number of households that participated in at least one event in the season.

The Direct Install track will be discontinued primarily because it was not cost-effective. PGE reported that despite attempts to improve this track's cost-effectiveness, Direct Install was not cost-effective. Additionally, PGE said that new enrollments via Direct Install have declined significantly over the last two years and customers are confused by the differences between the delivery tracks and the incentives they provide. As of June 1, 2022, PGE no longer enrolls customers via Direct Install and will keep the current Direct Install participants in the pilot. By discontinuing Direct Install, PGE expects the cost-effectiveness and customer experience of the Smart Thermostat pilot to improve.

Summer 2021 formed valuable implementation learnings from the extreme heat dome event. PGE and Resideo reported that the one extreme heat event (on June 28, 2021) produced the lowest load shift of the season but was still impactful. Both parties explained that during extreme heat, the cooling system could not reach the desired setpoint and continued to run, thus never cycling off and offering less available load to shift. Based on the results of this evaluation, PGE will review its expectations around load shifting during extreme heat events, will prioritize customer health and safety, and will emphasize in future customer communications that event participation is the customer's choice and that their health and safety comes first.

Load Impacts

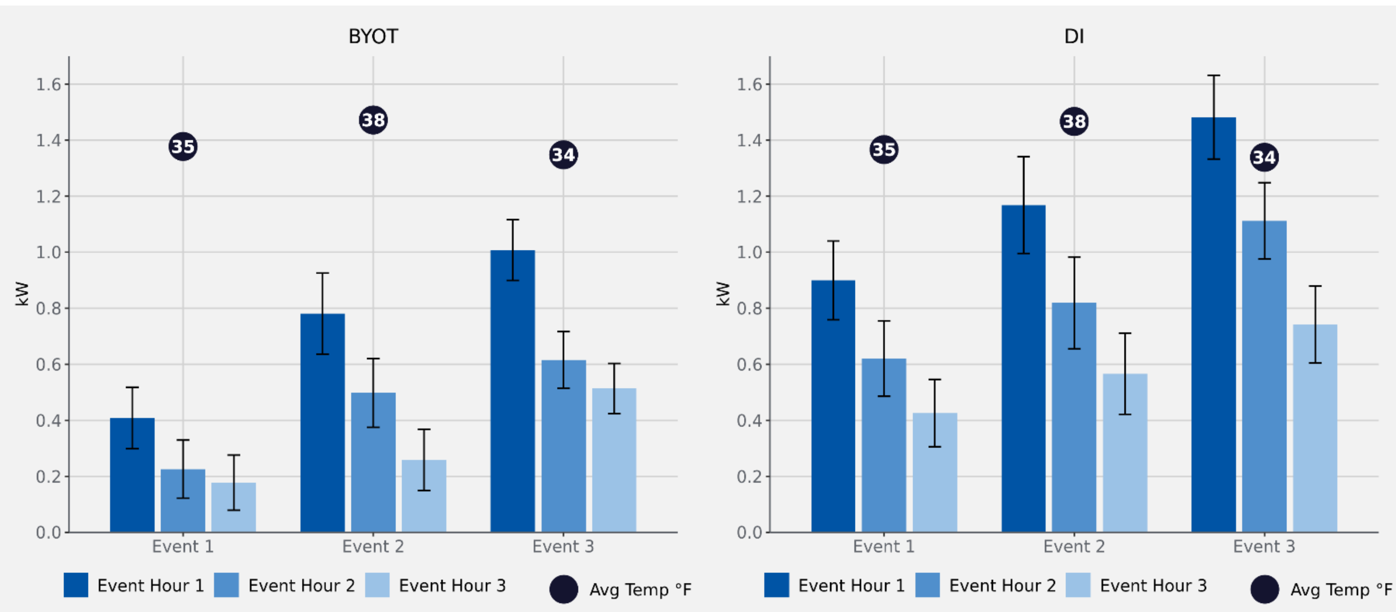
Cadmus assessed the pilot load impacts by pilot track and season, with the main findings below.

Winter 2020/2021

PGE called three events in the winter 2020/2021 season. All events began at 7:00 a.m. and lasted three hours. None of the events met the temperature threshold criteria for calling events (the maximum temperature forecasted for event hours is 32°F).

Figure 2 shows the average demand savings per participant home by event hour for winter 2020/2021. The average temperature during the event hours is also displayed. During Event 1, 45% of thermostats did not receive the temperature setback signal and thus failed to dispatch. Savings per participant home were highest in Hour 1, ranging between 0.4 kW and 1.0 kW for BYOT customers and between 0.9 kW and 1.5 kW for Direct Install customers. All hourly savings estimates were statistically significant at the 5% level.

Figure 2. Demand Savings by Event and Event Hour – Winter 2020/2021

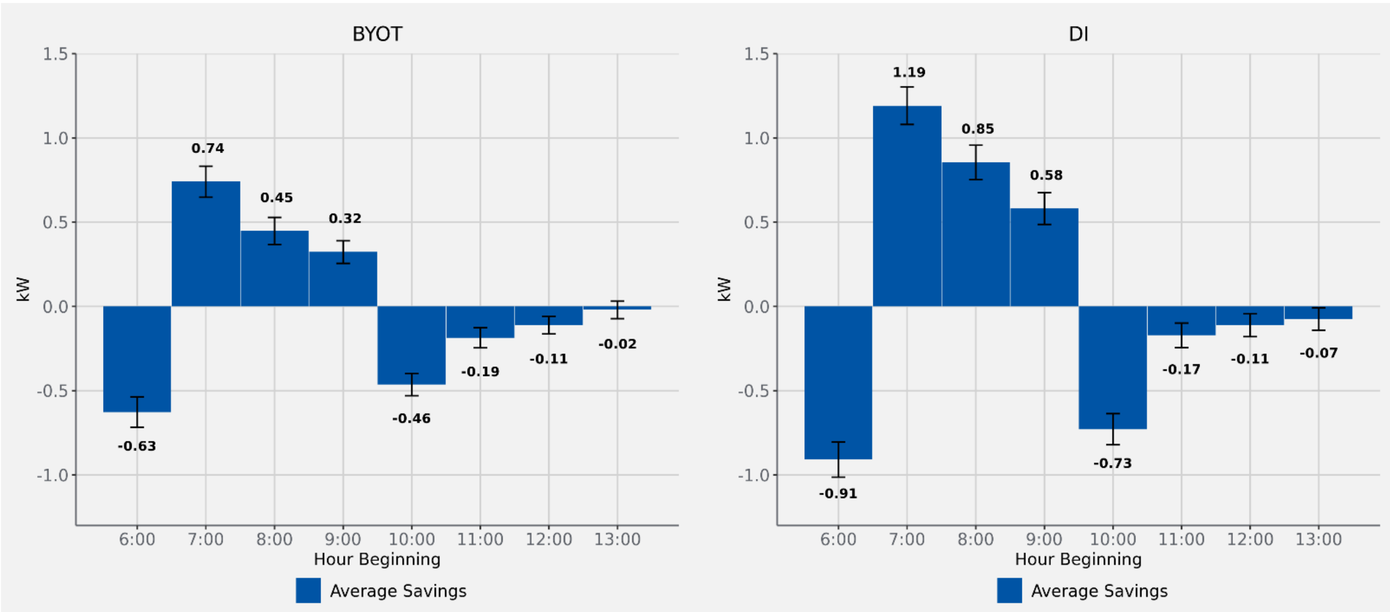


Notes: All events started at 7:00 a.m. and ended at 10:00 a.m. During Event 1, 45% of thermostats dispatched did not receive the temperature setback signal. None of the events met the temperature indicative threshold of 32°F. Estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars show 90% confidence intervals.

In winter 2020/2021, Direct Install participants had higher demand savings than BYOT participants. This difference could be due to home age: BYOT has higher proportion of newer homes, which likely have higher thermal efficiency and can therefore better shift heating loads.

Figure 3 shows the pre-conditioning, event, and post-event demand impacts for winter 2020/2021 demand response events. On average, preconditioning during the hour immediately preceding the event increased electricity demand by 0.6 kW and 0.9 kW per participant home for BYOT and Direct Install, respectively. Snapback in the first hour after the event concluded also increased demand by 0.5 kW for BYOT and 0.7 kW for Direct Install. After accounting for preconditioning and snapback effects, each event reduced daily energy consumption, as shown by the larger total area above than below the x axis.

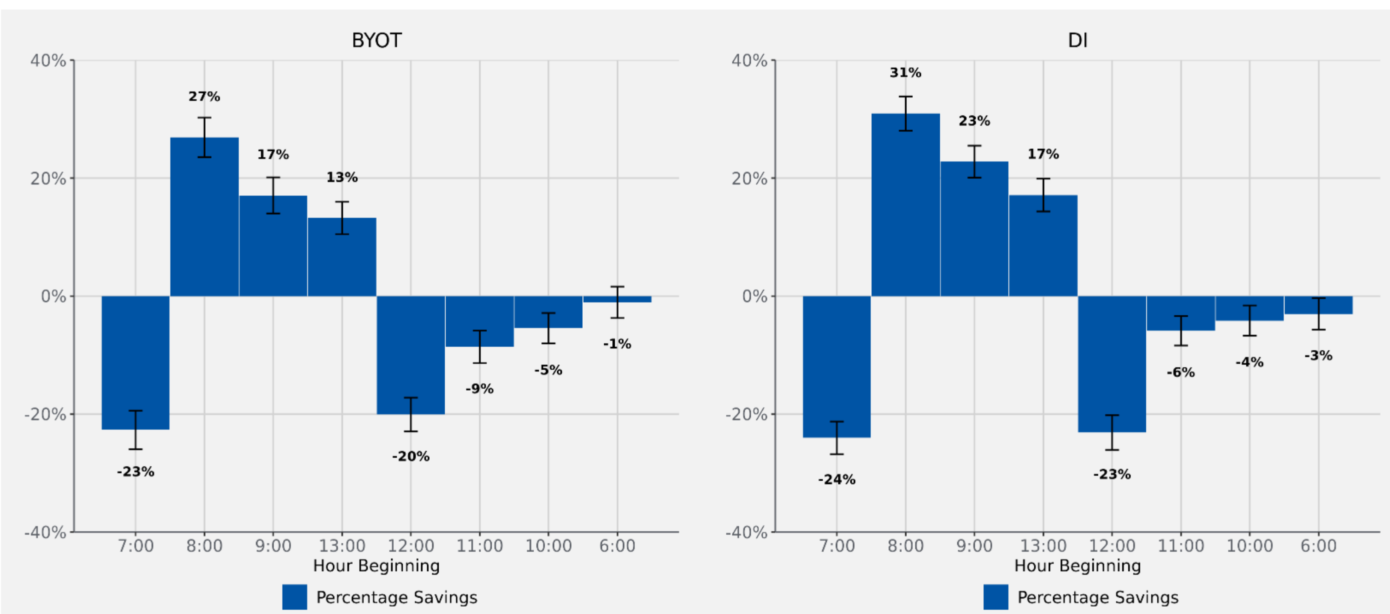
Figure 3. Average Demand Savings (kW) – Winter 2020/2021



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars show 90% confidence intervals based on standard errors clustered on homes.

Figure 4 shows the demand impacts as a percentage of baseline demand. Savings during the first event hour were 27% for BYOT customers and 31% for Direct Install customers. In the last event hour, savings as a percentage of baseline demand decreased to 13% and 17% for BYOT and Direct Install, respectively.

Figure 4. Percentage Demand Savings – Winter 2020/2021



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars indicate 95% confidence intervals based on standard errors clustered on homes. Percentage demand savings was calculated as kilowatt savings divided by baseline demand.

Table 6 shows the evaluated megawatt savings for the winter 2020/2021 events. Cadmus estimated the megawatt savings by multiplying the average demand savings per participant by the number of enrolled participants on the day of the event. For BYOT, the evaluated total savings ranged from 0.7 MW to 1.9 MW. For Direct Install, the evaluated total savings ranged from 1.8 MW to 3.1 MW. The differences across events are driven by weather and event dispatch failures; during Event 1, 45% of thermostats did not receive the temperature setback signal.

Table 6. Total Demand Savings (MW) – Winter 2020/2021

Track	Event	Average Temperature (°F)	Evaluated Average Savings Per Participant Per Event (kW)	Analysis Sample		Enrolled Participants	Evaluated Demand Savings (MW)
				Treatment Customers	Matched Comparison Customers		
BYOT	1	35	0.27	2,535	1,710	2,558	0.7
	2	38	0.51	2,553	1,710	2,576	1.3
	3	34	0.71	2,642	1,712	2,666	1.9
	Average	**36**	**0.50**	**2,577**	**1,711**	**2,600**	**1.3**
Direct Install	1	35	0.65	2,749	1,529	2,763	1.8
	2	38	0.85	2,755	1,529	2,769	2.4
	3	34	1.11	2,794	1,529	2,808	3.1
	Average	**36**	**0.87**	**2,766**	**1,529**	**2,780**	**2.4**
Pilot Total		**36**	**0.69**	**5,343**	**3,240**	**5,380**	**3.7**

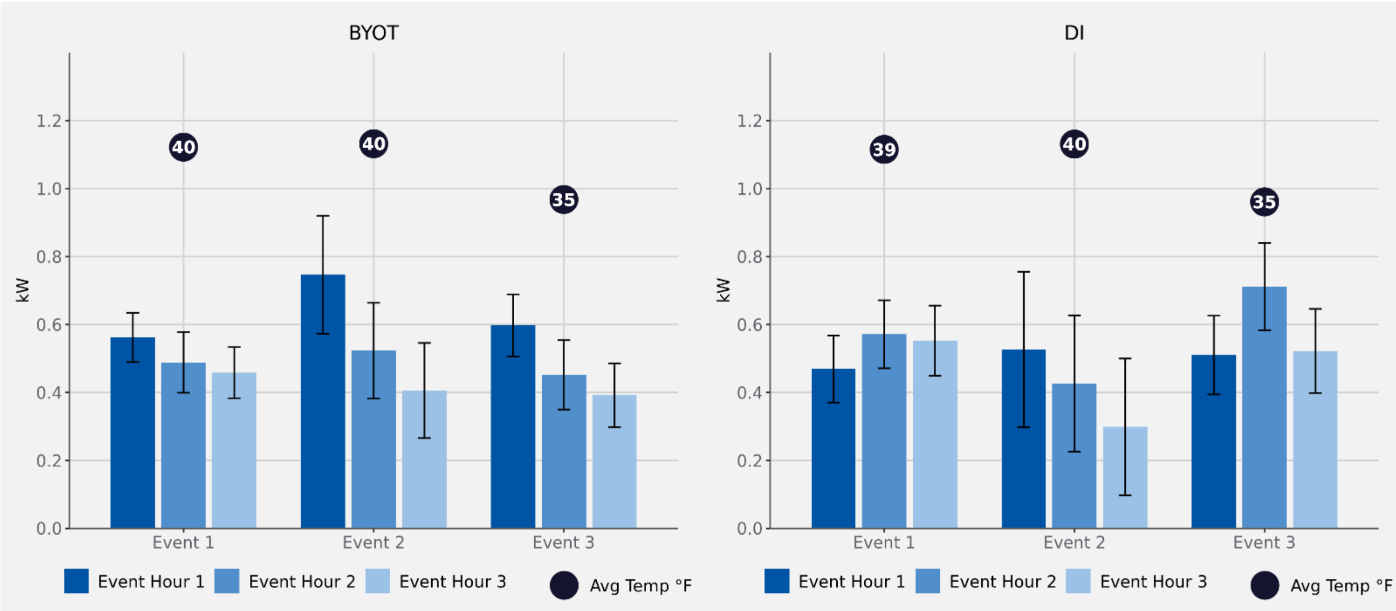
Notes: All events occurred between 7:00 a.m. and 10:00 a.m. Cadmus calculated evaluated demand savings by multiplying the average per-participant savings by the number of enrolled participants. During Event 1, 45% of thermostats dispatched did not receive the temperature setback signal. None of the events met the temperature indicative threshold of 32°F.

Winter 2021/2022

During the winter 2021/2022 season, PGE ran two evening events that started at 5:00 p.m. and one morning event that started at 7:00 a.m.; all events were three hours long. PGE had not called an evening event in winter in several years and ran the two 5:00 p.m. events to test the pilot's current evening demand response capacity. None of the events were temperature indicative.

Figure 5 shows the average demand savings per participant home for each event hour in winter 2021/2022. BYOT demand savings followed the typical pattern in which the highest savings per participant home were achieved during the first hour followed by lower savings in each successive event hour. Direct Install savings followed this trend during the morning event (Event 2), but during the evening events savings were highest in the second event hour. All hourly savings estimates were statistically significant at the 5% level. BYOT and Direct Install participants achieved similar demand savings on average across all winter 2021/2022 event hours.

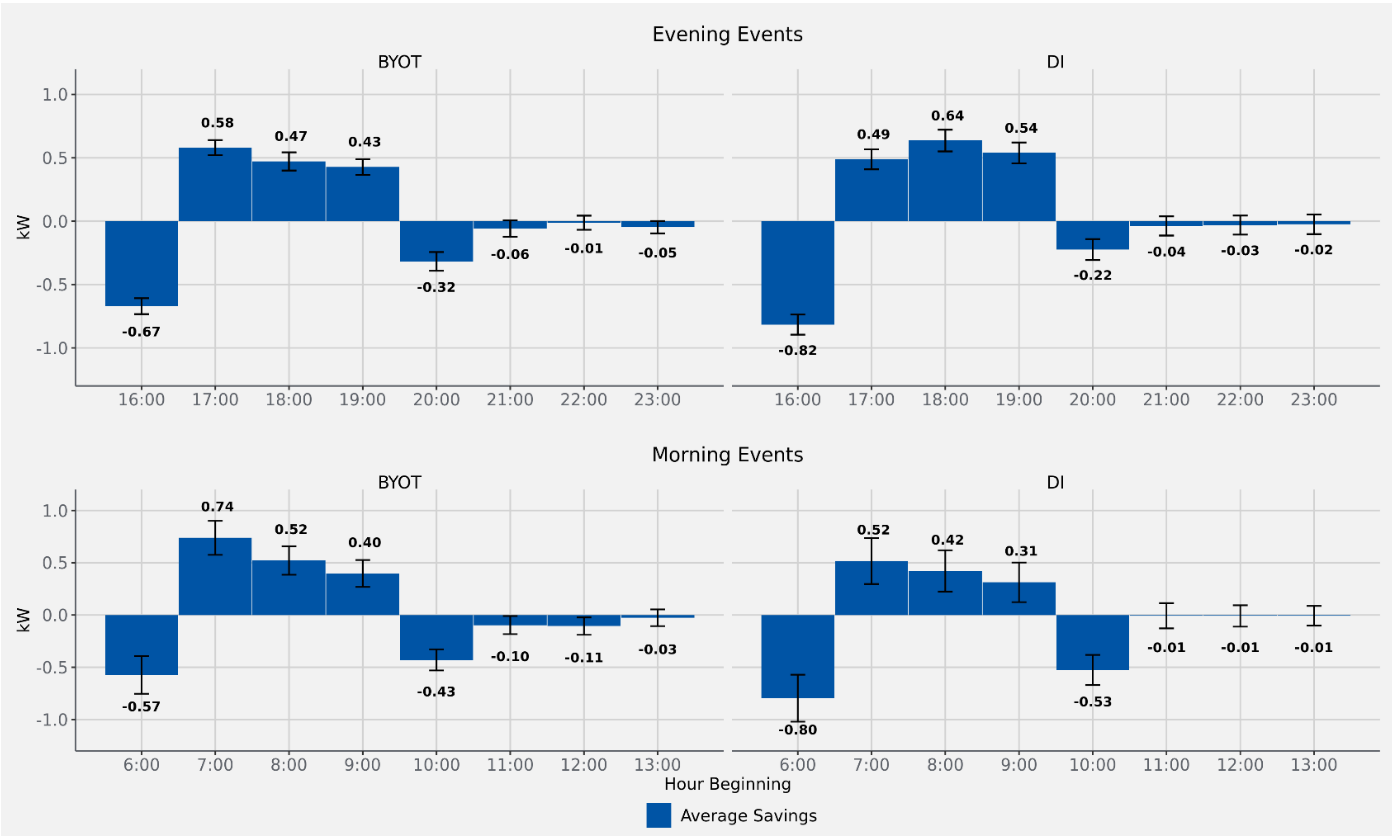
Figure 5. Demand Savings by Event and Event Hour – Winter 2021/2022



Notes: Events 1 and 3 started at 5:00 p.m. and ended at 8:00 pm. Event 2 began at 7:00 a.m. and ended at 10:00 a.m. None of the events met the temperature indicative threshold of 32°F. These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars show 90% confidence intervals. Average temperatures may differ slightly between BYOT and DI participants because the averages are calculated using the temperature at the weather station closest to each home and the spatial distribution of BYOT and DI homes across PGE's service area differs.

Figure 6 shows the average demand savings before, during, and after winter 2021/2022 demand response events by enrollment track and the timing of the event (morning versus evening). Preconditioning increased electricity demand by between 0.6 kW and 0.7 kW per participant home for BYOT customers, and by 0.8 kW for Direct Install customers. Snapback in the first post-event hour increased demand by 0.3 kW to 0.4 kW for BYOT and by 0.2 kW to 0.5 kW for Direct Install. After accounting for preconditioning and snapback effects, the events led to a small net decrease in energy consumption, evident from the larger impact area above the x-axis compared to below the x-axis.

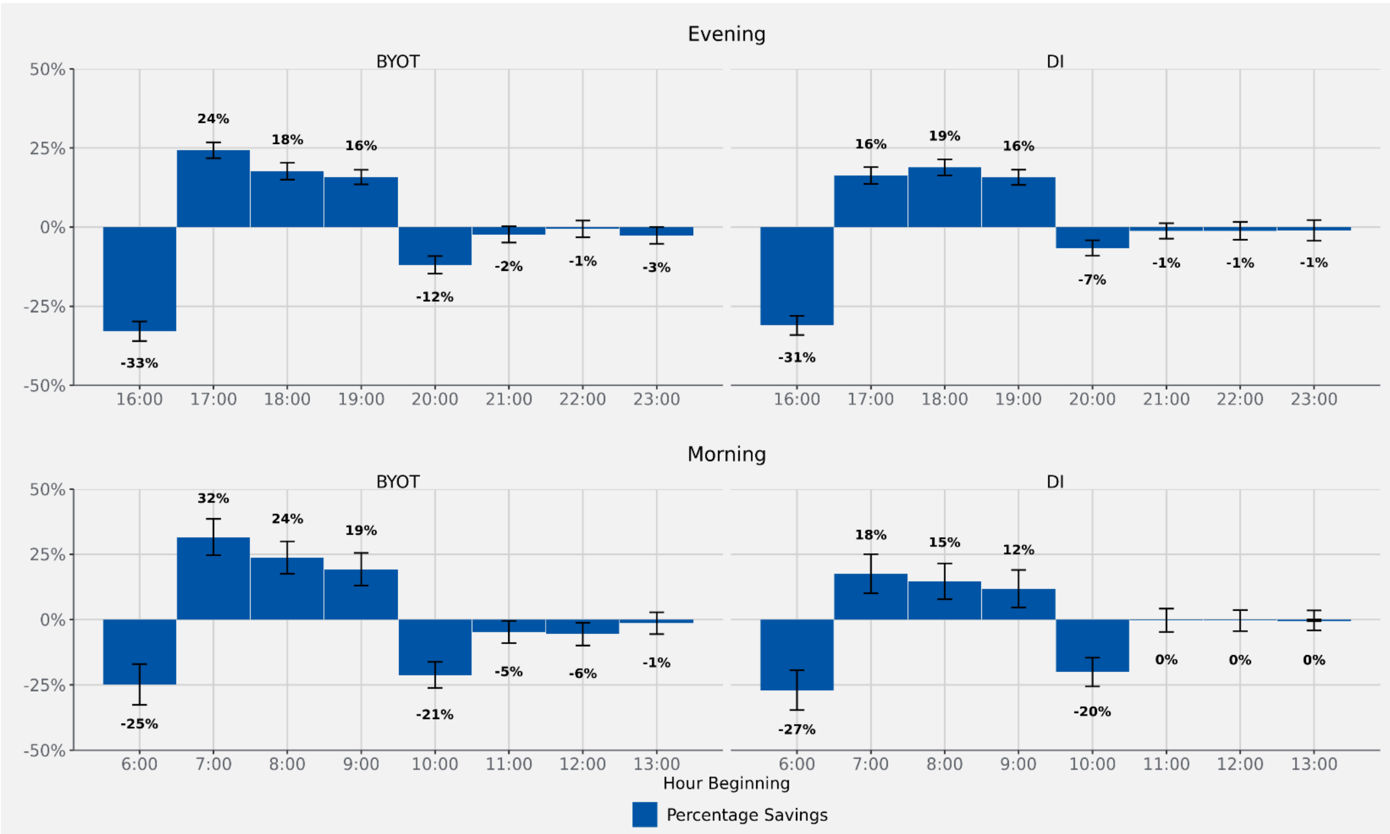
Figure 6. Average Demand Savings (kW) – Winter 2021/2022



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars show 90% confidence intervals based on standard errors clustered on homes.

Figure 7 shows the demand impacts as a percentage of baseline demand. Hour 1 savings for BYOT participants ranged from 24% to 32% and decreased to 16% to 19% in the last event hour. In evening events, Direct Install participant savings remained stable throughout the event (16% in both the first and last event hour). In the morning event, Direct Install participant savings fell from 18% in the first event hour to 12% in the last event hour.

Figure 7. Percentage Demand Savings – Winter 2021/2022



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars indicate 95% confidence intervals based on standard errors clustered on homes. Cadmus calculated the percentage demand savings as kilowatt savings divided by baseline demand.

Table 7 shows the evaluated megawatt savings for the winter 2021/2022 events. For BYOT, the evaluated total savings ranged between 2.0 MW and 2.3 MW. For Direct Install, total savings ranged from 1.2 MW to 1.7 MW.

Table 7. Total Demand Savings (MW) – Winter 2021/2022

Track	Event	Average Temperature (°F)	Evaluated Average Savings Per Participant Per Event (kW)	Analysis Sample		Enrolled Participants	Evaluated Demand Savings (MW)
				Treatment Customers	Matched Comparison Customers		
BYOT	1	40	0.50	4,040	2,203	4,040	2.0
	2	40	0.56	4,046	2,195	4,046	2.3
	3	35	0.48	4,141	2,202	4,141	2.0
	Average	**38**	**0.51**	**4,076**	**2,200**	**4,076**	**2.1**
Direct Install	1	39	0.53	2,863	749	2,863	1.5
	2	40	0.42	2,858	747	2,858	1.2
	3	35	0.58	2,866	749	2,866	1.7
	Average	**38**	**0.51**	**2,862**	**748**	**2,862**	**1.5**
Pilot Total		**38**	**0.51**	**6,938**	**2,948**	**6,938**	**3.6**

Notes: Events 1 and 3 started at 5:00 p.m. and ended at 8:00 pm. Event 2 began at 7:00 a.m. and ended at 10:00 a.m. Cadmus calculated the evaluated demand savings by multiplying the average per-participant savings by the number of enrolled participants. None of the events met the temperature indicative threshold of 32°F.

Winter Performance Metrics

Table 8 reports key performance metrics for winter residential smart thermostat demand response based on the winter 2020/2021 and winter 2021/2022 evaluations. Typically, these metrics would be based on temperature-indicative events (32°F or below); however, as no events in either season met this threshold, the metrics are based on all events in these seasons. These performance metrics are intended to help PGE system operators better understand the demand response capabilities of smart thermostats.

Table 8. Pilot Performance Metrics – Winter 2020/2021 and Winter 2021/2022

Key Metrics		Winter 2020/2021			Winter 2021/2022					
		BYOT	Direct Install	Pilot Average	BYOT		Direct Install		Pilot Average	
					Morning Event	Evening Events	Morning Event	Evening Events	Morning Event	Evening Events
Number of Events		3	3	3	1	2	1	2	1	2
Average Savings (kW)	Event Hour 1	0.74 (27%)	1.19 (31%)	0.97 (29%)	0.75 (32%)	0.58 (24%)	0.53 (18%)	0.49 (16%)	0.66 (25%)	0.54 (21%)
	Event Hour 2	0.45 (17%)	0.85 (23%)	0.66 (20%)	0.52 (24%)	0.47 (18%)	0.43 (15%)	0.64 (19%)	0.48 (20%)	0.54 (18%)
	Event Hour 3	0.32 (13%)	0.58 (17%)	0.45 (15%)	0.41 (20%)	0.42 (16%)	0.3 (11%)	0.54 (16%)	0.36 (16%)	0.47 (16%)
Minimum Savings (kW)	Event Hour 1	0.41 (14%)	0.90 (22%)	0.66 (19%)	0.75 (32%)	0.56 (24%)	0.53 (18%)	0.47 (16%)	0.66 (25%)	0.52 (20%)
	Event Hour 2	0.23 (8%)	0.62 (16%)	0.43 (13%)	0.52 (24%)	0.45 (16%)	0.43 (15%)	0.57 (18%)	0.48 (20%)	0.50 (17%)
	Event Hour 3	0.18 (7%)	0.43 (12%)	0.30 (10%)	0.41 (20%)	0.39 (14%)	0.3 (11%)	0.52 (14%)	0.36 (16%)	0.44 (14%)
Maximum Savings (kW)	Event Hour 1	1.01 (35%)	1.48 (37%)	1.25 (36%)	0.75 (32%)	0.60 (25%)	0.53 (18%)	0.51 (17%)	0.66 (25%)	0.56 (21%)
	Event Hour 2	0.62 (23%)	1.11 (28%)	0.87 (26%)	0.52 (24%)	0.49 (19%)	0.43 (15%)	0.71 (20%)	0.48 (20%)	0.58 (19%)
	Event Hour 3	0.51 (20%)	0.74 (21%)	0.63 (21%)	0.41 (20%)	0.46 (18%)	0.3 (11%)	0.55 (17%)	0.36 (16%)	0.50 (17%)
Average Savings Degradation (difference from previous hour savings) (kW)	Event Hour 1 to Event Hour 2	-0.29 (-39%)	-0.33 (-28%)	-0.31 (-32%)	-0.22 (-30%)	-0.11 (-19%)	-0.1 (-19%)	0.15 (31%)	-0.17 (-26%)	0.00 (-1%)
	Event Hour 2 to Event Hour 3	-0.13 (-29%)	-0.27 (-32%)	-0.20 (-31%)	-0.12 (-22%)	-0.05 (-10%)	-0.13 (-30%)	-0.1 (-16%)	-0.12 (-25%)	-0.07 (-13%)
Average Preconditioning (the hour before the event begins) (kW)		-0.62 (-22%)	-0.90 (-24%)	-0.77 (-23%)	-0.57 (-24%)	-0.67 (-33%)	-0.77 (-26%)	-0.82 (-31%)	-0.65 (-25%)	-0.73 (-32%)
Average Snapback (the hour after the event ends) (kW)		-0.47 (-20%)	-0.73 (-23%)	-0.60 (-22%)	-0.42 (-20%)	-0.32 (-12%)	-0.51 (-19%)	-0.22 (-7%)	-0.45 (-20%)	-0.28 (-9%)
Average Event Day Energy Savings (kWh)		0.12	0.77	0.45	0.58	0.45	-0.03	0.56	0.33	0.50

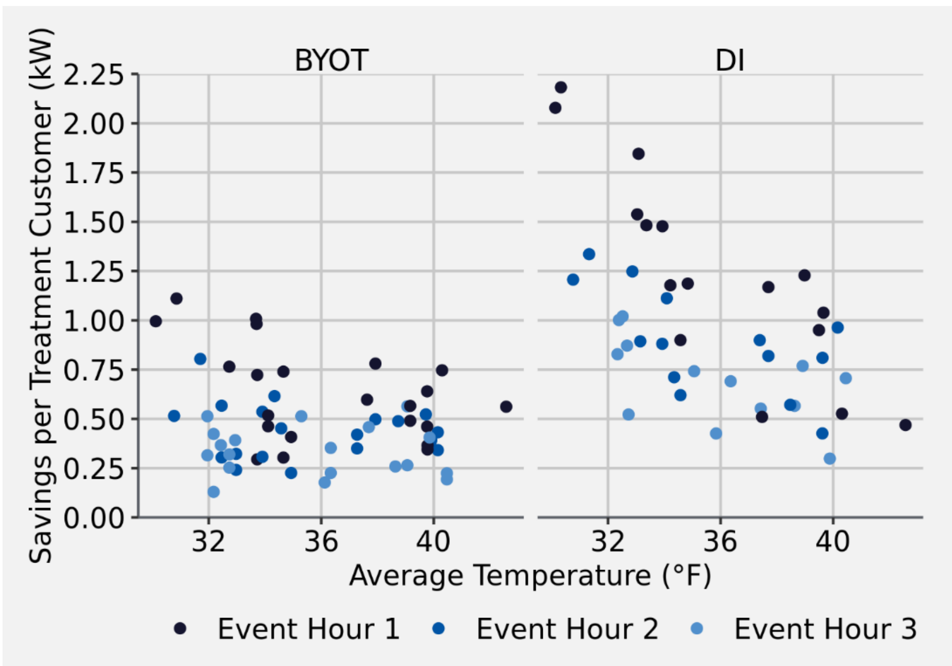
Notes: Average kilowatt savings are the average demand savings per participant home across event hours. Minimum and maximum kilowatt savings are the minimum and maximum of the average demand savings per participant home across event hours. Average savings degradation is the difference between the average savings per participant home in an event hour and the average savings in the previous hour. Average preconditioning is the average change in demand per participant home from preconditioning in the hour preceding the start of the event. Average snapback is the increase in demand per participant home in the first hour after the event ends. Average event day energy savings is the average change in energy consumption per participant home on event days. Load impacts as a percentage of baseline demand are shown in parentheses.

Winter Temperature Response

Home heating loads are driven by outside temperature, and it is expected that demand response savings potential will be higher on colder winter events. Understanding the relationship between demand response savings and outside temperature will be important for operationalizing thermostat demand response. Cadmus analyzed winter demand savings and weather data from 2018 to 2022 to estimate this relationship.

Figure 8 shows estimates of the average savings per participant plotted against outside temperature for event hours in the 2018/2019, 2019/2020, 2020/2021, and 2021/2022 winter seasons by enrollment track. Events are color-coded by the first, second, and third event hours since demand response savings tend to diminish over each event. As expected, the figure indicates an inverse relationship between savings and temperature, a relationship that appears stronger for participants enrolled in the Direct Install track. The relationship is strongest during the first and second event hours.

Figure 8. Winter Temperature Response



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data.

To investigate the temperature response relationship more rigorously, Cadmus ran ordinary least squares (OLS) linear regressions of event hour savings on hour-of-event indicator variables (Hour 1, Hour 2, and Hour 3), pilot year indicators (winter 2018/2019, winter 2019/2020, winter 2020/2021, and winter 2021/2022), and event hour temperature (Table 9). We ran separate models for each enrollment track. In winter, demand savings decreased by 0.044 kW per 1°F for Direct Install participants. The relationship between demand savings and temperature for BYOT was weaker and not statistically different from zero, possibly due to the inclusion of customers with natural gas heat in the 2018/2019 season. The estimated relationships between savings and temperature are valid for the range of temperatures observed in the previous four winters. The estimated relationships may not hold for temperatures outside this range.

Table 9. Temperature Response Regression Estimates

Season	Track	Weather Variable	Regression Coefficient with Standard Error	Adjusted R^2	N
Winter	BYOT	Temperature	-0.006 (0.007)	0.53	61
	Direct Install	Temperature	-0.044 (0.012)	0.80	43

Notes: Temperature response estimates are based on Cadmus' OLS regression analysis of event hour savings on hour-of-event indicator variables (Hour 1, Hour 2, and Hour 3), pilot year indicators (winter 2018/2019, winter 2019/2020, winter 2020/2021, and winter 2021/2022), and event hour temperature. N is the number of observations of event hour savings and temperature. Heteroskedasticity-robust standard errors are in parentheses.

Winter Impacts by Customer Segments

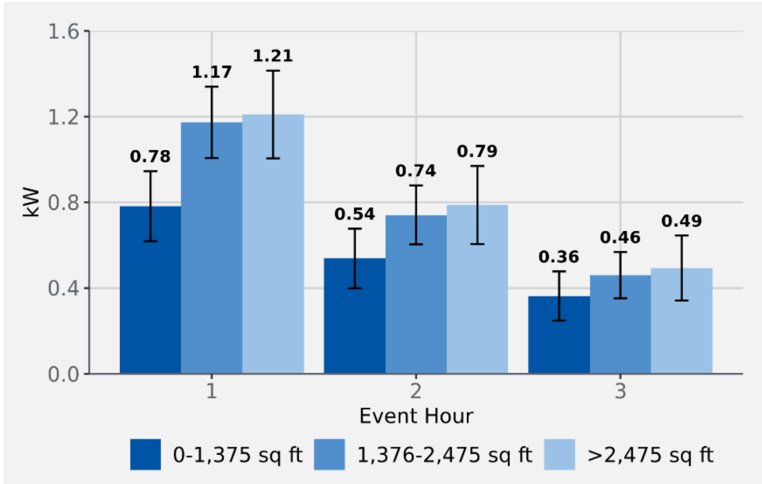
Cadmus estimated event impacts for different customer or home segments to determine whether the Smart Thermostat pilot savings varied in the population. PGE can use this information to target customer groups with a higher savings potential for enrollment. Enrolling larger numbers of such customers could improve the pilot cost-effectiveness.

Cadmus evaluated winter event impacts by HVAC equipment, backup heating fuel for customers with heat pumps, home size, and substation. Except for the substation analysis, we matched Smart Thermostat participants to nonparticipants with the same characteristics. For example, we matched participants with electric forced-air furnaces to nonparticipants with smart thermostats and electric forced-air furnaces. Then we ran a separate regression to estimate the impact of each characteristic (that is, using the previous example, we ran separate regressions for electric forced-air furnaces and heat pumps). For winter impacts, we included all events in the analysis.

The main takeaways from this analysis were:

1. Demand savings were higher for larger homes. Figure 9 displays the average demand savings per participant by home size (square footage) in each event hour for winter 2020/2021. Hour 1 savings for the largest quartile of homes were 55% larger than savings for the smallest quartile of homes.

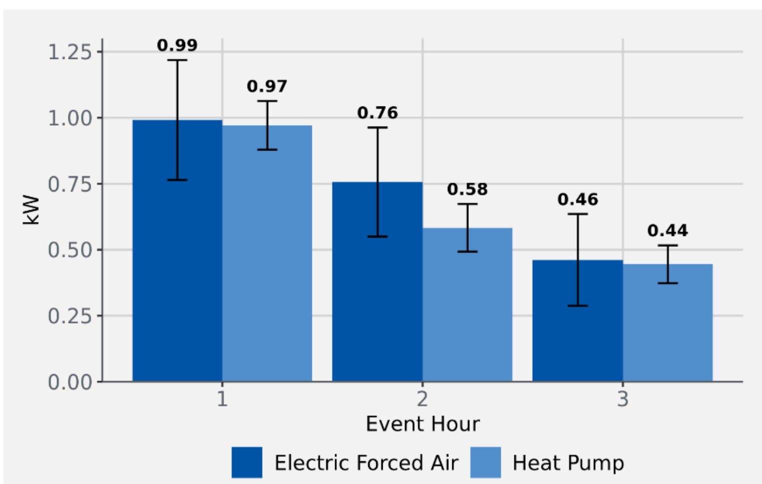
Figure 9. Demand Savings by Home Size – Winter 2020/2021



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars indicate 95% confidence intervals based on standard errors clustered on homes. The interquartile range of home sizes (25%-75%) is 1,376-2,475 square feet.

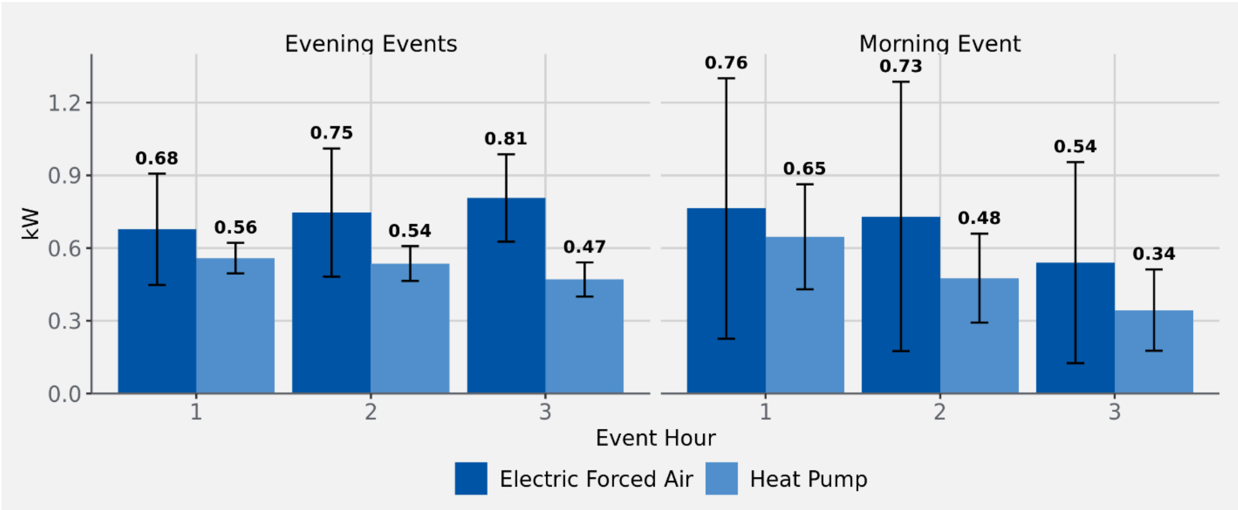
2. Electric forced-air furnace homes tended to save more than heat pump homes, but the differences were not statistically significant in most event hours. Average demand savings per participant by event hour and HVAC system are displayed for winter 2020/2021 in Figure 10 and for winter 2021/2022 in Figure 11. During evening events, electric forced-air furnace homes saved more than heat pump homes during the last event hour.

Figure 10. Demand Savings by HVAC Equipment – Winter 2020/2021



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

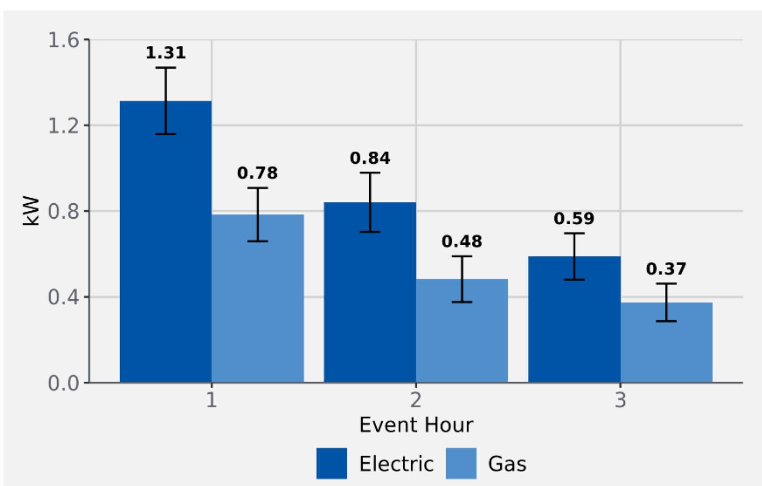
Figure 11. Demand Savings by HVAC Equipment – Winter 2021/2022



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

3. Heat pump homes with electric backup heat had higher demand savings than those with natural gas backup heat. For winter 2020/2021, Cadmus estimated impacts by backup heating fuel for customers with heat pumps. Figure 12 displays demand savings for participants by electric or natural gas backup heating fuel, showing that savings in Hour 1 were 68% higher for homes with electric backup heat.

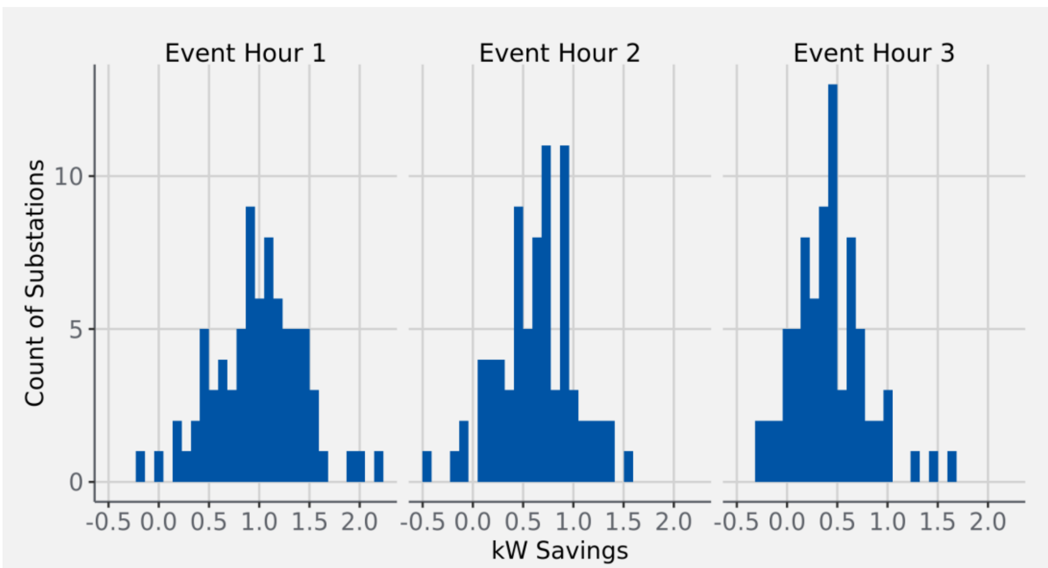
Figure 12. Demand Savings by Backup Heating Fuel for Homes with Heat Pumps – Winter 2020/2021



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

4. Smart thermostat demand savings per participant varied significantly between PGE substations. The distribution of substation demand savings is displayed in Figure 13 for winter 2020/2021 and in Figure 14 for winter 2021/2022. Each figure shows a histogram of substation average demand savings per participant by winter event hour for PGE substations with at least 30 enrolled participants. The x-axis shows different ranges (i.e., "bins") of average demand savings per participant and the y axis shows the count of substations in each range. For example, in the first hour of winter 2020/2021, substation demand savings are centered around 1 kW per participant, and in the second and third hours, the distribution shifts progressively towards zero, as the savings decrease. In winter 2020/2021, substation average savings in Hour 1 ranged from 0.28 kW to 2.21 kW per participant. During evening events in winter 2021/2022, the Hour 1 substation savings ranged from 0.27 kW to 1.34 kW per participant. In the winter 2021/22 morning event, the Hour 1 substation average savings ranged from 0.11 kW to 1.43 kW per participant.[11] The range of savings likely reflects differences between substations in the size, age, and heating equipment types of homes served by the stations. PGE may use substation-level estimates of demand savings to assess the potential benefits of smart thermostats for managing local distribution system electricity demand or to increase the program cost-effectiveness by marketing the smart thermostat program more aggressively to customers served by substations with large average savings per home. Cadmus provided PGE with a separate data file with substation savings estimates by event hour.

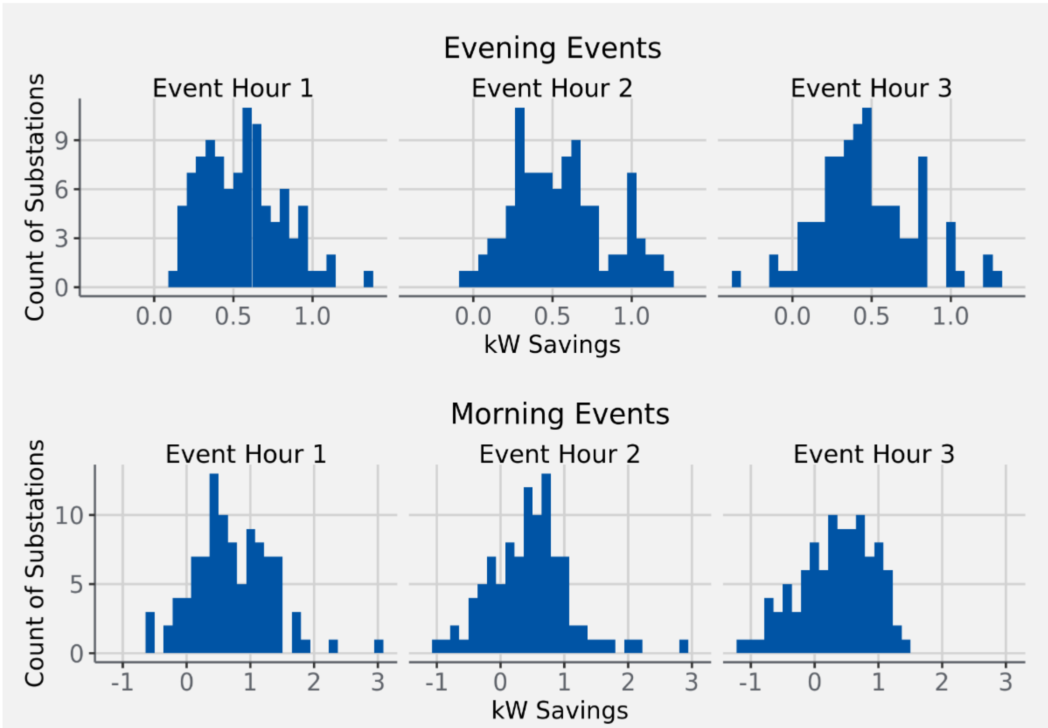
Figure 13. Distribution of Substation Demand Savings by Event Hour – Winter 2020/2021



Notes: The figures show histograms of substation average demand savings per participant by winter event hour for substations with at least 30 participants. These substation demand savings estimates are based on Cadmus' panel regression analysis of customer AMI data.

11 This result only includes substations with Hour 1 demand savings that were statistically significant at the 10% confidence level.

Figure 14. Distribution of Substation Demand Savings by Event Hour – Winter 2021/2022



Notes: The figures show histograms of substation average demand savings per participant by winter event hour for substations with at least 30 participants. The substation demand savings estimates are based on Cadmus' panel regression analysis of customer AMI data.

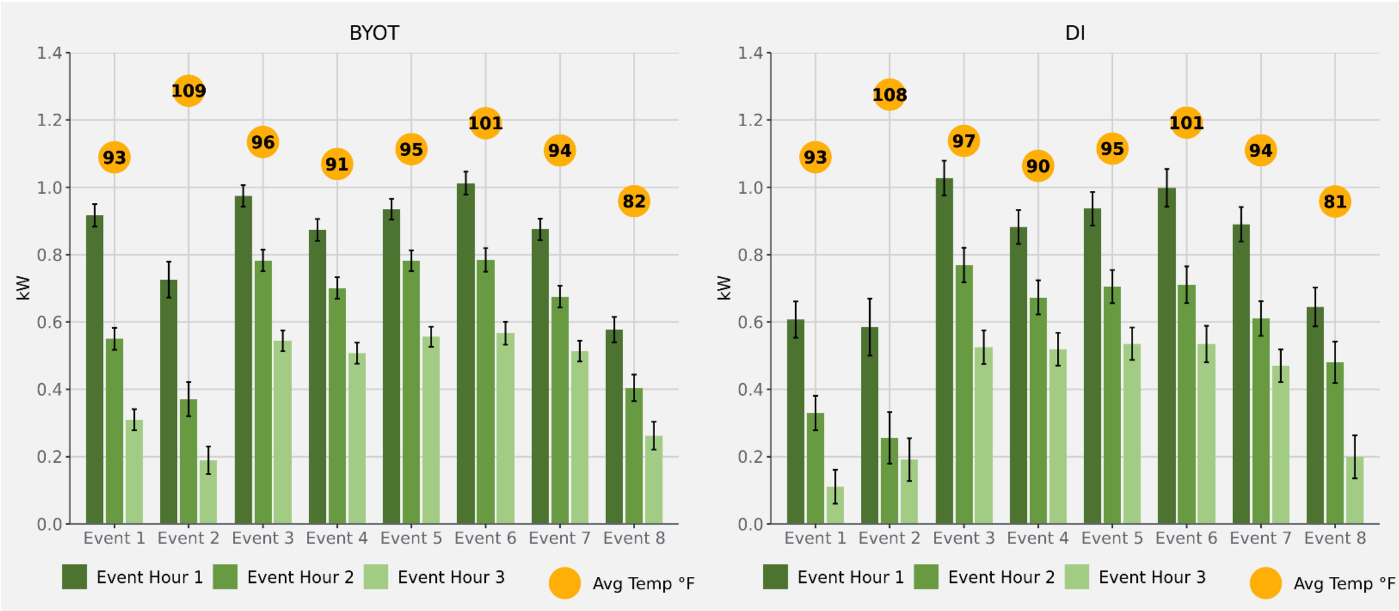
Summer 2021

During summer 2021, PGE dispatched eight demand response events. Each event was initiated on a non-holiday weekday at 5:00 p.m. and lasted three hours. Seven of the eight events were temperature indicative with event temperatures at or above 90°F, and one event occurred during extreme heat conditions, with event temperatures nearing 110°F. During Event 1, only thermostats controlling central air conditioners (80% of participants) were dispatched due to a communications glitch.

PGE ran two experiments during summer 2021 to test the impacts of sending pre-event notifications and IDR. PGE randomly assigned participants to one of three implementation groups: a treatment group that received pre-event notifications, a treatment group that received IDR event dispatches, and a control group that received standard demand response event dispatches (i.e., neither IDR nor pre-event notifications). Unless otherwise noted, the summer 2021 event impacts are estimated across all program participants (including all experiment treatment and control group homes) and thus reflect the impacts of the experiments on demand savings. The findings from the experiments are discussed below in the *Implementation Experiments* section.

Figure 15 shows the average kilowatt savings per participant home for each event hour by enrollment track during summer 2021 as well as the average temperature during each event. Demand savings were highest in the first event hour, then diminished over the remaining hours. Savings for all event hours were statistically significant at the 5% significance level.

Figure 15. Demand Savings by Event and Event Hour – Summer 2021

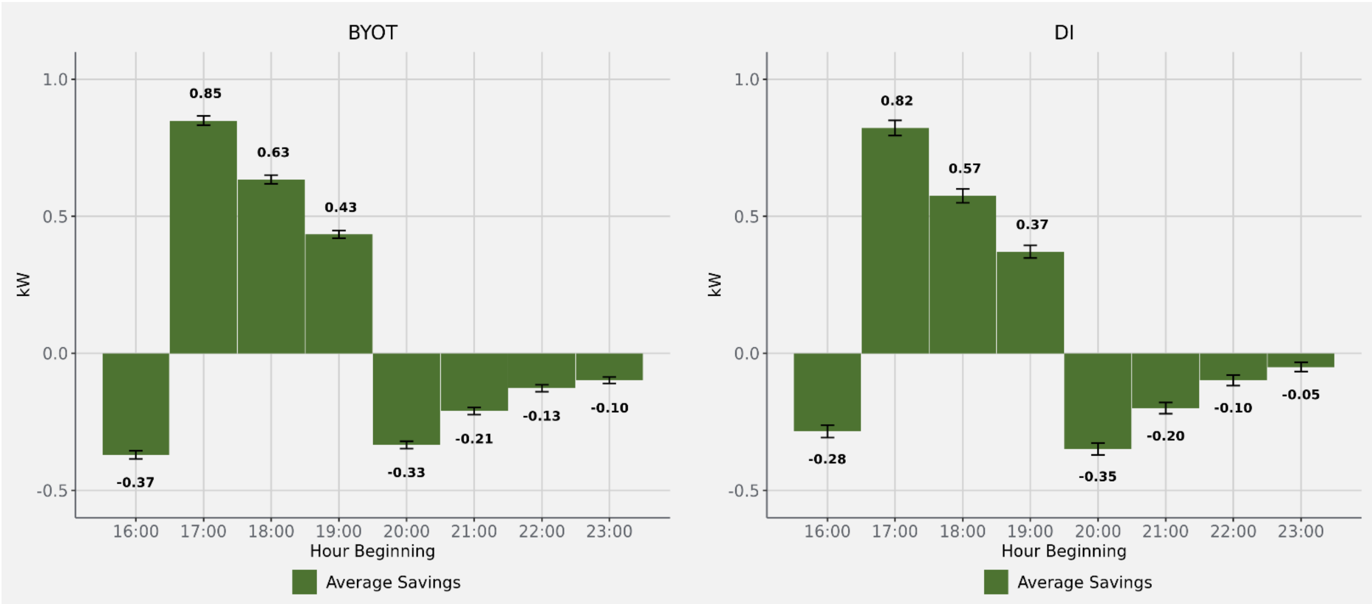


Notes: All events started at 5:00 p.m. and ended at 8:00 p.m. During Event 1, only thermostats controlling air conditioners were dispatched due to a communications glitch. Event 8 did not meet the temperature indicative threshold of 90°F. These estimates are based on Cadmus' panel regression analysis of customer AMI meter data for all treated participants, regardless of dispatch strategy, and matched nonparticipants. Error bars show 90% confidence intervals based on standard errors clustered on homes. Average temperatures may differ slightly between BYOT and DI participants because the averages are calculated using the temperature at the weather station closest to each home and the spatial distribution of BYOT and DI homes across PGE's service area differs.

For most events during the summer 2021 season, BYOT and Direct Install performed similarly. During Event 1, demand savings for Direct Install customers was lower than demand savings for BYOT customers, likely due to an error in dispatching thermostats controlling heat pumps and the higher proportion of heat pumps among Direct Install homes (41% versus 14% for BYOT).

Figure 16 displays estimates of the average demand impacts per enrolled participant before, during, and after summer 2021 events. Preconditioning increased demand by 0.4 kW and 0.3 kW per participant home for BYOT and Direct Install, respectively. Snapback in the first hour following the events increased demand by 0.3 kW for BYOT customers and by 0.4 kW for Direct Install customers. After accounting for preconditioning and snapback effects, each event generated a net decrease in energy consumption, evident from the larger impact area above the x-axis compared to below the x-axis.

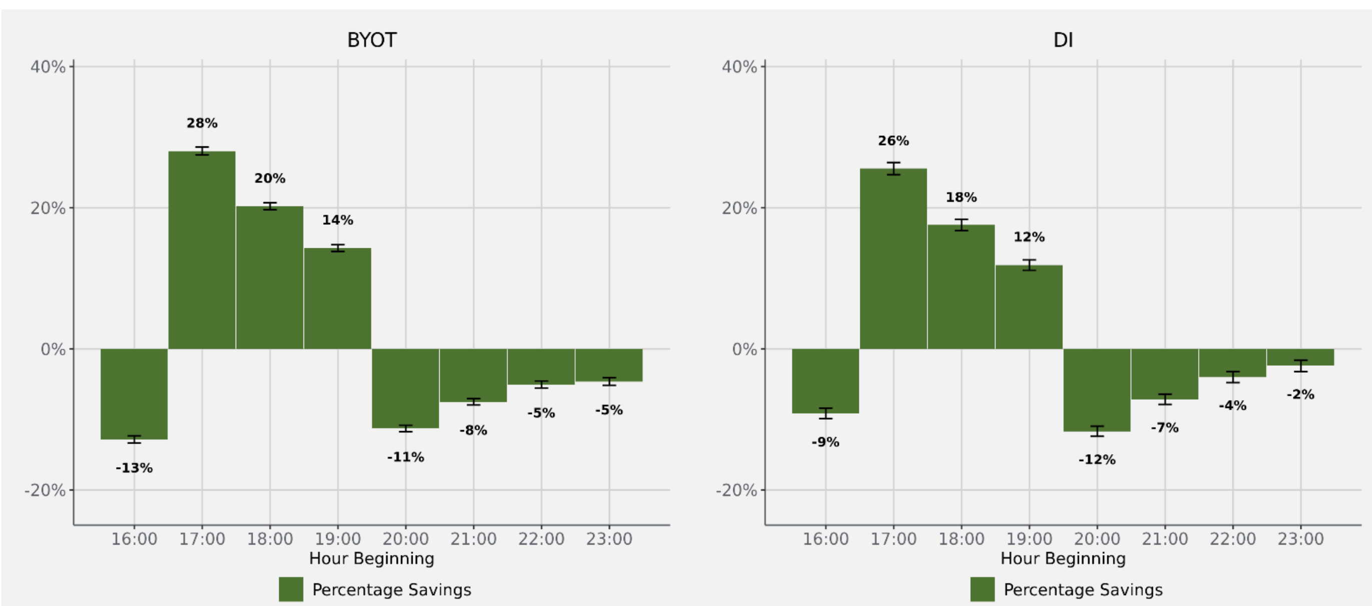
Figure 16. Average Demand Savings (kW) – Summer 2021



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data for all treated participants, regardless of dispatch strategy, and matched nonparticipants. Error bars indicate 90% confidence intervals based on standard errors clustered on homes.

Figure 17 reports the demand impacts as a percentage of baseline demand. Savings during Hour 1 were 28% and 26% of baseline demand for BYOT and Direct Install, respectively. In Hour 2, savings as a percentage of baseline demand decreased to 20% for BYOT and 18% for Direct Install. By Hour 3, BYOT savings decreased to 14% and Direct Install savings decreased to 12%.

Figure 17. Percentage Demand Savings – Summer 2021



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI meter data for all treated customers, regardless of dispatch strategy, and matched nonparticipants. Cadmus calculated percentage savings as kilowatt demand savings divided by baseline demand. Error bars indicate 90% confidence intervals based on standard errors clustered on homes.

Table 10 presents the megawatt savings from the pilot during each summer 2021 event by enrollment track. For BYOT, the average savings were 0.64 kW per participant home across all event hours, while average savings among Direct Install customers were 0.59 kW. Total evaluated savings ranged from 9.1 MW to 17.7 MW for the BYOT track and from 1.9 MW to 4.4 MW for the Direct Install track.

Table 10. Total Savings (MW) – Summer 2021

Track	Event	Average Temperature (°F)	Evaluated Average Savings Per Participant Per Event (kW)	Analysis Sample		Enrolled Participants	Evaluated Demand Savings (MW)
				Treatment Customers	Matched Comparison Customers		
BYOT	1	93	0.59	20,889	11,167	21,000	12.4
	2	109	0.43	21,044	11,167	21,156	9.1
	3	96	0.77	21,962	11,169	22,077	16.9
	4	91	0.69	21,961	11,168	22,077	15.3
	5	95	0.76	22,178	11,168	22,294	16.9
	6	101	0.79	22,307	11,169	22,424	17.7
	7	94	0.69	22,288	11,142	22,449	15.4
	8	82	0.41	22,643	11,169	22,761	9.4
	Average	**95**	**0.64**	**21,909**	**11,165**	**22,030**	**14.1**
Direct Install	1	93	0.35	5,525	4,534	5,551	1.9
	2	108	0.34	5,525	4,534	5,551	1.9
	3	97	0.77	5,622	4,535	5,650	4.4
	4	90	0.69	5,622	4,534	5,650	3.9
	5	95	0.73	5,647	4,535	5,675	4.1
	6	101	0.75	5,647	4,535	5,675	4.2
	7	94	0.66	5,645	4,520	5,684	3.7
	8	81	0.44	5,732	4,535	5,759	2.5
	Average	**95**	**0.59**	**5,621**	**4,533**	**5,649**	**3.3**
Pilot Total		**95**	**0.63**	**27,530**	**15,698**	**27,679**	**17.5**

Notes: These results show impacts for all treated customers, regardless of dispatch strategy. All events started at 5:00 p.m. and ended at 8:00 p.m. Cadmus calculated evaluated demand savings by multiplying the average savings per participant homes by the number of participant homes. During Event 1, only thermostats controlling central air conditioners were dispatched due to a communications glitch. Event 8 did not meet the temperature indicative threshold of 90°F.

Summer Performance Metrics

Table 11 displays key pilot performance metrics for summer 2021. The metrics provide information about the performance of smart thermostats based on events with outside temperatures exceeding the indicative temperature threshold (90°F) except the June 28 extreme heat dome event due its exceptional nature. The metrics are based on estimates of kilowatt impacts per participant home in the experiment control group (those who received the standard demand response event dispatch and did not receive pre-event notifications) before, during, and after events for customers.

Table 11. Pilot Performance Metrics – Summer 2021

Key Metrics		BYOT	Direct Install	Pilot Average
Number of Temperature Indicative Events		6	6	6
Average Savings (kW)	Event Hour 1	1.12 (37%)	1.08 (33%)	1.11 (36%)
	Event Hour 2	0.74 (24%)	0.69 (21%)	0.73 (23%)
	Event Hour 3	0.44 (15%)	0.41 (13%)	0.44 (14%)
Minimum Savings (kW)	Event Hour 1	0.93 (31%)	0.63 (20%)	0.87 (29%)
	Event Hour 2	0.57 (19%)	0.37 (11%)	0.53 (17%)
	Event Hour 3	0.30 (10%)	0.18 (6%)	0.28 (9%)
Maximum Savings (kW)	Event Hour 1	1.23 (36%)	1.29 (35%)	1.24 (36%)
	Event Hour 2	0.79 (22%)	0.80 (21%)	0.79 (22%)
	Event Hour 3	0.50 (18%)	0.49 (17%)	0.49 (18%)
Average Change in Savings (difference from previous hour savings) (kW)	From Event Hour 1 to Event Hour 2	-0.37 (-33%)	-0.39 (-36%)	-0.38 (-34%)
	From Event Hour 2 to Event Hour 3	-0.30 (-40%)	-0.28 (-41%)	-0.30 (-40%)
Average Preconditioning (the hour before the event begins) (kW)		-0.45 (-16%)	-0.31 (-10%)	-0.42 (-14%)
Average Snapback (the hour after the event ends) (kW)		-0.36 (-12%)	-0.37 (-12%)	-0.37 (-12%)
Average Event Day Energy Savings (kWh)		1.00	1.13	1.02

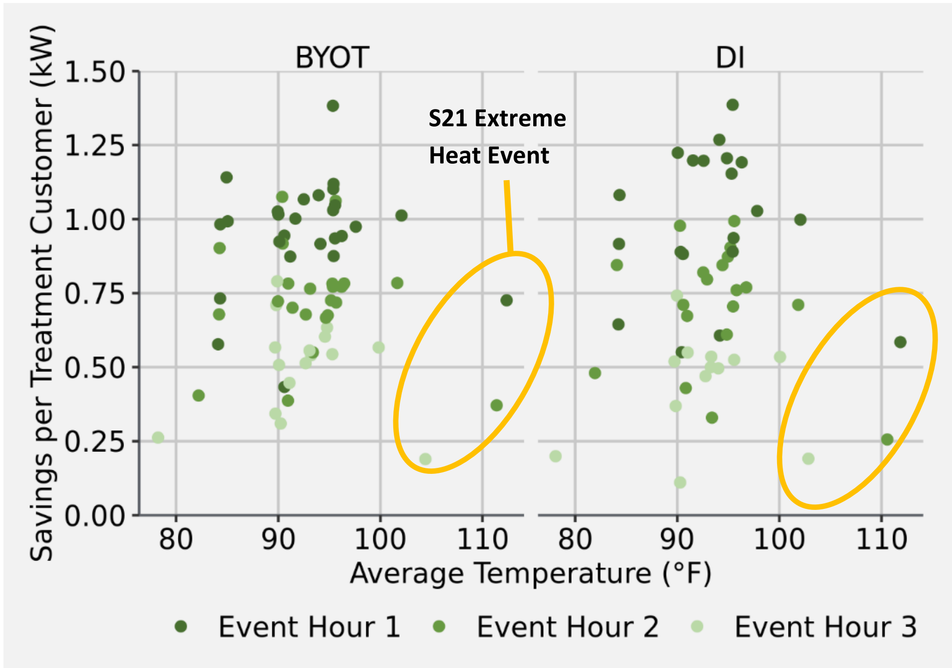
Notes: Summer 2021 metrics are based on the impacts of customers who received standard demand response treatment for all events. These metrics exclude the September 9 event, which was not temperature indicative, and the June 28 extreme heat dome event, which is an outlier. Average kilowatt savings are the average demand savings per participant home across event hours. Minimum and maximum kilowatt savings are the minimum and maximum of the average demand savings per participant home across event hours. Average change in savings is the difference between the average savings per participant home in an event hour and the average savings in the previous hour. Average preconditioning is the average change in demand per participant home from preconditioning in the hour preceding the start of the event. Average snapback is the increase in demand per participant home in the first hour after the event ends. Average event day energy savings is the average change in energy consumption per participant home on event days. Demand impacts as a percentage of baseline demand are shown in parentheses.

Summer Temperature Response

Demand response savings potential will likely be higher on hotter and more humid summer event days when demand for air conditioning increases. Cadmus analyzed demand savings and weather data from the summer seasons in 2019, 2020, and 2021 to estimate the nature of this relationship.

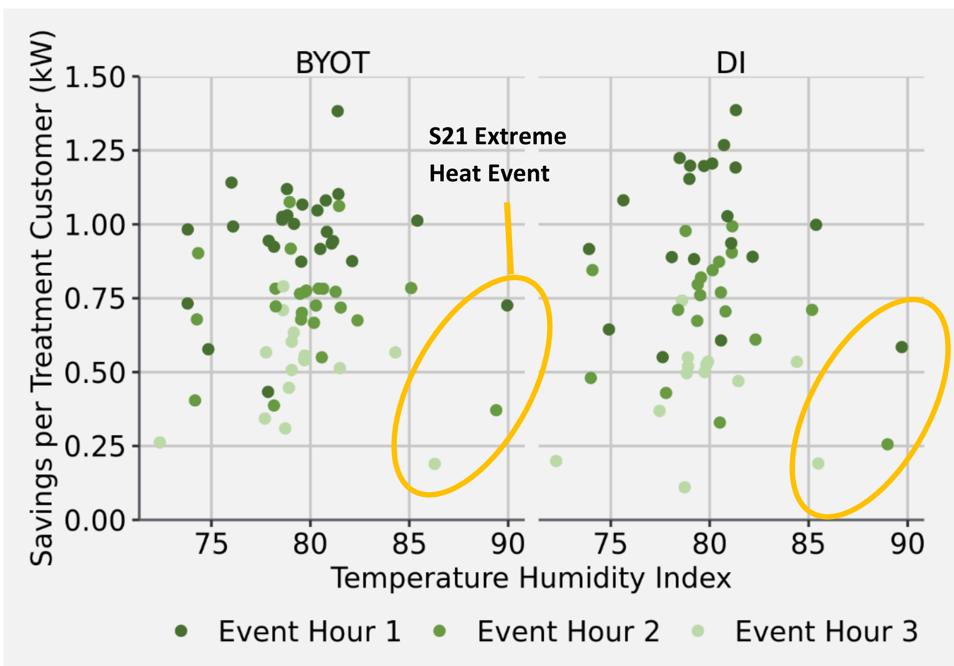
Figure 18 and Figure 19 show hourly savings in the 2019, 2020, and 2021 summer seasons plotted against temperature and the temperature-humidity index (THI), respectively. The points representing the extreme heat dome event on June 28, 2021 are indicated: after excluding this outlier, both figures suggest that demand response savings increased with temperature and THI. As with winter savings, the relationships are strongest during the first and second event hours.

Figure 18. Summer Temperature Response



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data.

Figure 19. Summer Temperature-Humidity Index Response



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data.

Factors such as annual changes in the composition of the program population or changing patterns of air conditioning use across months can introduce noise and make it hard to discern any relationships depicted in Figure 18 and Figure 19. To control for these factors, Table 12 shows the results of OLS linear regressions of event hour savings on event hour temperature or THI as well as hour-of-event indicator variables, pilot year indicators, and an indicator for September events. In the summer, conditional on event hour, program year, and month of summer, demand response savings increased by about 0.012 kW/°F and 0.027 kW/THI for BYOT participants. Direct Install participant savings increased by 0.016 kW/°F and 0.034 kW/THI. All estimates are statistically significant at the 5% level, and, as the model R^2 statistics show, the model independent variables explain much of the variation in average demand savings across event hours. The estimates showing the relationship between demand savings and outside temperature or THI may be of interest to PGE grid operators wanting to forecast the expected demand savings.

Table 12. Temperature and Temperature-Humidity Index Response Regression Estimates

Season	Track	Weather Variable	Regression Coefficient with Standard Error	Adjusted R^2	N
Summer	BYOT	Temperature	0.012 (0.005)	0.63	63
		THI	0.027 (0.008)	0.65	63
	Direct Install	Temperature	0.016 (0.006)	0.68	49
		THI	0.034 (0.011)	0.70	49

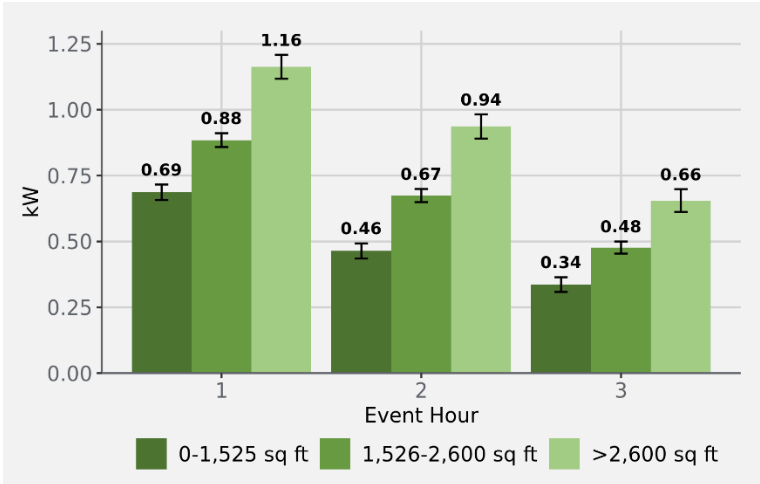
Notes: Temperature response estimates are based on Cadmus' OLS regression analysis of event hour savings on hour-of-event indicator variables (Hour 1, Hour 2, and Hour 3), pilot year indicators (summer 2019, summer 2020, and summer 2021), event hour temperature (or THI), and an indicator variable for September events. N is the number of observations of event hour savings and temperature. Heteroskedasticity-robust standard errors are in parentheses.

Summer Impacts by Customer Segments

Cadmus evaluated summer event impacts by HVAC equipment, home size, and substation. The estimates are based on all temperature-indicative summer events, except the extreme heat dome event (Event 2).

1. Larger homes had higher smart thermostat demand savings in summer. Figure 20 displays the average demand savings per participant by home size in each event hour for summer 2021. Savings of the largest homes are greater in each event hour and 70% greater in Hour 1 than that of the smallest homes.

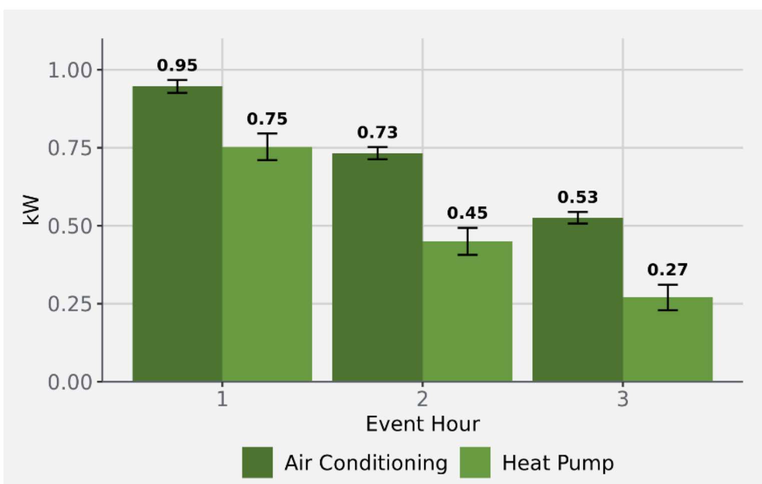
Figure 20. Demand Savings by Home Size – Summer 2021



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars indicate 95% confidence intervals based on standard errors clustered on homes. The interquartile range of home sizes (25%-75%) is 1,526-2,600 square feet.

2. Homes with central air conditioning had higher smart thermostat demand savings than homes with heat pumps. Figure 21 displays average demand savings per participant by event hour and HVAC system for summer 2021. In summer, Hour 1 savings were 25% larger in central air conditioner homes. Since air conditioners and heat pumps use equivalent technology to cool homes, this difference may be explained by home characteristics. Of homes in the analysis, homes with central air conditioning (26%) are more likely to be in the highest square footage quartile than homes with heat pumps (18%). Factors such as how well-insulated homes are may also contribute to differences in outcomes by cooling system.

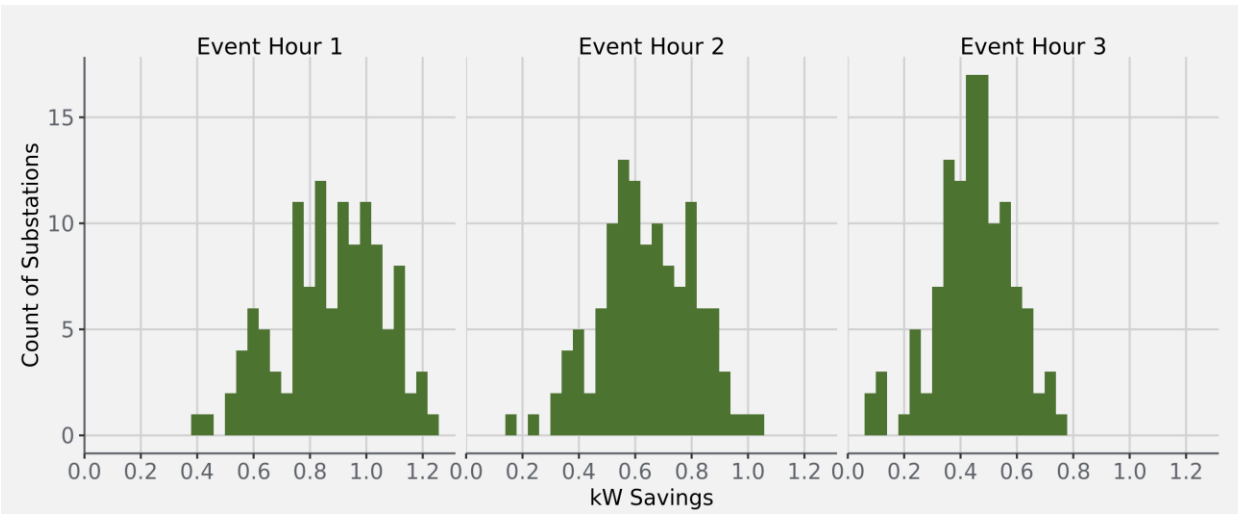
Figure 21. Demand Savings by HVAC Equipment – Summer 2021



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI data. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

3. In summer 2020, smart thermostat demand savings per participant varied significantly between PGE substations with at least 30 enrolled participants. The distributions of substation demand savings by event hour are displayed in Figure 22 for summer 2021. Each figure shows a histogram of substation average demand savings per participant by summer event hour for PGE substations with at least 30 enrolled participants. Hour 1 demand savings by substation ranged from 0.40 kW to 1.23 kW per participant. The spatial variation in demand savings is likely attributable to differences between substations in the size, age, and space cooling equipment types of homes served by the substations. PGE may use substation-level estimates of demand savings to assess the potential benefits of smart thermostats for managing local distribution system electricity demand or to increase the program cost-effectiveness by marketing the smart thermostat program more aggressively to customers served by substations with large average savings per home.

Figure 22. Distribution of Substation Demand Savings by Event Hour – Summer 2021



Notes: The figures show histograms of substation average demand savings per participant by summer event hour for substations with at least 30 participants. The substation demand savings estimates are based on Cadmus' panel regression analysis of customer AMI data.

Historical Pilot Performance

Average demand savings per Smart Thermostat pilot participant were lower in current seasons than in the previous seasons. Table 13 shows estimates of average demand savings per participant and the percentage demand savings across all event hours in each season. For each season, the average savings per participant were estimated across all event hours of the season.

Table 13. Demand Savings Compared to Previous Seasons

Season	Demand Savings per Participant Home		
	BYOT	Direct Install	Pilot Average
Winter 2021/2022	**0.51 kW (21%)**	**0.51 kW (17%)**	**0.51 kW (19%)**
Winter 2020/2021	**0.50 kW (20%)**	**0.87 kW (24%)**	**0.69 kW (22%)**
Winter 2019/2020	0.83 kW (31%)	1.63 kW (41%)	1.36 kW (39%)
Summer 2021	**0.64 kW (21%)**	**0.59 kW (18%)**	**0.63 kW (20%)**
Summer 2020	0.82 kW (30%)	0.94 kW (30%)	0.85 kW (30%)

Note: The parentheses denote average demand savings as a percentage of baseline demand. Demand savings per participant home are the average of estimated savings across all event hours in the season. All events in winter 2020/2021, summer 2021, and winter 2021/2022 were three hours. In winter 2019/2020, there was one three-hour event, one two-hour event, and one one-hour event. In summer 2020, there were two three-hour events and four two-hour events. Pilot average savings are an average of the impact estimates for BYOT and Direct Install weighted by the number of participants enrolled in each track. Summer 2021 results include all treated customers who received one of several dispatch strategies (standard demand response, standard demand response and pre-event notification, or IDR).

Winter savings decreased each season since 2019/2020. The decreases are attributable to several factors, including changes between seasons in the starting time, duration, weather conditions, and dispatch success of events. In winter 2019/2020, events were dispatched only in the morning, were of shorter duration, and were on colder days (average event temperatures ranged from 28°F to 34°F). In winter 2020/2021, all events were dispatched in the morning, but they were each three hours long and occurred on warmer days (average event temperatures ranged from 34°F to 38°F). Additionally, nearly half of thermostats dispatched in the first event of winter 2020/2021 did not receive the temperature setback signal. In winter 2021/2022, all events were three hours long and two of the three events were dispatched in the evening when temperatures were warmer (average event temperatures ranged from 35°F to 40°F).

In summer 2021, the pilot achieved average demand savings of approximately 0.63 kW per participant home, a decrease of 26% from savings achieved in summer 2020 (0.85 kW). The difference in savings performance is due to changes in event dispatch strategies, extreme temperature conditions, event duration, dispatch failures, and the composition of the participant population. Summer 2020 had a mix of two- and three-hour events, and there were no reported dispatch anomalies. In summer 2021, all events were three hours and two events occurred when temperatures were above 100°F. During one event in summer 2021, only thermostats controlling air conditioners were dispatched. In six of the eight summer 2021 events, approximately one-third of thermostats received an IDR dispatch strategy, which aims to deliver consistent load reductions in each event hour but reduces overall savings.

To account for the differences in event length and dispatch strategies or anomalies when comparing seasonal performance, Cadmus compared savings for like events. Table 14 displays the average preconditioning savings, average savings in the event first hour (Hour 1), average Hour 1 temperature, and the percentage of thermostats remaining in the event at the end of Hour 1 that occurred at similar times of day, used the same load control strategy, and did not have any dispatch anomalies. Winter demand savings among like events have decreased since the 2019/2020 season, likely due in part to warmer event temperatures. However, Hour 1 savings in summer 2021 increased compared to summer 2020. This improvement may be due to more intensive precooling and higher participation rates.

Table 14. Year-over-Year Performance Indicators

Season	Year-over-Year Performance Indicators			
	Average Pre-Conditioning Savings Per Participant	Average Hour 1 Savings Per Participant	Average Hour 1 Temperature	% Thermostats Remaining at End of Hour 1
Winter 2021/2022	**-0.65**	**0.66**	**40**	**92%**
Winter 2020/2021	**-0.96**	**1.12**	**36**	**89%**
Winter 2019/2020	-0.49	1.59	34	N/A
Summer 2021	**-0.43**	**1.16**	**96**	**87%**
Summer 2020	-0.30	1.07	94	82%

Notes: All winter indicators include events that did not meet the temperature indicative threshold because no winter 2020/2021 or winter 2021/2022 events were temperature indicative. Winter 2020/2021 indicators exclude Event 1 due to a dispatch failure. Winter 2021/2022 indicators exclude evening events because all events in winter 2019/2020 and winter 2020/2021 occurred in the morning. All summer indicators only include temperature indicative events. Summer 2021 indicators exclude Event 1 due to a dispatch failure and the June 28 extreme heat event because of its exceptional nature. Summer 2021 indicators are based on participant homes that received standard demand response and did not receive pre-event notifications.

Implementation Experiments

In summer 2021, PGE implemented two large field experiments to test the impacts of IDR and sending pre-event notifications to pilot participants. IDR involved altering the dispatch of thermostats to achieve delivery of a constant level of demand savings and to avoid degradation of savings across event hours. The pre-event email notifications involved notifying customers of upcoming events. Prior to summer 2021, PGE did not send smart thermostat participants pre-event notification emails.[12] Eligible smart thermostats were randomly assigned to one of three groups: an IDR treatment group, a pre-event notifications treatment group, or a control group. The control group received the standard demand response implementation strategy in all eight summer events and provided the baseline for measuring the treatment effects.

Pre-Event Notifications

PGE ran the pre-event notifications experiment as a randomized controlled trial. Smart Thermostat pilot participants with eligible thermostat brands were randomly assigned to a treatment group that received the notifications or a control group that did not receive pre-event notifications and provided a baseline for measuring the impacts. Table 15 shows the number of smart thermostat participants (unique customer-premise combinations) assigned to each group.

[12] In previous seasons, when demand response events began, Smart Thermostat participants were notified of events on the thermostat display and via their thermostat app.

Table 15. Pre-Event Notifications Experimental Design

Group	Sample Size (Smart Thermostat Enrollees)	Received Event Notification Emails from PGE?
Event Notification Treatment Group	3,552	Yes
Control Group	3,554	No

Notes: Cadmus calculated sample sizes based on summary table of random assignments PGE provided on July 14, 2021.

PGE called eight events during summer 2021 and tested the pre-event notification emails from Event 3 through Event 8. Customers in the treatment group received the event notification email on the morning of events.

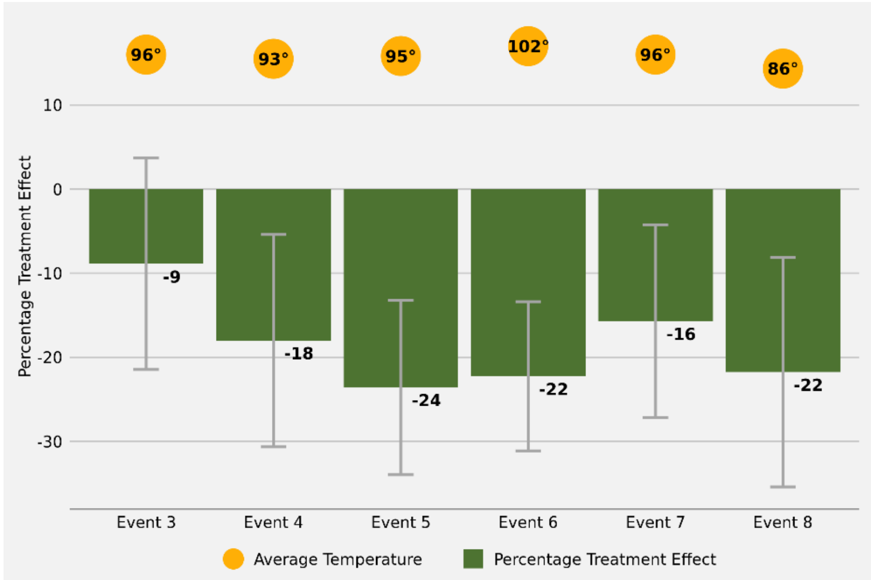
A detailed description of the analysis and findings is included in the Smart Grid Test Bed Project Final Evaluation Report.[13] But the two most important take-aways were as follows:

1. Sending pre-event notifications reduced the frequency of overriding during demand response events. Figure 23 shows estimates of the percentage treatment effects on overriding behavior by event. Sending pre-event notifications reduced overriding by between 16% (Event 7) and 24% (Event 5) relative to the baseline rate.[14] Absolute treatment effects, or the percentage point difference in override rates between the treatment and control group, ranged from 2.9 to 5.7 percentage points.

13 Portland General Electric. March 31, 2022. "Smart grid Test Bed Project Final Evaluation Report." Filing to The Public Utility Commission of Oregon. https://edocs.puc.state.or.us/efdocs/HAE/um1976hae155256.pdf

14 The treatment effect was not statistically significant in Event 3. Cadmus estimated the baseline rate of overriding for treatment group customers using the results of the panel regression model as the sum of the overriding rate of the control group (the coefficient on the event day fixed effect) and the coefficient on the stand-alone assignment to treatment indicator variable.

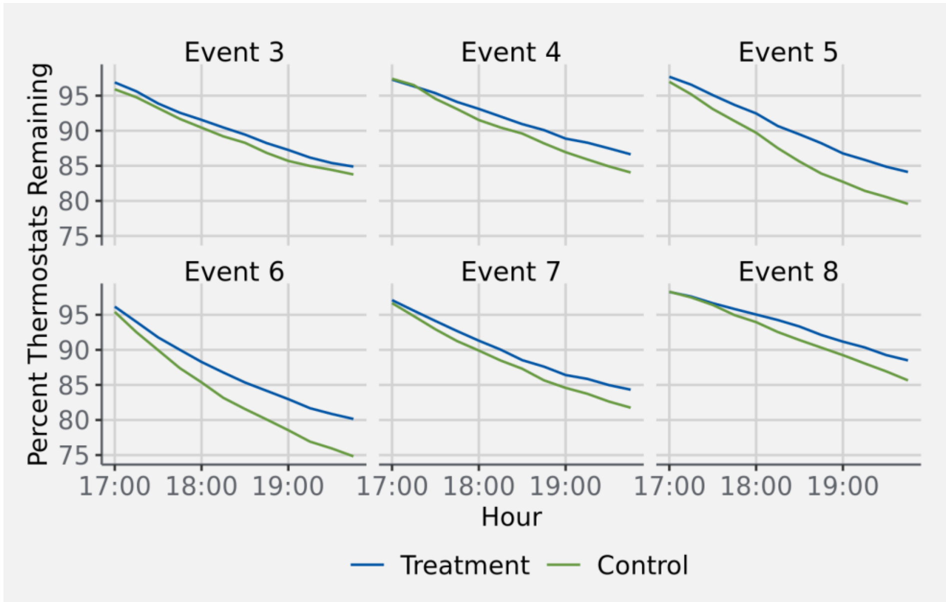
Figure 23. Pre-Event Notification Percentage Treatment Effects



Notes: Cadmus estimated treatment via a two-way fixed effects (enrollee and event) difference-in-differences regression of Smart Thermostat pilot enrollees overriding the demand response event. We estimated the percentage treatment effect by dividing the event estimated treatment effects by the event baseline rate of overriding. PGE sent pre-event notifications to participant homes for Events 3 through 8. Error bars show 90% confidence intervals based on standard errors clustered on Smart Thermostat pilot enrollees.

2. However, sending pre-event notifications did not increase demand response savings because avoided overrides occurred during the second half of events when demand savings were smaller. Figure 24 displays the percentage of thermostats remaining in the event (i.e., the percentage that did not override previously during the event) for each 15-minute event interval of events 3-8. In the events 4-8 that led to statistically significant reductions in overrides, the difference between the treatment and control groups in the percentage of thermostats remaining (not overriding) is small at the beginning of the events and does not become large until the event ends. This suggests pre-event notifications reduced overriding the most during the second half of events when demand savings were smaller and did not affect overriding in the first half of events when the savings were higher.

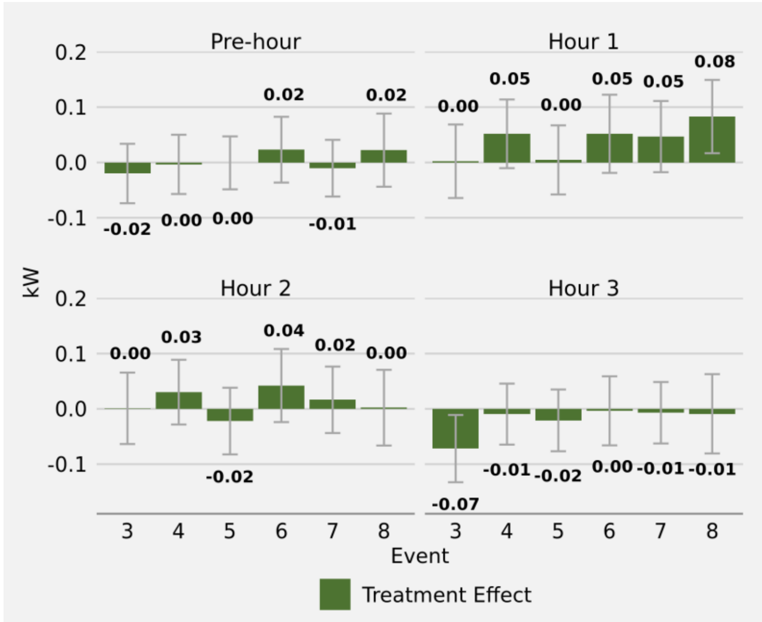
Figure 24. Percentage of Thermostats Remaining by Event Interval



Notes: Cadmus analysis of Resideo 15-minute interval telemetry data for thermostats participating in the pre-event notification experiment.

Figure 25 shows estimates of the kilowatt impacts of the pre-event notifications for Events 3 through 8. A negative treatment effect indicates a reduction in electricity demand and savings. In almost all event hours, the pre-event notifications did not lead to statistically significant load reductions relative to the control group. There were not statistically significant differences between the treatment and control groups, as indicated by the 90% confidence intervals including zero.

Figure 25. Pre-Event Notifications Demand Savings Treatment Effects



Notes: Cadmus estimated the kilowatt impacts of event notifications via a difference-in-differences regression of customer hour electricity demand using hour interval electricity consumption data for randomized treatment and control group customers. Error bars show 90% confidence intervals based on robust standard errors clustered on customers.

Intelligent Demand Response

PGE's Smart Thermostat demand response implementer, Resideo, offers an IDR dispatch strategy that customizes the thermostat setback for individual customers based on historical heating or cooling demand, the thermal properties of a home, and the brand of smart thermostat. The customization affects the degrees of temperature setback and when the setback occurs during events. In summer 2021, PGE ran an experiment to test whether IDR could achieve more consistent and lasting load reductions across event hours with minimal degradation of overall demand savings.

The experiment was implemented as a randomized controlled trial, in which enrolled participants were randomly assigned to a treatment or control group. Customers in the control group received the standard demand response event dispatch for all eight summer 2021 events and provided the baseline. Participant homes received standard demand response in Events 1 and 2 and received the IDR treatment in Events 3 through 8. Table 16 shows the number of Smart Thermostat participants assigned to each group. Cadmus evaluated the impacts of IDR on the frequency of event overriding and demand savings.

Table 16. Intelligent Demand Response Experimental Design

Group	Sample Size (Smart Thermostat Enrollees)	Demand Response Treatment
IDR Treatment Group	9,194	IDR
Control Group	14,847	Standard demand response

Notes: Cadmus calculated sample sizes based on a summary table of random assignments PGE provided on July 14, 2021.

Effect on Overriding Behavior

Cadmus used thermostat telemetry data provided by Resideo to analyze the effects of IDR on overriding behavior. Table 17 shows the override rates for the treatment and control groups. In Events 1 and 2, override rates for each group ranged between 25% and 27%, and there was no statistically significant difference between treatment and control group rates.[15] Although participant homes appear to have an override rate nearly twice the rate of the control group in Event 3, the participation status for some customers in the IDR group was incorrectly classified as an override: the override rates displayed for Event 3 do not reflect true participation for the IDR group. In Events 4 through 8, override rates for control group customers ranged from 14% to 25%, while override rates for the treatment group ranged from 10% to 20%; the differences in each of these events are statistically significant at 90% confidence.

Table 17. Overriding Rates for Intelligent Demand Response Experiment

Event	IDR Treatment		Control		Pre-Event Notification
	Number of Customers	Proportion Overrode	Number of Customers	Proportion Overrode	
1	2,233	27%	2,249	25%	No
2	2,986	25%	3,030	25%	No
3	3,032	29%	3,055	16%	Yes
4	2,994	14%	3,009	16%	Yes
5	2,902	18%	3,044	20%	Yes
6	2,990	20%	3,006	25%	Yes
7	2,953	16%	2,970	18%	Yes
8	2,909	10%	2,975	14%	Yes

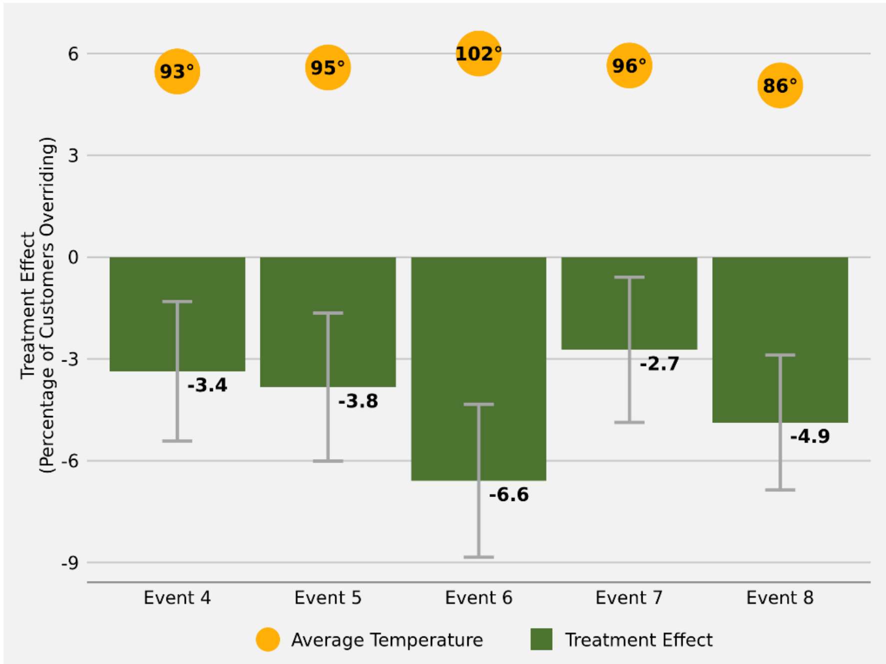
Notes: Cadmus calculated override rates from thermostat telemetry data Resideo provided for summer 2021, which includes devices from two of the three OEMs. We removed customers with heat pumps from the data for Event 1 because they did not receive the event dispatch. Participation status in Event 3 for some customers in the IDR group was incorrectly classified as an override: the participation rates displayed in Event 3 do not reflect true participation for the IDR group. Event 2 was an extreme heat dome event.

Cadmus conducted a regression analysis to estimate the treatment effect of IDR on overriding behavior. We estimated these impacts in a two-way fixed effects (customer and event) difference-in-differences regression between the treatment and control groups. The dependent variable of the panel regression model was a 0/1 indicator for whether the customer overrode the event. Figure 26 shows the treatment effects for Events 4 through 8.[16] In each event, treatment group participants were less likely to override the thermostat setpoint than control group customers. Treatment effects ranged from 2.7 percentage points in Event 7 to 6.6 percentage points in Event 6.

[15] Cadmus removed customers with heat pumps from the data for Event 1 because they erroneously did not receive the event dispatch.

[16] We excluded Event 3 because the participation status for some customers in the IDR group was incorrectly classified as an override.

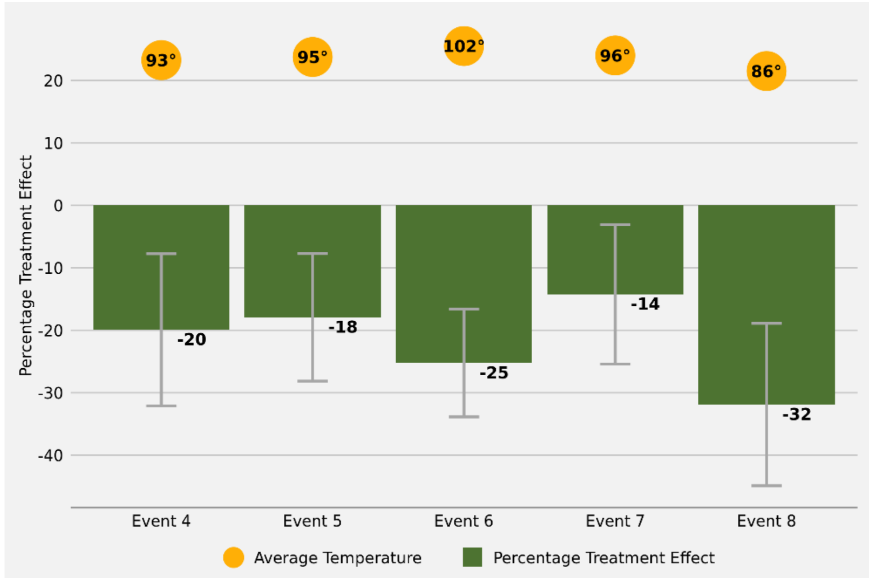
Figure 26. Intelligent Demand Response Treatment Effects



Notes: The treatment effect is the percentage point impact of the pre-event notification on overriding. Cadmus estimated treatment effects via a two-way fixed effects (enrollee and event) difference-in-differences regression of Smart Thermostat pilot enrollees overriding the demand response event controls. Error bars show 90% confidence intervals based on standard errors clustered on Smart Thermostat pilot enrollees.

Figure 27 shows the percentage treatment effect in each event. Cadmus estimated percentage treatment effects by dividing the percentage point treatment effects by the event baseline rate of overriding for participant homes. Percentage treatment effects ranged from 14% to 32%.

Figure 27. Intelligent Demand Response Percentage Treatment Effects



Notes: Cadmus estimated treatment effects via a two-way fixed effects (enrollee and event) difference-in-differences regression of Smart Thermostat pilot enrollees overriding the demand response event controls. Error bars show 90% confidence intervals based on standard errors clustered on Smart Thermostat pilot enrollees. We estimated the percentage treatment effect by dividing the event estimated treatment effects by the event baseline rate of overriding.

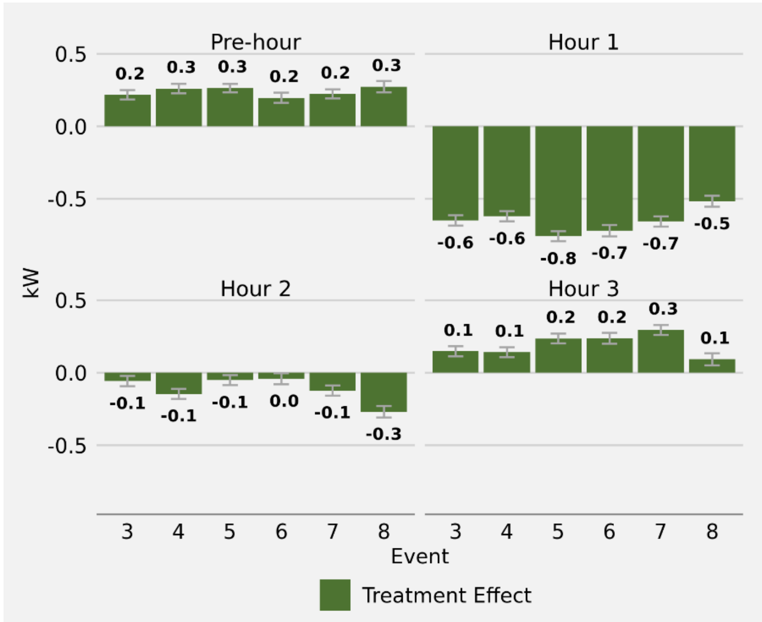
The reduction in overriding from IDR is likely due to delaying the dispatch of some IDR thermostats until later in the event, which would minimize the negative impacts of the events on the thermal comfort of customers whose thermostat dispatch was delayed and reduce the incentives for them to override the events.

Effect on Demand Savings

To estimate the effect of IDR on demand savings, Cadmus implemented a difference-in-differences regression of customer electricity demand using hour interval home electricity demand data on event days and the 10 hottest non-event, non-holiday weekdays in summer 2021 for randomized treatment and control group customers. The regression included hour-of-the-day and customer fixed effects, cooling degree hours, indicators for assignment to the treatment group, event-day indicators, and interactions between these variables. Cadmus tested for differences in energy use on non-event days and for Events 1 and 2 (before the IDR treatment began) and found that the randomized treatment and control groups had statistically equivalent consumption.

Figure 28 shows the effect of IDR treatment on demand savings in the preconditioning hour and in each event hour for Events 3 through 8. Positive values indicate an increase in savings relative to the control group, while negative values indicate a decrease in savings. In the preconditioning hour, the increase in electricity demand for participant homes was lower than that of the control group. However, in Hours 1 and 2, the treatment group’s savings were lower than the control group’s savings. In the last event hour, treatment group demand savings increased again relative to the control group. Across all hours of each event, savings for participant homes were less than savings for control group homes, as indicated for each event by the total area of bars with negative values being larger than the total area of bars with positive values.

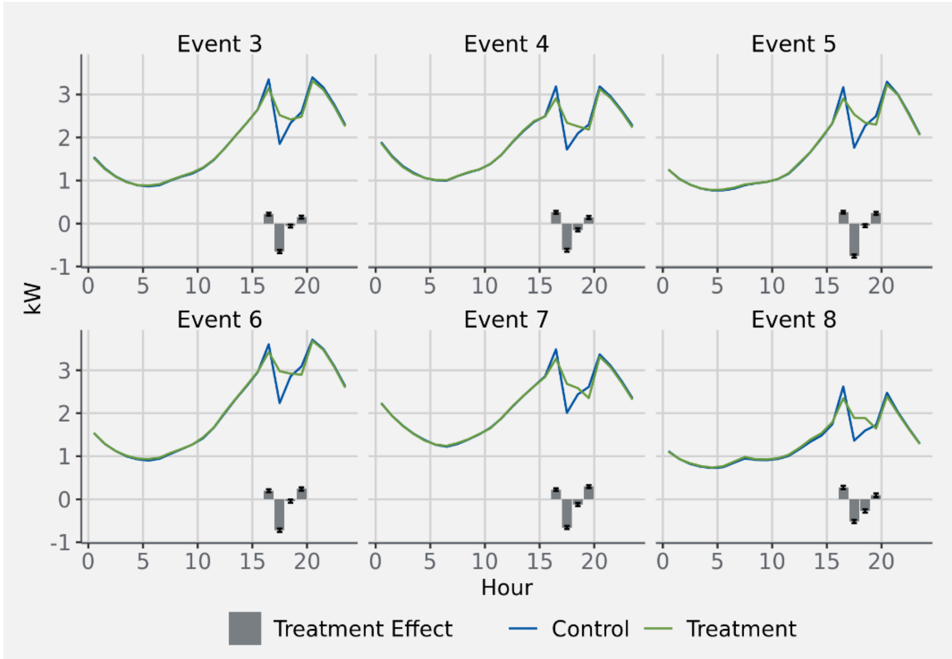
Figure 28. Intelligent Demand Response Demand Savings Treatment Effects



Notes: Cadmus estimated the kilowatt savings of IDR treatment in a difference-in-differences regression of customer hour electricity demand using hour interval home electricity demand data for randomized treatment and control group customers. In the figure, negative values indicate a decrease in savings. Error bars show 90% confidence intervals based on robust standard errors clustered on customers.

Figure 29 shows the average load shapes for treatment and control group customers on event days for Events 3 through 8. The load shapes demonstrate that the IDR treatment was effective in producing more consistent load impacts among participant homes throughout the three hours of events. However, this came at a cost to overall savings, as the cumulative treatment effect (indicated by grey bars) is negative. When determining whether to implement IDR in future seasons, PGE grid operators will need to consider which strategy is better for reducing stress on the grid during peak demand days: consistent load reductions throughout the course of the event or higher savings in the first event hour followed by savings that degrade in successive hours.

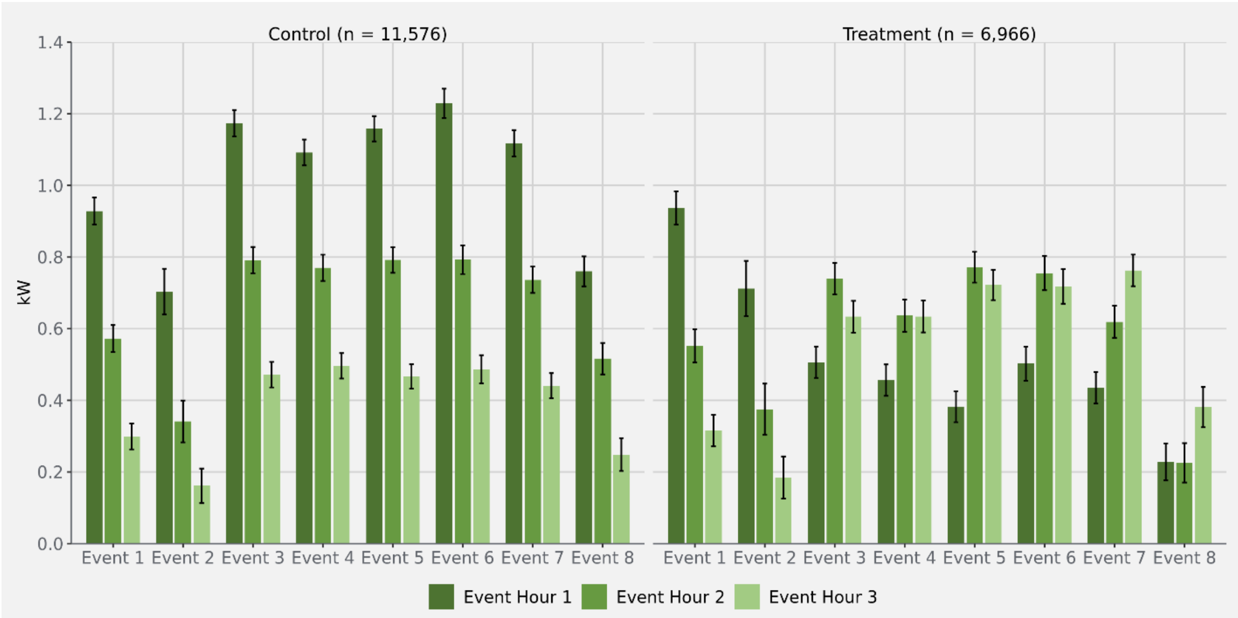
Figure 29. Intelligent Demand Response Treatment and Control Load Shapes



Notes: Cadmus estimated the kilowatt savings of IDR treatment in a difference-in-differences regression of customer hour electricity demand using hour interval home electricity demand data for randomized treatment and control group customers. In the figure, negative values indicate a decrease in savings. Error bars show 90% confidence intervals based on robust standard errors clustered on customers.

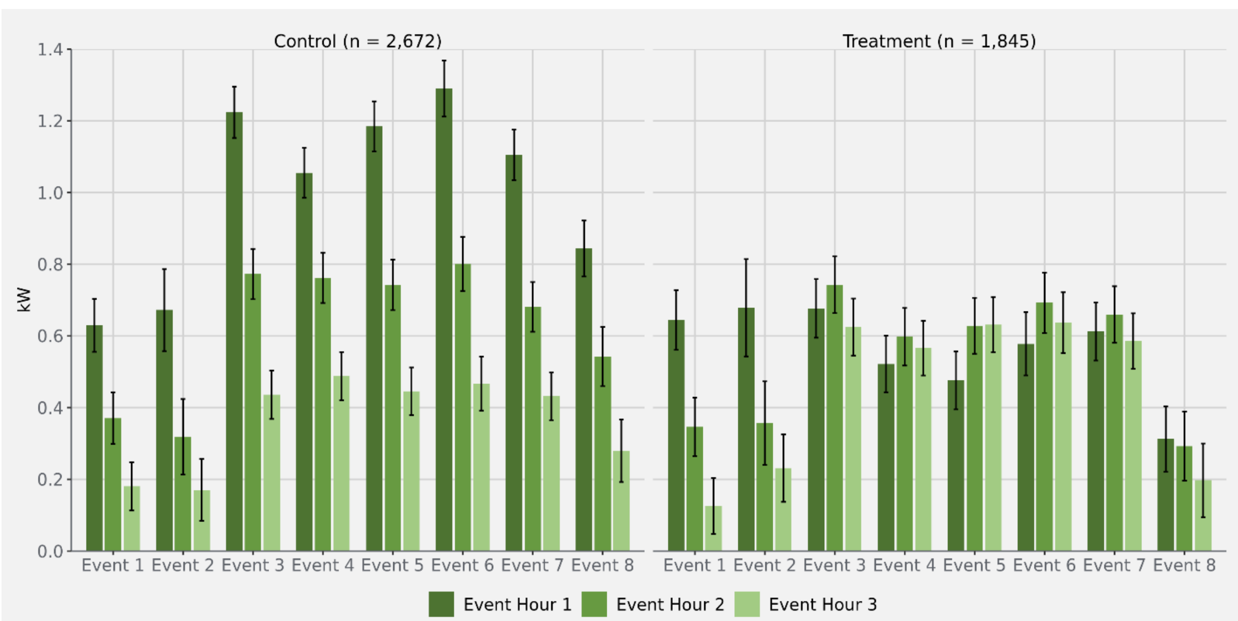
Figure 30 and Figure 31 display demand savings in each event for the IDR treatment and control groups for BYOT and Direct Install, respectively. The impacts for the IDR and standard DR treatments were estimated in a panel regression using the electricity demand of matched comparison group customers to establish a baseline. Savings for the treatment and control groups were similar in Events 1 and 2, before treatment began. In Events 3 through 8, savings among the treatment group were more consistent in each event hour, but average event savings were lower than control group savings.

Figure 30. IDR versus Standard DR Demand Savings - BYOT



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI meter data for IDR and standard DR participants and matched nonparticipants. Error bars show 90% confidence intervals based on standard errors clustered on homes.

Figure 31. IDR versus Standard DR Demand Savings – Direct Install



Notes: These estimates are based on Cadmus' panel regression analysis of customer AMI meter data for IDR and standard DR participants and matched nonparticipants. Error bars show 90% confidence intervals based on standard errors clustered on homes.

Overriding Analysis

Summary data of thermostat dispatch status from the summer 2021 event season indicated that approximately one-fourth to one-third of thermostat participants who received the event dispatch overrode the thermostat setpoint during the event.[17] Overriding can reduce demand savings, particularly if it occurs early in the event when savings are highest. Table 18 displays the participation status of thermostats in each event for the winter 2020/2021, summer 2021, and winter 2021/2022 event seasons. For each event, the table shows total number of thermostats enrolled, percentage that fully participated, amount that overrode as a percentage of total thermostats, the adjusted amount that overrode as a percentage of thermostats that received the event signal, and the percentage that were offline (not connected to the Wi-Fi), failed to confirm that the event control signal was received, or with a status that otherwise could not be confirmed. The data include BYOT and Direct Install participants. In winter seasons, participants overrode between 15% and 21% of thermostats in each event (adjusted). In summer, adjusted override rates ranged between 22% and 31%.

Table 18. Thermostat Dispatch Status

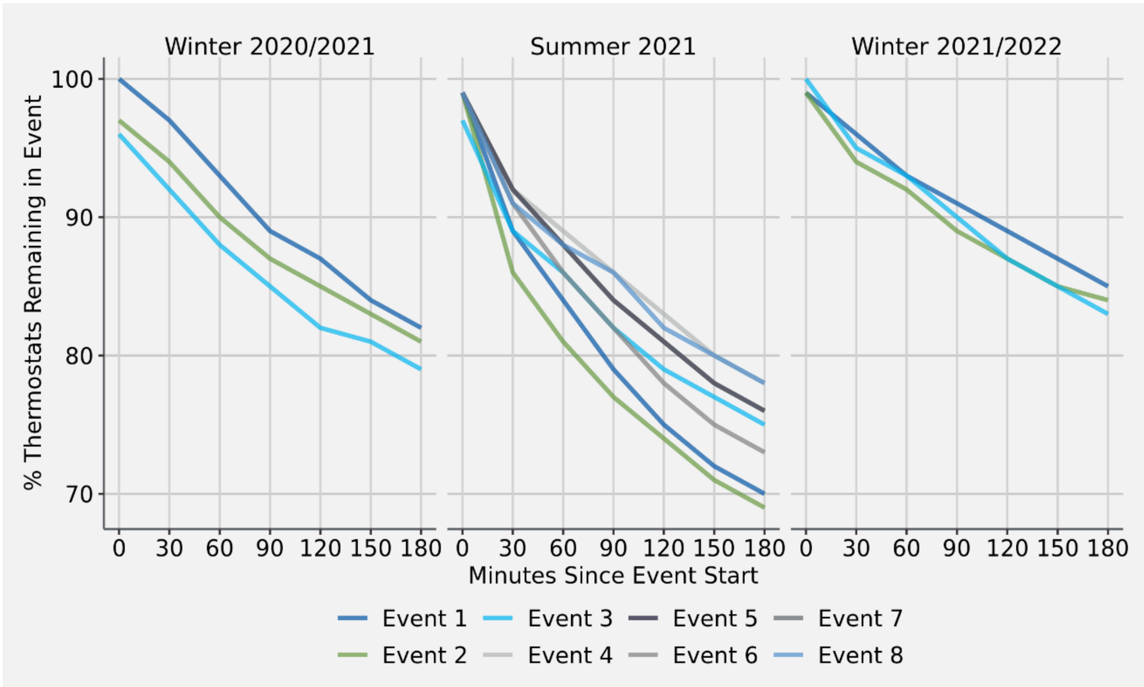
Season	Event	Date	Average Outdoor Temperature (°F)	Total Thermostats	Fully Participated	Opted Out	Adjusted Opted Out	Offline	Failed	Unknown
Winter 2020/2021	1	1/26/2021	35	5,872	37%	8%	18%	7%	45%	3%
	2	2/3/2021	38	5,843	73%	17%	19%	7%	0%	3%
	3	2/10/2021	34	5,821	71%	19%	21%	7%	0%	3%
Summer 2021	1	6/21/2021	93	23,321	67%	29%	30%	3%	0%	2%
	2	6/28/2021	109	29,145	65%	29%	31%	4%	0%	3%
	3	7/29/2021	96	29,798	71%	24%	25%	4%	0%	2%
	4	7/30/2021	91	30,098	74%	20%	22%	4%	0%	2%
	5	8/4/2021	95	30,037	71%	23%	24%	4%	0%	2%
	6	8/11/2021	101	30,100	69%	25%	27%	4%	0%	2%
	7	8/13/2021	94	30,268	71%	23%	24%	4%	0%	2%
	8	9/9/2021	82	30,362	73%	21%	22%	4%	0%	2%
Winter 2021/2022	1	1/27/2022	40	7,609	78%	14%	15%	8%	0%	0%
	2	2/2/2022	40	7,591	77%	15%	16%	8%	0%	0%
	3	2/23/2022	35	7,664	76%	16%	17%	9%	0%	0%

Notes: The average outdoor temperature is based on the temperature recorded at the National Oceanic and Atmospheric Administration weather station nearest to each participant's home. This table is based on summary data provided by Resideo on customer overriding and dispatch and connectivity failures for each event. Cadmus calculated values in the Opted Out column as the number of thermostats that opted out divided by Total Thermostats. The Adjusted Opted Out calculations exclude thermostats that were offline, failed to receive the event signal, or that had an otherwise unknown status.

Most overriding occurs before the end of the first event hour. Figure 32 displays the percentage of thermostats remaining in the event in each 30-minute event interval by season. In most events, there is a steeper decline in the percentage remaining up to the 60-minute interval, after which participation rates begin to level off. This pattern has a higher impact on demand savings than one in which participants override later in the event, because savings are highest in the first event hour and the thermostat cannot be controlled for the remaining event hours.

17 Override rate calculations excluded thermostats that were offline, failed to receive the event signal, or that had an otherwise unknown status.

Figure 32. Participation Rates by 30-Minute Event Interval



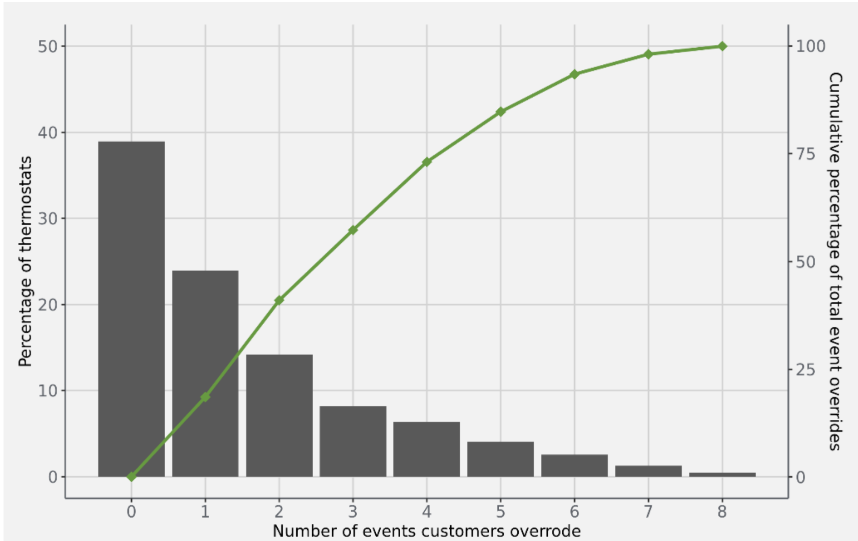
Notes: This figure is based on aggregated thermostat status reports provided by Resideo, which include all participant thermostats. The percentage remaining is less than 100% at the beginning of the events (0 minutes since event start) because some overriding occurred during the pre-conditioning phase.

To better understand the causes of overriding behavior and which customers override events, Cadmus analyzed thermostat telemetry data supplied by Resideo for individual pilot participants from the summer 2021 event season. Resideo provided these data in five-minute interval reads for two of the pilot's three OEMs and included the timestamp of the read, event ID and phase, temperature setback during demand response events, participation status, participation percentage, system mode, target temperature setpoint, HVAC system runtime, indoor temperature, and outdoor temperature. Cadmus used these data to summarize and analyze overriding behavior, including modeling the probability of overriding as a function of customer characteristics, thermal comfort, and previous override behavior.

Frequency of Overrides

Cadmus investigated the number of overrides per customer to determine whether most customers overrode at least once, or if a small percentage of customers were responsible for most overriding. Figure 33 displays the distribution of customers by the number of overrides during the summer 2021 season as well as the cumulative distribution of total overrides. The analysis is limited to thermostats for which data were available for all eight events.

Figure 33. Distribution of Customers by Event Overriding Frequency



Notes: This analysis is restricted to devices from two of the three OEMs for which data were available for all eight summer events. The bars show the percentage of thermostats overriding *n* events. The line references the second y axis and shows the percentage of thermostats overriding n or fewer events.

Most customers overrode at least one event—only 39% participated in all events. However, 23% of thermostats that overrode three or more of the eight events were responsible for 59% of the total event overrides throughout the season. This indicates that a lot of overriding is concentrated in a subset of the pilot population. Cadmus conducted a deeper review of customer and override data to understand the factors associated with high frequency overriders.

Factors Affecting Overriding Behavior

By linking thermostat telemetry data to Customer Information System data obtained from PGE,[18] Cadmus considered three factors that influenced customer overriding behavior:

- *Environmental factors* specific to or caused by events such as the outdoor temperature or changes in home interior temperature
- *Time-invariant customer characteristics* that make customers more or less likely to override all events
- *Customer time-varying experiences* such as the number of previous events or previous overrides

Cadmus limited its analysis to pilot participants who received the standard demand response treatment in all events and did not receive pre-event notifications to isolate factors that influence overriding behavior from the impacts of the IDR and pre-event notification treatments. All analyses were quasi-

[18] PGE removed all fields containing personally identifiable information from both datasets prior to delivery to Cadmus, and Cadmus could not tie these data back to individual customers.

experimental, as neither Cadmus nor PGE randomly assigned the factors hypothesized to cause overriding to customers.

Environmental

In theory, customers who become uncomfortable during events are more likely to override the temperature setback to return their home to a comfortable temperature. Cadmus used thermostat-level indoor temperature data to estimate the likelihood of overriding an event as a function of the level of discomfort a customer experienced during event hours. To accomplish this, we used hourly indoor temperatures from the 20 hottest non-event days to predict the counterfactual indoor temperature on event days if thermostats had not received the event setback. After removing approximately 10% of customers with inaccurate predictions, we calculated “discomfort degree hours” for each event hour as the difference between the actual temperature in the home during the event and the predicted counterfactual temperature. We then regressed a 0/1 indicator for whether the customer overrode the event in that hour against event hour indicators (pre-event hour, Hour 1, Hour 2, and Hour 3), the average hourly indoor temperature on non-event days, and discomfort degree hours.

Table 19 shows the effect of discomfort degree hours on the probability of overriding an event. The impacts are estimated relative to the overriding of customers whose indoor temperatures during events were less than 1°F above or below participants’ expected temperatures. Customers whose homes were at the normal temperature during events had a probability of overriding the event in a given event hour of 5.1%. Customers with interior temperatures greater than normal were more likely to override events. Participants whose homes were more than 3°F above non-event day indoor temperatures were 2.2 percentage points or 43% (=2.2/5.1) more likely to override, while participants whose homes were just 1°F or 2°F warmer than normal were only 1.0 percentage point (20%) more likely to override. Customers whose event day temperatures were lower than normal were less likely to override events.

Table 19. Effect of Thermal Comfort on Overriding

Difference in Indoor Temperature During Event	Effect on Probability of Override (Percentage Points)	Standard Error
More than 3°F above normal	2.2	0.3
2°F to 3°F above normal	2.0	0.3
1°F to 2°F above normal	1.0	0.3
1°F to 2°F below normal	-0.5	0.3
2°F 3°F below normal	-0.9	0.4
More than 3°F below normal	-0.8	0.8

Notes: This analysis is based on thermostat telemetry data for enrolled participants who received standard demand response and did not receive pre-event notifications. Data are limited to two of the pilot’s three OEMs. Effects on overriding probability are relative to customers whose indoor event temperatures are less than 1°F above or below normal. Robust standard errors are clustered on a customer thermostat.

Customer Characteristics

By joining the telemetry data with PGE’s Customer Information System data, Cadmus investigated whether certain customer groups were more or less likely to override events than others. We ran separate probability model regressions of overriding an event for different customer characteristics, including dwelling type (single family, multifamily, and manufactured home), home square footage, home age (built prior to 1960, built between 1960 and 1979, built between 1980 and 2000, and build after 2000), owner or renter, enrolled or not enrolled in a PGE renewable power program, enrollment track (BYOT or Direct Install), average monthly summer usage, number of seasons enrolled in the pilot, and average setpoint on non-event days (below 72°F, 72°F to 74°F, 74°F to 76°F, and above 76°F). Cadmus then ran a model including all categories with a statistically significant relationship to the probability of overriding. The results of the full regression are reported in Table 20.[19] For each customer group, the effect on override probability is relative to the omitted group.

Table 20. Characteristics of Overriders

Customer Group	Omitted Group	Effect on Probability of Override (Percentage Points)	Standard Error
Enrolled in a renewable power program	Not enrolled in a program	-2.2	0.7
Average monthly summer energy usage of 696 kWh to 979 kWh (2nd quartile)	Average monthly summer energy usage below 696 kWh	2.9	1.0
Average monthly summer energy usage of 980 kWh to 1,351 kWh (3rd quartile)		3.4	1.0
Average monthly summer energy usage above 1,351 kWh (4th quartile)		1.3	1.0
Average non-event day setpoint below 72°F	Average non-event setpoint above 76 F	3.9	1.0
Average non-event day setpoint between 72°F and 74°F		3.0	1.0
Average non-event day setpoint between 74°F and 76°F		1.9	1.0

Notes: Cadmus estimated the marginal effects on the probability of overriding using OLS in a fixed-effects panel regression model. The dependent variable equaled 1 if the customer overrode the event and 0 otherwise. The model included customer and event day fixed effects, and standard errors were clustered on customers.

Customers with preferences for lower non-event day temperature setpoints and customers with summer electricity consumption between the 25th and 75th percentiles were the most likely to override events. Customers with average non-event setpoints below 72°F were 3.9 percentage points more likely to override than customers with average setpoints above 76°F. In comparison, those who preferred temperatures of 74°F to 76°F were only 1.9 percentage points more likely to override. Except for customers in the highest quartile of average monthly summer energy consumption, those with higher average consumption were more likely to override events than participants in the lowest quartile of average monthly summer usage. Participants in the third quartile of summer consumers were 3.4 percentage points more likely to override than customers in the bottom quartile, whereas participants in the second quartile were only 2.9 percentage points more likely to override. Customers who had enrolled in one of PGE's renewable power programs were 2.2 percentage points less likely to override than participants who had not enrolled in one of these programs. The other customer

19 The model also included home square footage, which had a statistically significant effect on the probability of overriding when modeled separately, but did not have a statistically significant effect when controlling for the other characteristics in the model.

characteristics Cadmus evaluated—dwelling type, home age, home size, enrollment track, and owner versus renter—did not affect the probability of overriding.

Prior Experiences and Behavior

Pilot participants' experiences and behavior from event to event may also influence how likely they are to override. The structure of the pilot's participation incentive may impact a participant's decision to override given their participation in previous events. Customers who enrolled through the BYOT track need to participate in at least 50% of the season's event hours to receive the seasonal participation incentive, and PGE can charge Direct Install enrollees for the cost of the thermostat and installation if they do not meet the 50% participation requirement. Thus, if a customer overrode the thermostat setpoint during the preceding event, they may be motivated by the participation terms to remain in the current event.

Cadmus estimated the effect of overriding the previous event on the probability of overriding the next event using a fixed-effects panel regression analysis with enrollment track indicators (BYOT and Direct Install), event number indicators for Events 2 through 8, and customer fixed effects. Table 21 shows the regression results.

Table 21. Effect of Previous Overrides

Variable	Effect on Probability of Override (Percentage Points)	Standard Error
Override in previous event	-11.0***	1.2
Override in previous event interacted with Direct Install participant indicator	1.4	2.3

Notes: Cadmus based override probability estimates on a fixed-effects panel regression analysis of overriding on an indicator for overriding the previous event interacted with enrollment track indicators (BYOT or Direct Install), event number indicators for Events 2 through 8, and customer fixed effects. *** indicates statistical significance at the 1% level.

Overriding the previous event significantly reduced the probability of overriding the next event: participants who overrode the previous event were 11 percentage points less likely to override. Cadmus included an interaction between the enrollment track indicator for DI and an indicator for overriding the previous event determine whether the difference in incentives or other customer experiences between BYOT and Direct Install resulted in a difference in probability of overriding. As the coefficient on the interaction variable and standard error in Table 21 shows there was no significant difference in the effect by track. We also considered whether the encouragement email affected the probability of overriding, but we could not estimate the effect of the encouragement email because all participants who qualified for the encouragement received the email.[20] The effect of the encouragement could not be distinguished from the effect of time-invariant customer characteristics affecting overriding. In addition, Cadmus estimated the effect of previous overrides limiting the data to Events 3 through 8 (after the encouragement email was sent) and found a similar effect as the effect displayed in Table 21.

Of the three factors that influence overriding behavior Cadmus analyzed (environmental, time-invariant customer characteristics, and time-varying customer experiences), thermal comfort and time-invariant

[20] The encouragement email was sent to participants who opted out of 50% of event hours in Events 1 and 2.

customer characteristics were the strongest drivers of overriding. However, much of the overriding behavior is not explained by these factors. Although some of the factors that motivate overriding are beyond PGE's control, such as customers' preferred setpoints, PGE can use some of these findings to try to reduce overriding. For instance, since customers enrolled in a renewable power program are less likely to override, PGE may choose to market the Smart Thermostat pilot to customers who sign up for renewable power to recruit participants with a lower propensity for overriding.

Customer Experience

To assess customer experience with the Smart Thermostat pilot, Cadmus administered two online surveys with enrolled customers during summer 2021. Cadmus launched these two surveys the day after Event 4 (July 30, 2021) and the day after Event 7 (August 13, 2022), and combined the results. The following describes key findings from the surveys.

Cadmus contacted either a random sample or census of actively enrolled customers, depending on the track and experiment group. Table 22 shows the number of customers contacted and the response rate for the two event surveys combined. On average, these surveys achieved a response rate of 16%.

Table 22. Summer 2021 Event Survey Samples and Response Rates

	Population	Sample Frame [a]	Number of Completes (Achieved Sample)	Response Rate
By Track				
BYOT	20,320	3,600	524	15%
Direct Install	4,737	3,321	588	18%
Unknown	661	N/A	N/A	N/A
By Experiment Group				
Group A - IDR Treatment	8,577	2,000	328	16%
Group B - Notification Treatment	3,231	1,787	268	15%
Group C - Control	13,910	3,134	516	16%
Overall	**25,718**	**6,921**	**1,112**	**16%**

[a] Cadmus selected a mix of stratified random sampling and census of records for the surveys.

While the majority of respondents said they felt comfortable during a summer 2021 event, the season saw the biggest degradation in comfort to date. During summer events, the smart thermostat's temperature is set back by 1°F to 3°F. As shown in Figure 34, respondents' thermal comfort before and during a summer 2021 event showed a statistically significant degradation. Half the respondents expected this comfort level from participating in the pilot. Only 28% of respondents found the event to be less comfortable than what they had expected. Summer 2021 had the largest degradation of comfort before and during an event (27 percentage points) compared to summer 2020 (19 percentage points) and summer 2019 (14 percentage points). Summer 2021 was the hottest event season to date and the high temperatures likely contributed to lower comfort.

Figure 34. Summer 2021 Customer Event Comfort

Note: Respondents rated their comfort level on a 0 to 10 scale, where 0 meant *extremely uncomfortable* and 10 meant *extremely comfortable*. Cadmus defined a rating of 6 to 10 as *comfortable*.
Source: Survey Questions. "On Friday before the Peak Time Event, how comfortable was the interior temperature of your home?" and "On Friday during the Peak Time Event, how comfortable was the interior temperature of your home?" and "How did the comfort level you experienced during the event compare to the level of comfort you expected from participating in PGE's Smart Thermostat Program?"

Summer 2021 had the lowest customer satisfaction to date. Program satisfaction decreased significantly from summer 2020 to summer 2021 (Figure 35 and Table 23).[21] One hypothesis for the lower program satisfaction is that summer 2021 was the hottest event season to date: the high temperatures could have contributed to lower comfort, thus leading to lower program satisfaction. Figure 36 provides support for this hypothesis, showing that summer 2021 had the highest average outdoor temperature and the lowest program satisfaction results. Another hypothesis could be customer fatigue with the program, as the pilot has been around since 2015 and most enrolled customers have experienced multiple event seasons. It is not known whether customer satisfaction changes the longer a customer is in the program (and this could be a topic to explore in future evaluations).

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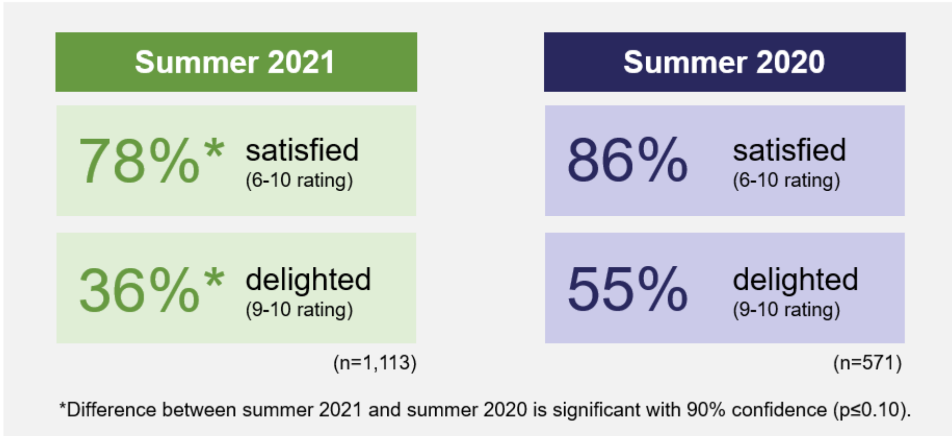
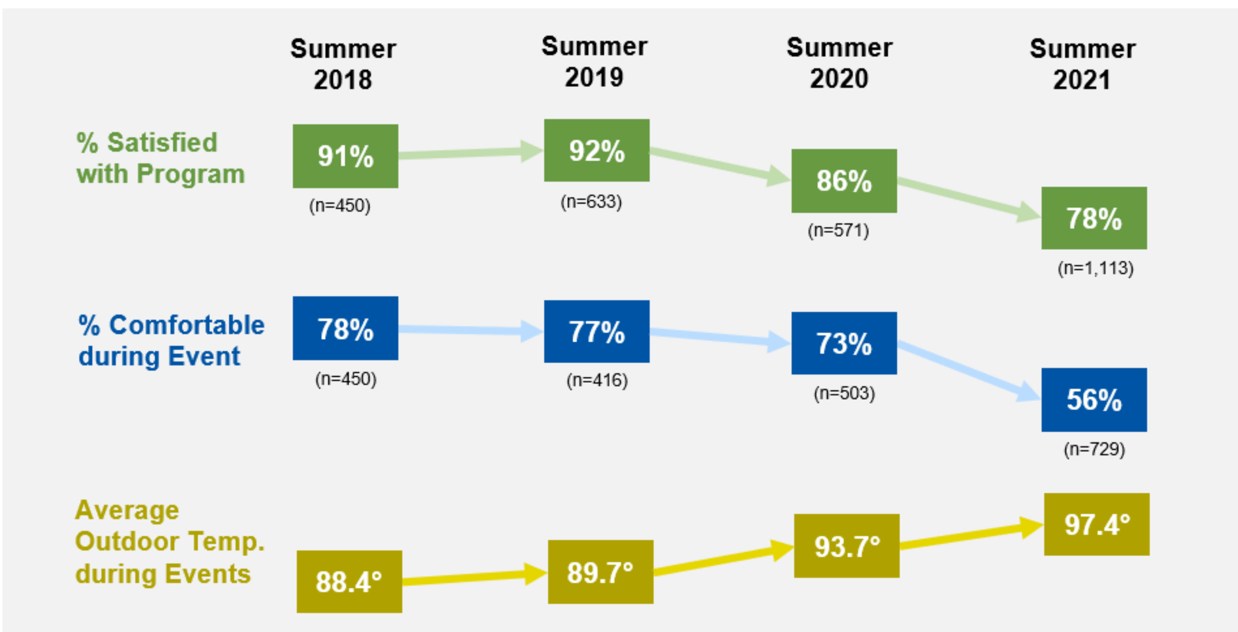
[21] The results in Figure 35 and Figure 36 were calculated using all smart thermostat participant survey responses. The 2018 results are for BYOT customers, the 2019 results are for BYOT and DI, the 2020 results are for DI customers, and the 2021 results are for BYOT and DI customers. When we restrict the analysis sample to DI customers, the same trends in customer satisfaction and comfort are evident. The percentages of DI customers satisfied were 92% in 2019, 86% in 2020, and 79% in 2021. The percentages of DI customers comfortable were 79% in 2019, 73% in 2020, and 62% in 2021.

Figure 35. Summer 2021 Customer Satisfaction with Program



Note: Respondents rated their satisfaction with the Smart Thermostat pilot on a 0 to 10 scale, where 0 meant *extremely dissatisfied* and 10 meant *extremely satisfied*. PGE defined a 6 to 10 rating as satisfied and a 9 or 10 rating as delighted. Source: Survey Question. "Please rate your overall satisfaction with PGE's Smart Thermostat Program."

Figure 36. Satisfaction-Comfort-Temperature Trends



Source: Cadmus summer 2018 through summer 2021 customer surveys.

Table 23. Program Satisfaction by Track

	Summer 2018	Summer 2019	Summer 2020	Summer 2021
BYOT	91% satisfied (n=450)	92% satisfied (n=409)	Not surveyed	77% satisfied (n=524)
Direct Install	Not surveyed	92% satisfied (n=224)	86% satisfied (n=571)	79% satisfied (n=589)

Source: Cadmus summer 2018 through summer 2021 customer surveys.

Customer satisfaction with the program depends on comfort during the event. Figure 36 illustrates that as the average outdoor temperature increased, customer comfort during events and their satisfaction with the program tended to decrease.[22] Cadmus ran regressions to assess the relationships between respondents' comfort ratings and program satisfaction ratings using the summer 2021 survey data. The results to the regression analysis (as detailed in *Appendix C*) indicated that thermal comfort affected customer satisfaction with the program:

- Being comfortable during an event was associated with much higher program satisfaction. Comfort during the event increased the probability of program satisfaction by 38 to 45 percentage points (85% to 88%) relative to the satisfaction of respondents who were uncomfortable.
- Being less comfortable than expected during an event decreased the likelihood of being satisfied with the program by 43 to 49 percentage points (49% to 53%), depending on the experiment group. Differences between the IDR and notifications groups were not statistically significant.
- Being comfortable during an event reduced the likelihood of attempts to change the thermostat settings (i.e., saw the event override warning message) by about 13 percentage points (20%) in the control group and by 20 percentage points (60%) in the IDR group.

IDR can be implemented with minimal impact to customer comfort and satisfaction. No significant differences emerged in comfort and satisfaction between IDR and standard demand response (control group). As shown in Table 24, respondents who received IDR were just as satisfied and comfortable as those who received standard demand response. The only areas where significant differences emerged between the two approaches were in event awareness and notice of the event override warning message. Fewer IDR respondents noticed the event and saw the event participation warning message compared to standard demand response respondents.

[22] In addition to outdoor temperature, customer fatigue, differences in the survey method (event surveys versus end-of-season experience surveys), and track (BYOT versus Direct Install) could also contribute to these differences.

Table 24. Summer 2021 Survey Results by Intelligent Demand Response Experiment Group

Survey Item	Treatment Group - IDR (n≤325)	Control Group - Standard Demand Response (n≤515)
General event awareness	74% aware	81% aware
AC status during event	63% had their AC on	64% had their AC on
Pre-cooling awareness	40% noticed	35% noticed
Adjusted thermostat during event via thermostat display	28% made adjustment	28% made adjustment
Adjusted thermostat during event via smartphone app	27% made adjustment	22% made adjustment
Event participation warning message	37% saw warning	49% saw warning
Ending event participation	51% ended event	44% ended event
Comfort before event	84% comfortable	82% comfortable
Comfort during event	52% comfortable	55% comfortable
Degradation in comfort	32-point degradation	27-point degradation
Program satisfaction	80% satisfied 32% delighted	76% satisfied 37% delighted

Note: Items shaded in yellow indicate a significant difference between the treatment group and control group, with 90% confidence ($p \leq 0.10$).

Because of the randomized controlled trial design, Cadmus was able to run regressions to assess the causal relationships between IDR and standard demand response on event awareness, comfort, overriding, and satisfaction. The regression analysis (as detailed in *Appendix C*) revealed several findings:

- IDR decreased event awareness by 7 percentage points, or 9%.
- IDR had no statistically significant effect on customer comfort during events.
- IDR reduced the probability that customers saw a warning they were about to override (that is, that they attempted to take an action that would result in an override) by 12.6 percentage points, or 25%.
- IDR had no statistically significant effect on satisfaction with the program.

Customers liked the event notification emails, but these emails did not make a difference in their satisfaction. Of those who received the event notification emails from PGE, 72% (n=270) remembered receiving the event notification emails. Among those who remembered receiving the notification emails, 99% (n=184) said they understood what PGE was asking them to do in the email. Nearly all respondents (98%, n=180) found the event notification emails useful and said they would like to continue receiving the event notifications.

Although respondents who received the event notification emails liked receiving them, this did not make a difference in their satisfaction. Program satisfaction was similar between the treatment group (79% satisfied, n=266) and control group (80% satisfied, n=160). The regression analysis also revealed that receiving an event notification had no statistically significant effects on satisfaction.

Table 25 summarizes the differences and similarities in survey results between the two event notification experiment groups.

Table 25. Summer 2021 Survey Results by Event Notification Experiment Group

Survey Item	Treatment Group - Received Notification Email (n≤266)	Control Group - Did Not Receive Notification Email (n≤160)
General event awareness	86% aware	60% aware
AC status during event	73% had their AC on	75% had their AC on
Pre-cooling awareness	36% noticed	16% noticed
Program satisfaction	79% satisfied 44% delighted	80% satisfied 40% delighted

Note: Items shaded in yellow indicate a significant difference between treatment group and control group, with 90% confidence ($p \leq 0.10$).

Planned Program Implementation Changes and Future Considerations

PGE is working on several improvements for the upcoming summer and winter seasons to move the pilot closer to full deployment. First, PGE plans to roll out the pre-event notification emails to all participants. Second, PGE plans to develop unenrollment confirmation emails for customers to help catch any customers who were unaware that actions they took with their thermostat resulted in unenrollment. In addition, PGE would like to reduce the number of participants who unenroll by collecting and analyzing data on customer unenrollment reasons. Third, PGE plans to increase the customer engagement touchpoints during the seasons to improve retention.

Appendix A. Evaluation Methodology

This section describes Cadmus' methodology for evaluating the Smart Thermostat pilot.

Evaluation Design

To estimate the demand response impacts of the pilot, Cadmus worked with PGE to implement a *post hoc* matched comparison group design. In order to maximize the demand reduction capacity of the pilot, all enrolled customers received the load control signals during demand response events. Cadmus selected a matched comparison group from residential PGE customers who were eligible for the pilot but had not enrolled.[23] We estimated savings by comparing the average demand of treatment and comparison group customers during event hours.

There are typically two types of impact effects that can be measured, depending on the inclusion of distinct treatment participant groups:

- Intent to treat treatment effect (ITT) – the average impact per home (or other relevant unit of analysis) for homes that the utility intended to treat
- Treatment effect on the treated (TOT) – the average impact per treated home

In a smart thermostat demand response context, the ITT effect is the average demand savings per home the utility attempts to control. ITT is estimated across homes (thermostats) that receive and execute the setback, homes that receive and execute the commands and then override those commands, and homes that do not receive or execute the commands due to some operational issue. In its evaluations of PGE's thermostat pilots, Cadmus has estimated and reported the ITT because these effects are the most relevant for utility planning, utility operations, and assessing cost-effectiveness. ITT reflects the impacts of operational issues and overrides on the demand savings that PGE achieved.

The estimate of the TOT (sometimes also referred to as the local average treatment effect) indicates the demand savings for homes that receive and execute the setback commands. To estimate the TOT, Cadmus would need to determine the percentage of homes that did not execute the demand response setback using telemetry data from the demand response service providers. We can recover an estimate of the TOT by dividing the ITT estimate by the percentage of homes that executed the setback commands. For example, if the estimate of the ITT effect equals 1 kW per home and 80% of homes successfully executed the setback, the estimate of the TOT effect equals 1.2 kW (or 1 kW/0.8). This calculation assumes that the 20% of homes that did not receive or execute the setback have zero demand savings during the event. This calculation shows the average demand savings per home for homes that executed the setback.

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[23] We defined eligible nonparticipants as customers who received a smart thermostat rebate from Energy Trust of Oregon and had compatible HVAC equipment (electric forced-air furnace or heat pump for winter events and central air conditioner or heat pump for summer events).

Data Collection and Preparation

Cadmus collected and prepared several types of data for analysis:

- ***Participant enrollment data***, provided by PGE, tracked enrollment for pilot participants. These data included anonymized unique account identifiers, pilot enrollment and unenrollment dates (if applicable), service address zip code, and eligibility for seasonal participation as determined by HVAC equipment.
- ***Customer Information System data***, provided by PGE for all customers in its service territory, included an indicator for participation in Energy Trust of Oregon's smart thermostat rebate program as well as customer demographics (HVAC equipment type, home size, home age, solar net metering, participation in other PGE programs, and average monthly consumption in the previous year).
- ***Interval consumption data***, provided by PGE for all residential customers, included watt-hour electricity consumption at 15- or 60-minute intervals, measured using AMI meters.
- ***Local weather data***, which included hourly average temperatures from December 2020 through February 2022 for five National Oceanic and Atmospheric Administration weather stations. Cadmus used zip codes to identify weather stations nearest to each participant's home and merged the weather data with each participant's AMI data.
- ***Event data***, provided by PGE, included the dates and times of all load control events.
- ***Summarized telemetry data***, provided by Resideo, included counts of total thermostats that participated in each event and the number of thermostats that overrode events, were offline, failed to confirm that the event control signal was received, or whose status could otherwise not be confirmed. These data were not provided at the individual customer level.

  Customer level telemetry data, provided by Resideo, included interval timestamp, event ID and phase, temperature setback during demand response events, participation status, participation percentage, system mode, target temperature setpoint, HVAC system runtime, indoor temperature, and outdoor temperature. These data were provided in five-minute interval reads from June 1 through September 30, 2021.

Analysis Samples

Cadmus took several steps to clean the AMI meter data and prepare it for analysis:

- Adjusted timestamps to account for daylight savings time
- Removed a small number of duplicate interval readings from the data
- Adjusted timestamps from the end of the read period to the start of the read period
- Summed 15-minute interval consumption data to obtain hourly interval consumption
- Dropped a small number of hourly observations missing one or more 15-minute interval readings
- Since all events occurred on weekdays, removed holidays, weekends, and days outside of event seasons

Cadmus excluded a small number of customers from the analysis sample who:

- Lacked AMI meter data,
- Had an average daily consumption greater than 300 kWh (suggesting they were not residential customers), or
- Had more than 50% of average hourly demand that were outliers.

Table A-1 shows the attrition of customers from the analysis sample for each season. Each row represents a level of filtering, with the corresponding number of participants assigned to each group after the filter step. A customer is the unique combination of Service Agreement ID-Service Premise ID in the raw Smart Thermostat pilot data obtained from PGE.

Table A-1. Final Analysis Sample Attrition by Season

<table>
<tr><th rowspan="3">Filter</th><th colspan="4">Enrolled Participants</th><th colspan="4" rowspan="2">Nonparticipant Match Candidates</th></tr>
<tr><th colspan="2">BYOT</th><th colspan="2">Direct Install</th></tr>
<tr><th>Customers</th><th>Percent</th><th>Customers</th><th>Percent</th><th colspan="2">Customers</th><th colspan="2">Percent</th></tr>
<tr><td colspan="9">Winter 2020/2021</td></tr>
<tr><td>Customers in tracking data</td><td>2,666</td><td>100.0%</td><td>2,808</td><td>100.0%</td><td colspan="2">N/A</td><td colspan="2">N/A</td></tr>
<tr><td>Customers in AMI data</td><td>2,647</td><td>99.3%</td><td>2,802</td><td>99.8%</td><td colspan="2">4,214</td><td colspan="2">100.0%</td></tr>
<tr><td>Customers with average daily usage ≤300 kWh</td><td>2,646</td><td>99.2%</td><td>2,800</td><td>99.7%</td><td colspan="2">4,212</td><td colspan="2">100.0%</td></tr>
<tr><td>Customers without outlier average hourly demand</td><td>2,642</td><td>99.1%</td><td>2,794</td><td>99.5%</td><td colspan="2">4,206</td><td colspan="2">99.8%</td></tr>
<tr><td rowspan="2">Customers included in analysis</td><td rowspan="2">2,642</td><td rowspan="2">99.1%</td><td rowspan="2">2,794</td><td rowspan="2">99.5%</td><td>BYOT</td><td>DI</td><td>BYOT</td><td>DI</td></tr>
<tr><td>1,712</td><td>1,529</td><td>40.6%</td><td>36.3%</td></tr>
<tr><td colspan="9">Summer 2021</td></tr>
<tr><td>Customers in tracking data</td><td>22,761</td><td>100.0%</td><td>5,759</td><td>100.0%</td><td colspan="2">N/A</td><td colspan="2">N/A</td></tr>
<tr><td>Customers in AMI data</td><td>22,692</td><td>99.7%</td><td>5,750</td><td>99.8%</td><td colspan="2">19,715</td><td colspan="2">100.0%</td></tr>
<tr><td>Customers with average daily usage ≤300 kWh</td><td>22,690</td><td>99.7%</td><td>5,749</td><td>99.8%</td><td colspan="2">19,708</td><td colspan="2">100.0%</td></tr>
<tr><td>Customers without outlier average hourly demand</td><td>22,645</td><td>99.5%</td><td>5,732</td><td>99.5%</td><td colspan="2">19,670</td><td colspan="2">99.8%</td></tr>
<tr><td rowspan="2">Customers included in analysis</td><td rowspan="2">22,645</td><td rowspan="2">99.5%</td><td rowspan="2">5,732</td><td rowspan="2">99.5%</td><td>BYOT</td><td>DI</td><td>BYOT</td><td>DI</td></tr>
<tr><td>11,170</td><td>4,535</td><td>56.7%</td><td>23.0%</td></tr>
<tr><td colspan="9">Winter 2021/2022</td></tr>
<tr><td>Customers in tracking data</td><td>4,226</td><td>100.0%</td><td>2,899</td><td>100.0%</td><td colspan="2">N/A</td><td colspan="2">N/A</td></tr>
<tr><td>Customers in AMI data</td><td>4,203</td><td>99.5%</td><td>2,893</td><td>99.8%</td><td colspan="2">4,093</td><td colspan="2">100.0%</td></tr>
<tr><td>Customers with average daily usage ≤300 kWh</td><td>4,203</td><td>99.5%</td><td>2,892</td><td>99.8%</td><td colspan="2">4,092</td><td colspan="2">100.0%</td></tr>
<tr><td>Customers without outlier average hourly demand</td><td>4,199</td><td>99.4%</td><td>2,886</td><td>99.6%</td><td colspan="2">4,086</td><td colspan="2">99.8%</td></tr>
<tr><td rowspan="2">Customers included in analysis</td><td rowspan="2">4,194</td><td rowspan="2">99.2%</td><td rowspan="2">2,888</td><td rowspan="2">99.6%</td><td>BYOT</td><td>DI</td><td>BYOT</td><td>DI</td></tr>
<tr><td>2,203</td><td>749</td><td>53.8%</td><td>18.3%</td></tr>
</table>

Notes: Nonparticipant match candidates were limited to residential customers in PGE's service territory with smart thermostats and eligible HVAC systems. A customer is defined as the unique combination of Service Agreement ID-Service Premise ID.

The final analysis sample includes participants used in the impact estimation and excludes a small number of customers who were missing AMI data, had average daily consumption greater than 300 kWh, or had a high proportion of outliers among their average hourly demand.

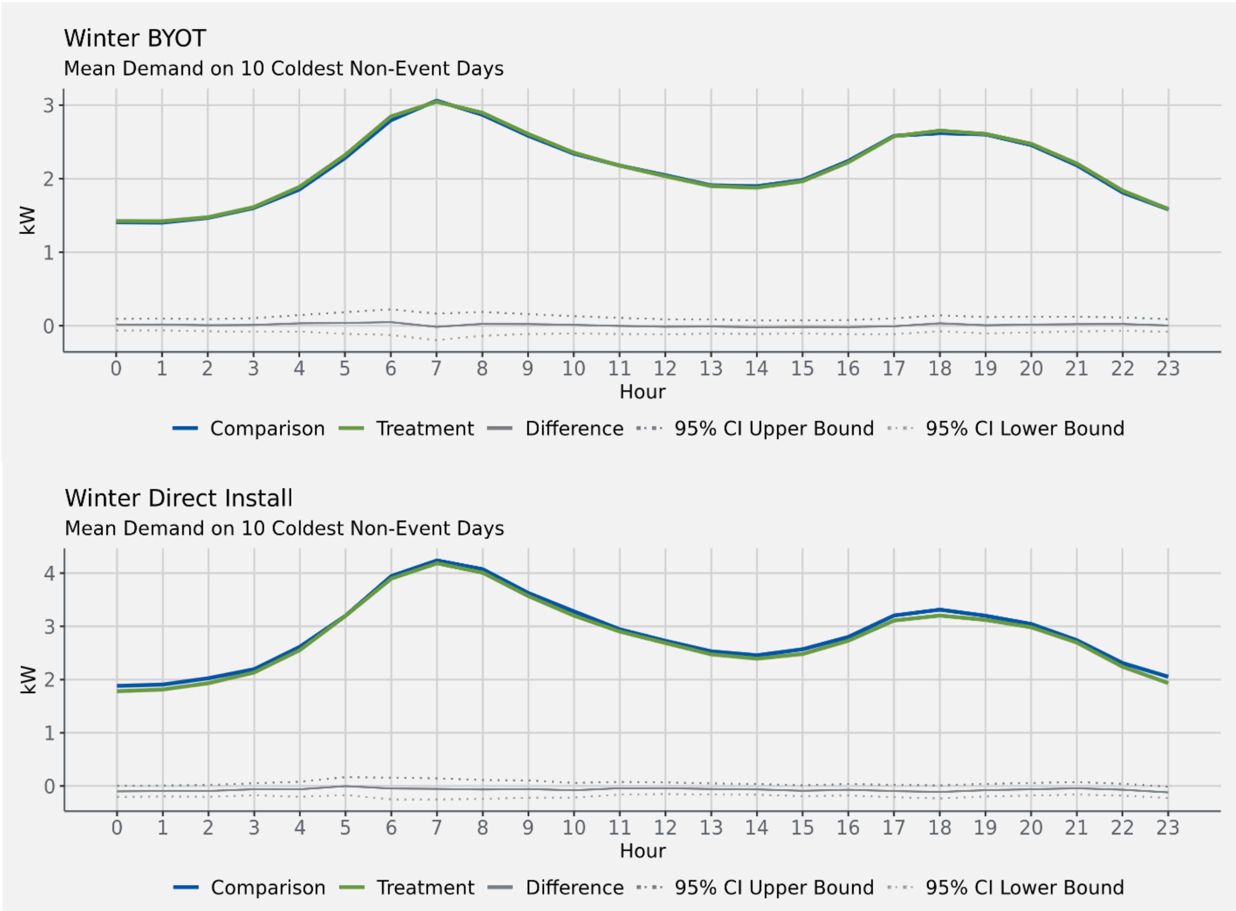
Matched Comparison Group Selection

Cadmus used logistic regression models to estimate propensity scores for enrollment in the pilot for each customer based on their average hourly demand and average daily consumption on the 10 coldest (in winter) and 10 hottest (in summer) non-event, non-holiday weekdays. We used additional customer details to refine the models, including a solar net metering indicator and dwelling type. For both enrollment tracks, the Cadmus team matched nonparticipants with smart thermostats and eligible HVAC systems to participant homes based on minimum differences in propensity scores. Since the population of eligible nonparticipants was smaller than the participant population, Cadmus allowed nonparticipants to be matched to more than one participant to improve the match quality. We then assigned weights to the matched comparison customers proportional to the number of treatment customers to which they were matched.

The Cadmus team evaluated the quality of the matches by comparing the average load shapes of the treatment and matched comparison groups on near-event non-holiday weekdays. Figure A-1, Figure A-2, and Figure A-3 show average demand by hour for 10 near-event weekdays in winter 2020/2021, 10 near-event weekdays in summer 2021, and 10 near-event weekdays in winter 2021/2022, respectively. The average demand excludes days that were not event days or holidays. The figures also plot the estimated difference and confidence interval for the estimate. The figures demonstrate that the hourly differences between the two groups' demand were small and statistically insignificant across most hours on non-event days, indicating that the matching approach was successful. There were small (<0.2 kW) statistically significant differences[24] between Direct Install participant and comparison group demand in hour 23 in winter 2020/2021 and in hours 0 and 23 in winter 2021/2022. However, the difference-in-difference panel regression approach used to estimate demand savings controls for differences in customer demand.

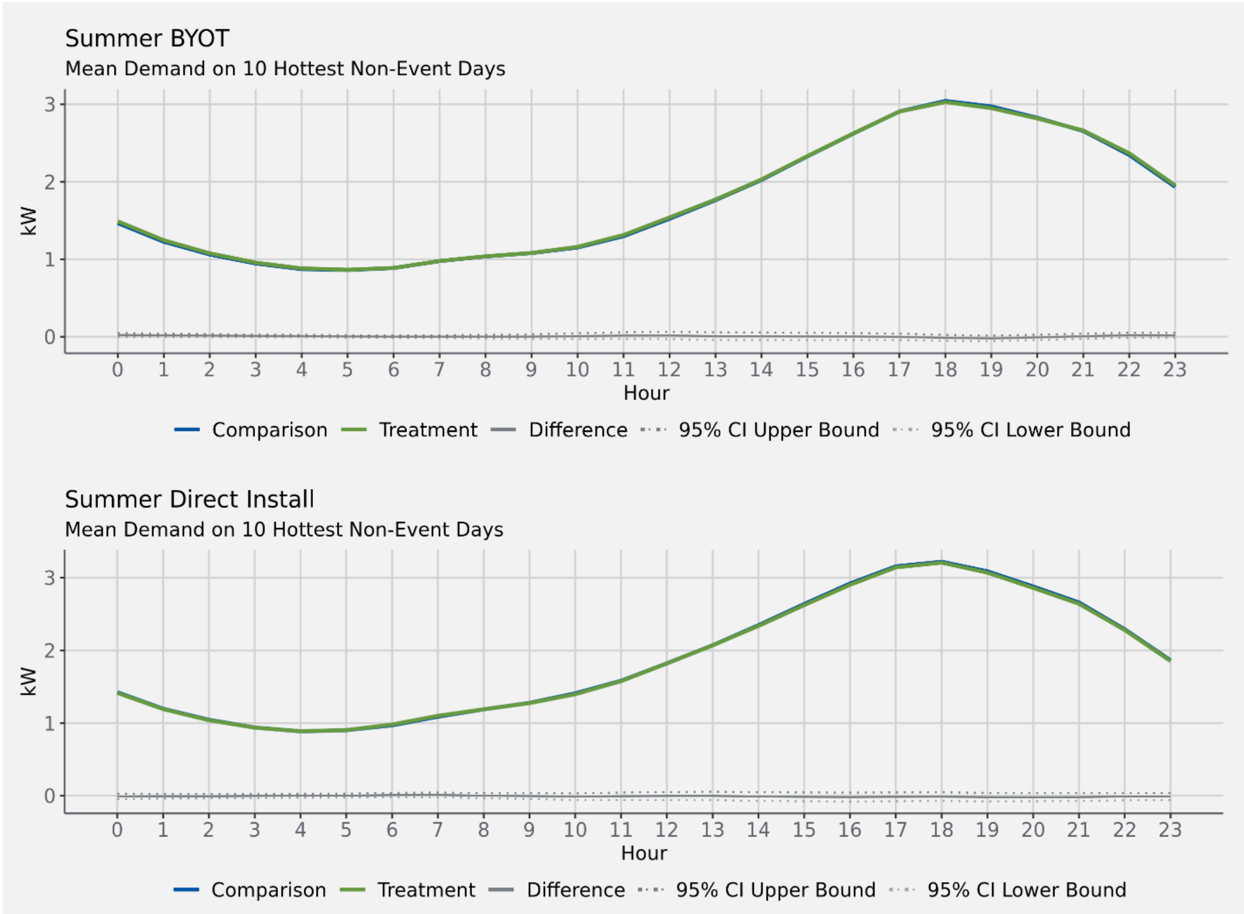
[24] Differences were statistically significant at the 95% confidence level.

Figure A-1. Equivalency of Treatment and Matched Comparison Groups – Winter 2020/2021



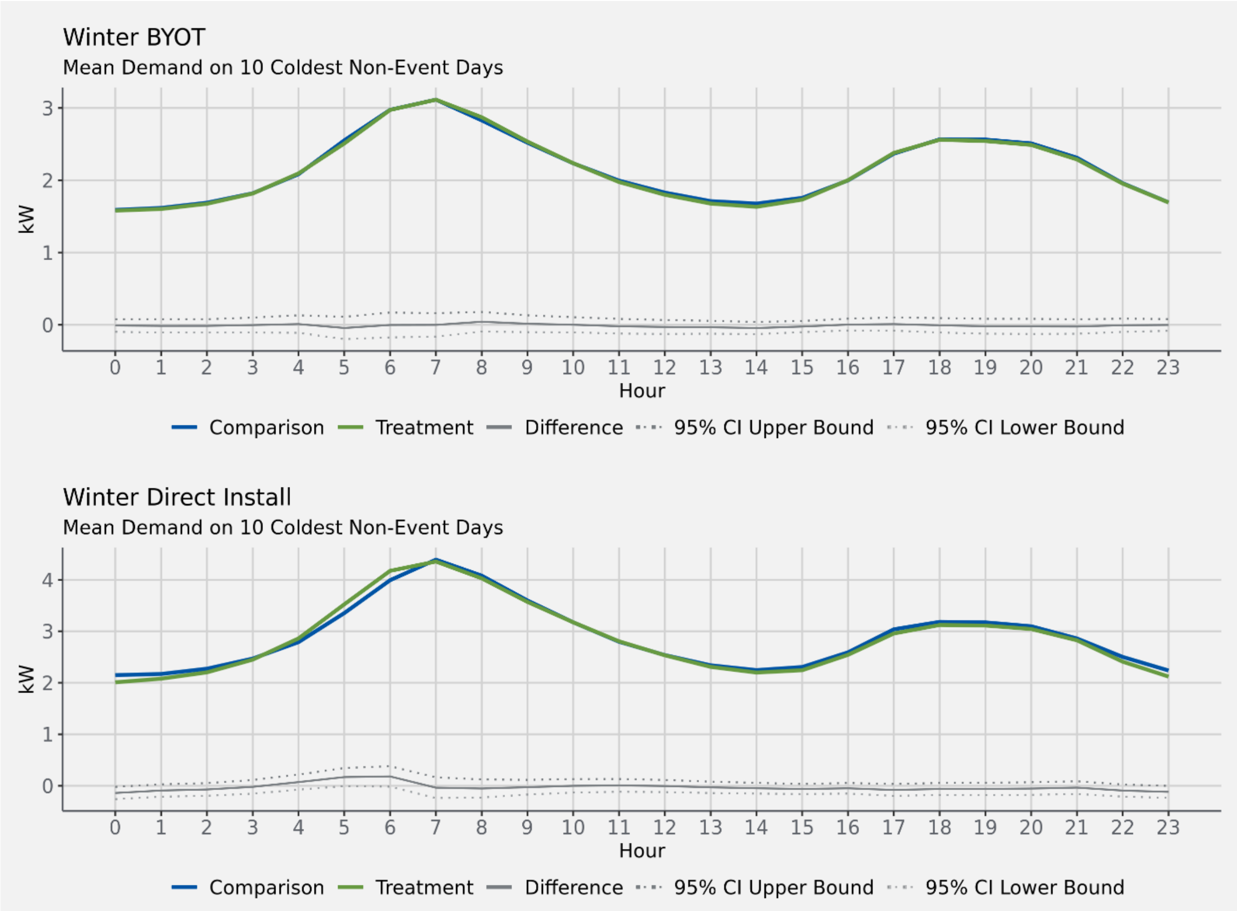
Note: Figures show average demand per customer on the ten coldest non-event, non-holiday weekdays during the winter 2020-2021 season. The analysis ranges from December 1st, 2020 to February 28th, 2021.

Figure A-2. Equivalency of Treatment and Matched Comparison Groups – Summer 2021



Note: Figures show average demand per customer on the ten hottest non-event, non-holiday weekdays during the summer 2021 season. The analysis ranges from June 1 to September 30, 2021.

Figure A-3. Equivalency of Treatment and Matched Comparison Groups – Winter 2021/2022



Note: Figures show average demand per customer on the ten coldest non-event, non-holiday weekdays during the winter 2021-2022 season. The analysis ranges from December 1, 2021 to February 28, 2022.

Load Impact Analysis

Savings Estimation Approach

Cadmus estimated savings by collecting individual customer AMI meter interval consumption data and by comparing the demand of customers in the treatment and matched comparison groups during each event hour. We employed panel regression analysis to estimate demand impacts for the two hours before, three hours during, and four hours after each event. In addition to assignment to the treatment or comparison group, the panel regression controlled for the impacts of hour-of-the-day, weather, and differences between customers in their average demand.

Letting 'i' denote the customer, where i=1, 2, …, N, and letting 't' denote the hour of the day, where t=1, 2, …, T, the model took the following form:

Equation 1

$$kWh_{it} = \sum_{k=0}^{23} \beta_k Hour_{kt} + \sum_{k=0}^{23} \gamma_k Hour_{kt} * DH_{it} + \sum_{k=0}^{23} \vartheta_k Hour_{kt} * I(Treat = 1)_i + \sum_{k=0}^{23} \tau_k Hour_{kt} * DH_{it} * I(Treat = 1)_i + \sum_{m=1}^{9} \sum_{j=1}^{J} \pi_{mj} I(Event = 1)_{mjt} + \sum_{m=1}^{9} \sum_{j=1}^{3} \theta_{mj} I(Treat = 1)_i * I(Event = 1)_{mjt} + \sum_{m=1}^{9} \sum_{n=1}^{N} \varphi_{mn} I(PostEvent = 1)_{nmt} + \sum_{m=1}^{9} \sum_{n=1}^{N} \delta_{mn} I(Treat = 1)_i * I(PostEvent = 1)_{nmt} + \sum_{m=1}^{9} \sum_{l=1}^{L} \omega_{ml} I(PreEvent = 1)_{mlt} + \sum_{m=1}^{9} \sum_{l=1}^{L} \rho_{ml} I(Treat = 1)_i * I(PreEvent = 1)_{mlt} + \varepsilon_{it}$$

Where:

kWh_{it} = Electricity consumption in kilowatt-hours of customer 'i' during hour 't'

β_k = Average load impact (kWh/hour) per customer during hour 'k' on customer consumption

$Hour_{kt}$ = Indicator variable for hour of the day; equals 1 if hour 't' is the kth hour of the day, where k=0, 1, 2, …, 23, and equals 0 otherwise

γ_k = Average effect per customer of a heating or cooling degree hour on customer consumption in hour 'k'

DH_{it} = Heating or cooling degree hour for customer 'i' in hour 't' for a given base temperature

ϑ_k = Average incremental load impact (kWh/hour) per customer for participant homes in hour 'k'

τ_k = Average incremental effect per heating or cooling degree hour per customer on consumption of participant homes in hour 'k'

π_{mj} = Average load impact (kWh/hour) per customer during hour 'j' of event 'm,' which affects treatment and control group customers

$I(Event=1)_{mjt}$ = Indicator variable for event hour; equals 1 if hour 't' is the jth hour, j=1,2,…J, where J=2 or 3 depending on event length of event m, m=1, 2, …, 9, and equals 0 otherwise

θ_{mj} = Average load impact (kWh/hour) per participant home during hour 'j' of event 'm'

$\pi_{mj} I(Treat=1)_i$ = Indicator variable for assignment to treatment group; equals 1 if customer 'i' was assigned to the treatment group and equals 0 otherwise

$\theta_{mj} \varphi_{mn}$ = Average load impact (kWh/hour) per customer during post-event hour 'n' of event 'm,' which affects treatment and control group customers

$I(PostEvent=1)_{nmt}$ = Indicator variable for post-event hour; equals 1 if hour 't' is the nth hour after the event, n=1,2,…,N, of event m, m=1, 2, …, 9, and equals 0 otherwise

δ_{mn} = Average load impact (kWh/hour) per participant home during post-event hour 'n' of event 'm'

ω_{ml} = Average load impact (kWh/hour) per customer during pre-event hour 'l' of event 'm,' which affects treatment and control group customers

$I(PreEvent=1)_{mlt}$ = Indicator variable for pre-event hour; equals 1 if hour 't' is the lth hour before the event, l=1,2,…,L, of event m, m=1, 2, …, 9, and equals 0 otherwise

ρ_{ml} = Average load impact (kWh/hour) per participant home during pre-event hour 'l' of event 'm'

ε_{it} = Random error for customer 'i' in hour 't'

Cadmus estimated the models by OLS and clustered the standard errors on customers to account for correlations over time in customer demand. The model included the 10 hottest non-holiday weekdays days in June, July, August, or September 2021 for the summer and the 10 coldest non-holiday weekend days in December, January, and February for winter 2020/2021 and 2021/2022. We estimated alternative model specifications to test the estimates' robustness to specification changes and found that the results were very robust.

Staff Interviews

During fall 2021 and spring 2022, Cadmus interviewed utility and implementation staff involved with the Smart Thermostat pilot. For the fall 2021 interviews, Cadmus conducted one interview each with PGE, Resideo, and CLEAResult to understand the pilot's winter 2020/2021 and summer 2021 operations and pilot delivery successes and challenges. In spring 2022, Cadmus only conducted one interview, with PGE staff, to learn about the pilot's winter 2021/2022 operations and pilot delivery successes and challenges.

Copies of the interview guides are provided in *Appendix D*.

Customer Surveys

Cadmus designed and administered two surveys during summer 2021:

- Summer 2021 survey for Event 4 (fielded on July 31, 2021)
- Summer 2021 survey for Event 7 (fielded on August 14, 2021)

The same survey instrument was used for both events. We administered these surveys within 48 hours following the event. Cadmus did not conduct any surveys for the winter seasons.

Survey Design

Cadmus administered both summer 2021 event surveys to customers enrolled in the pilot across tracks and experimental groups. The survey covered several topics:

- Event awareness
- Event notifications
- Thermal comfort before and during events

- Event participation and overrides
- Satisfaction with the program and with PGE

The survey took respondents about seven minutes to complete. Respondents did not receive an incentive for completing the survey.

A copy of the event survey is provided in *Appendix E*.

Survey Data Analysis

Cadmus compiled frequency outputs, analyzed open-end comments according to thematic similarities, and ran statistical tests to determine whether survey results differed significantly between subpopulations. Specifically, Cadmus compared survey results by experimental group at the 90% confidence level (or $p \leq 0.10$ significance level). When reporting the overall results, we weighted the survey data to closely align with the population proportions.

Appendix B. Additional Impact Findings

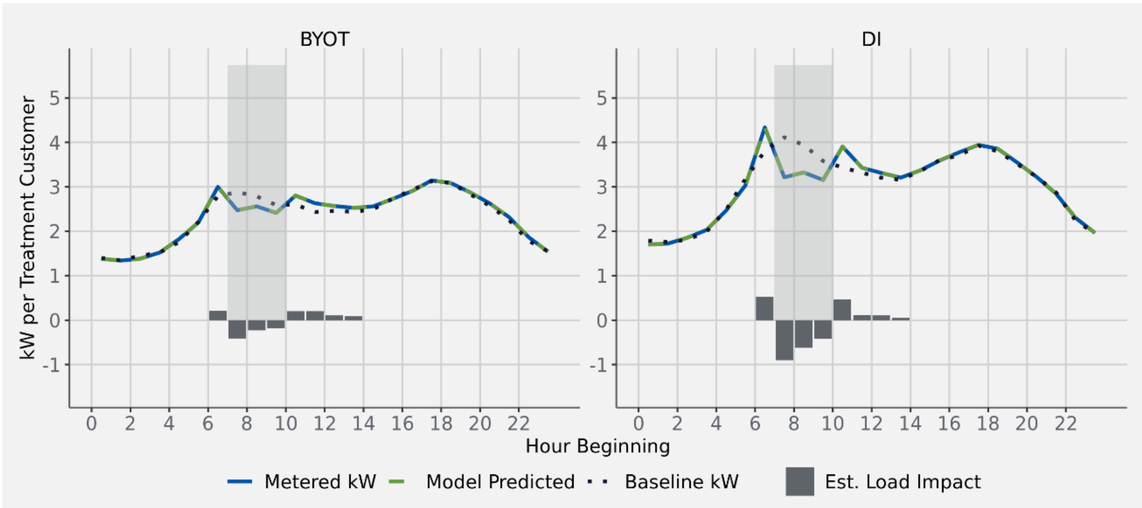
This appendix provides additional details about the demand impacts, including event day load impacts, point estimates of demand savings by event hour and event-day conservation effect, and demand savings by HVAC system type for the summer and winter seasons.

Load Impacts by Event Days – Winter 2020/2021

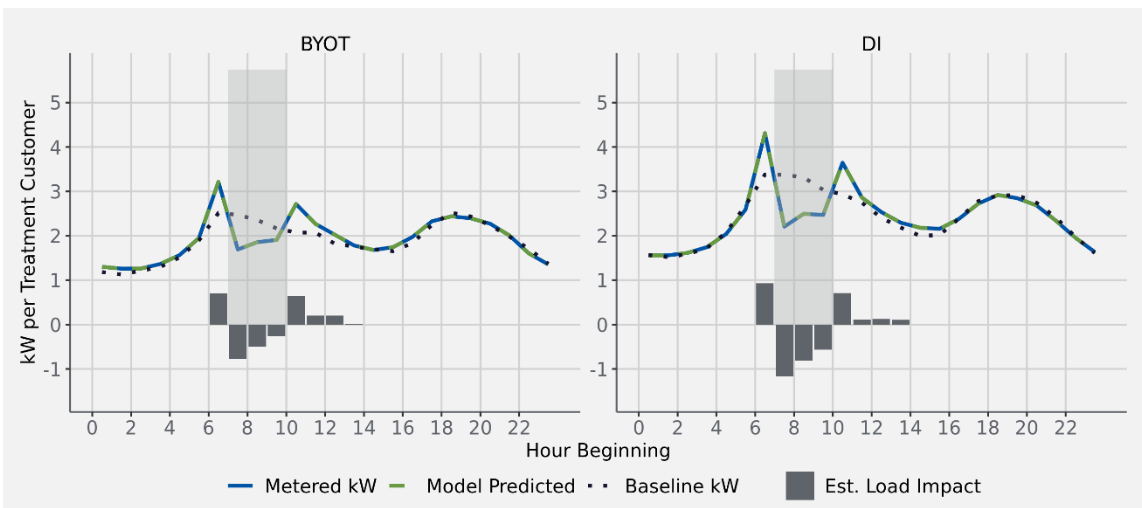
Figure B-1 displays estimates of the average load impacts per participant home for demand response events in winter 2020/2021. The bars show the estimated load impact for the hours before, during, and after each demand response event. The blue line shows the metered load. The dashed green line shows the model prediction of the metered load. The dotted line shows the baseline demand, which is the counterfactual of how much electricity the average customer would have used if the event had not been called.

Figure B-1. Average Daily Load Impacts per Participant Home by Event – Winter 2020/2021

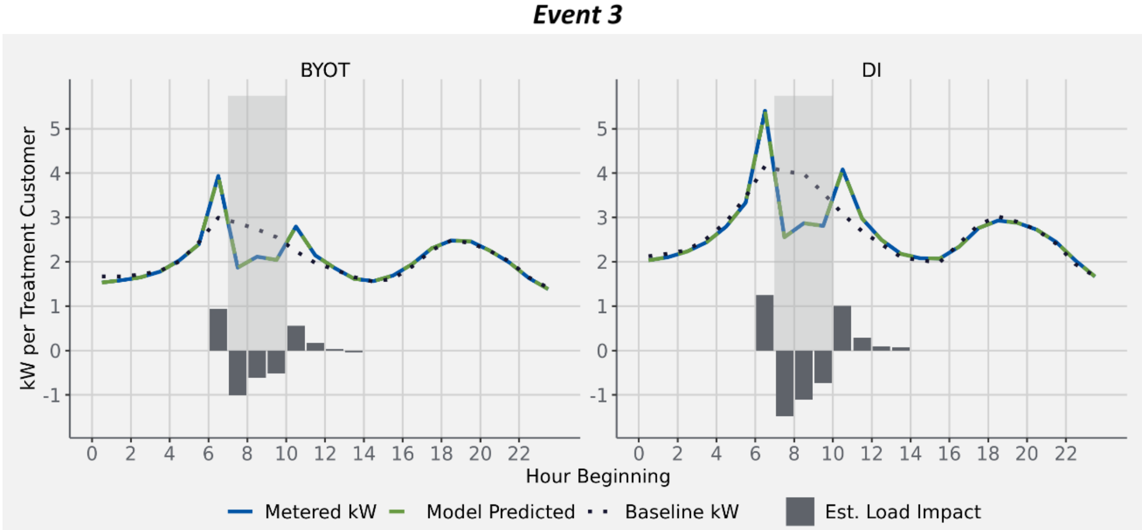
Event 1



Event 2



Event 3

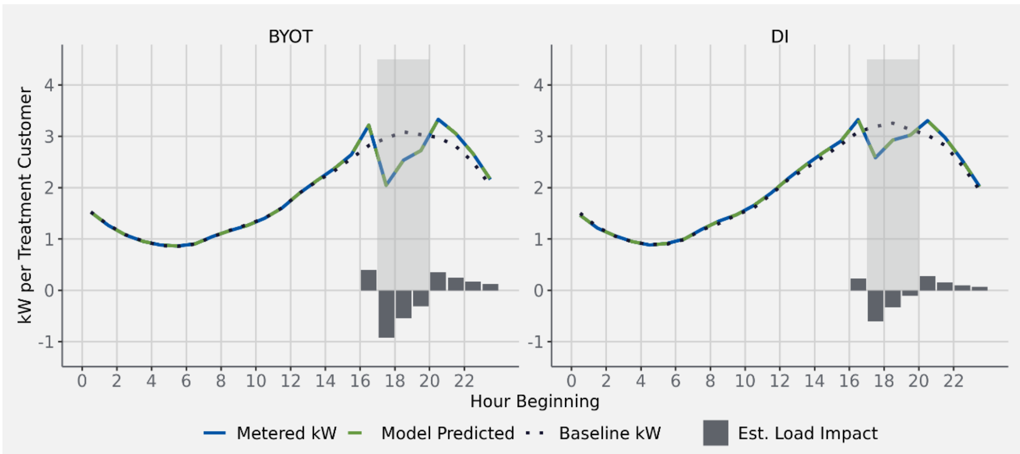


Load Impacts by Event Days – Summer 2021

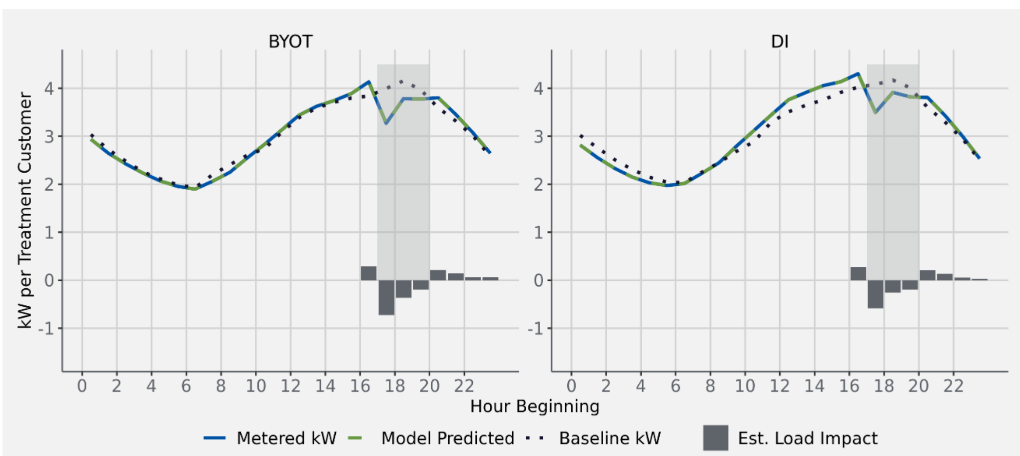
Figure B-2 displays estimates of the average load impacts per participant home for demand response events in summer 2021.

Figure B-2. Average Daily Load Impacts per Participant Home by Event – Summer 2021

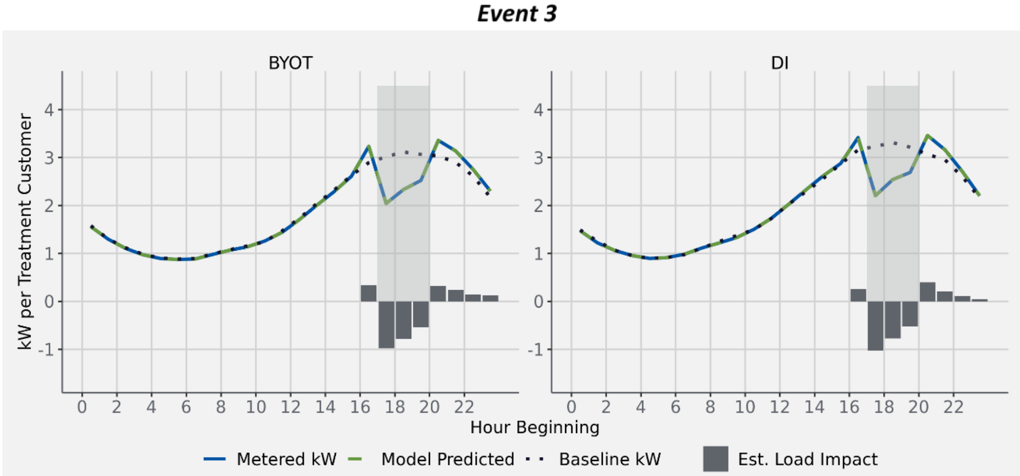
Event 1



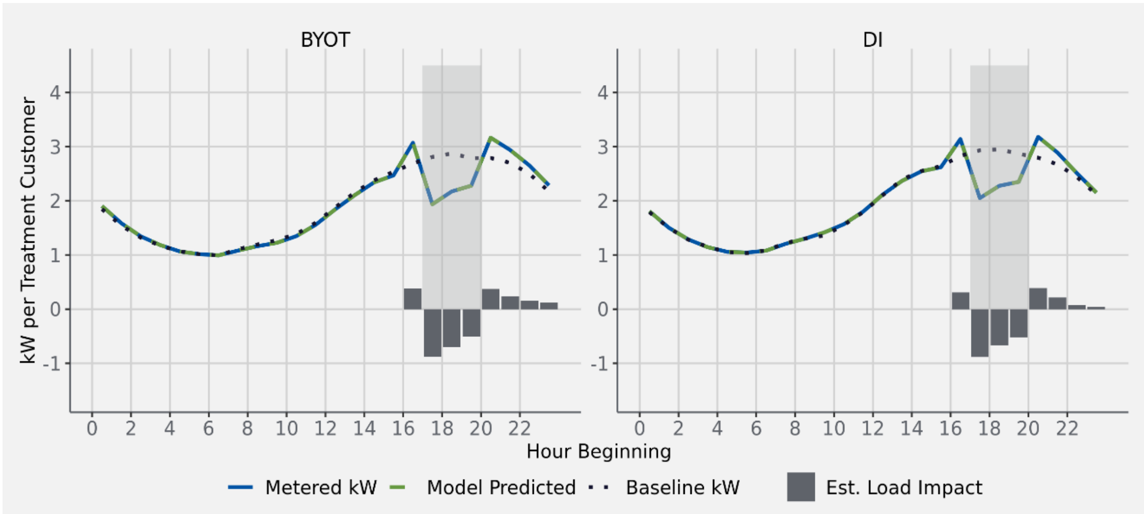
Event 2



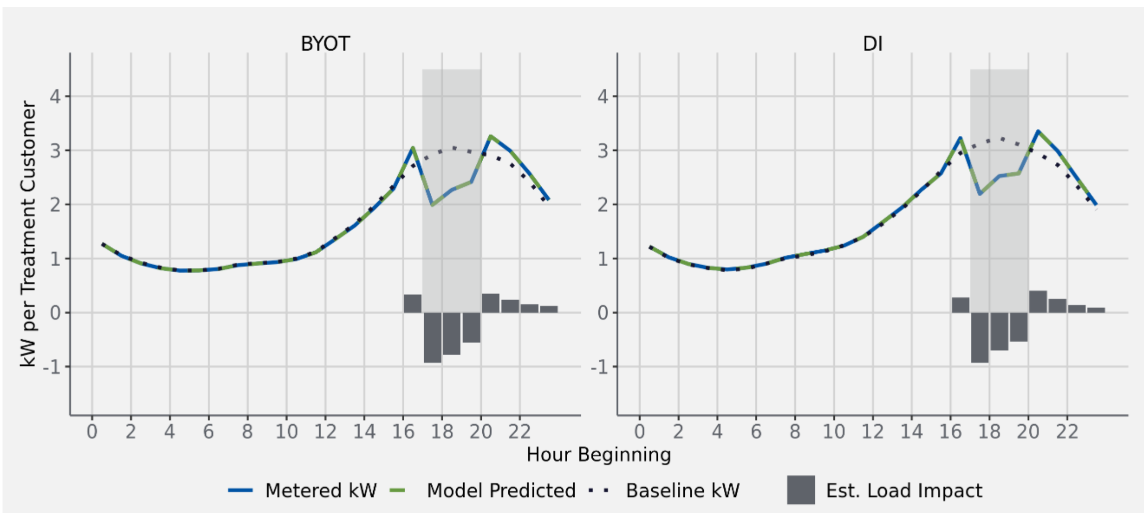
Event 3



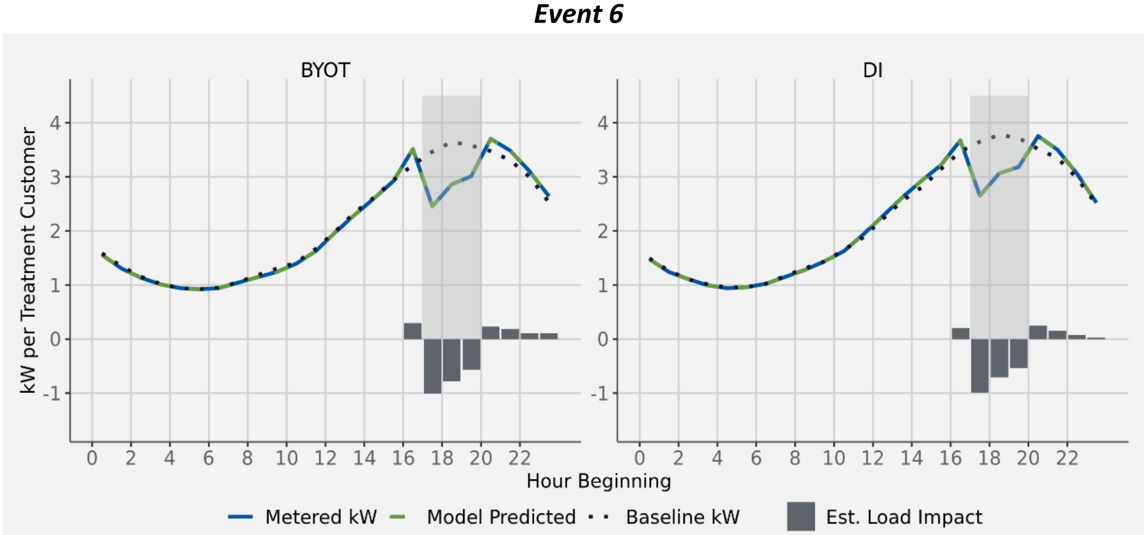
Event 4



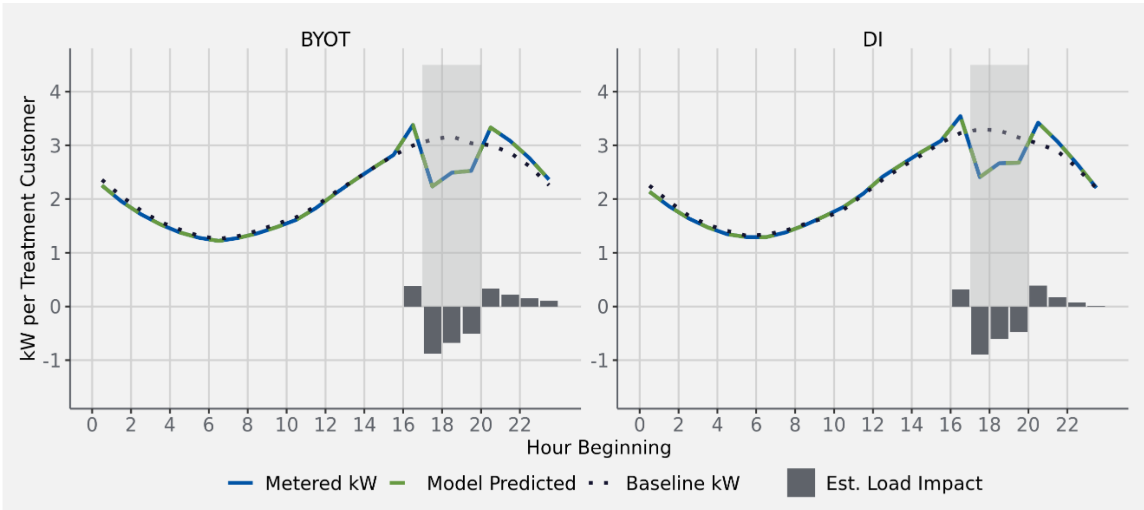
Event 5



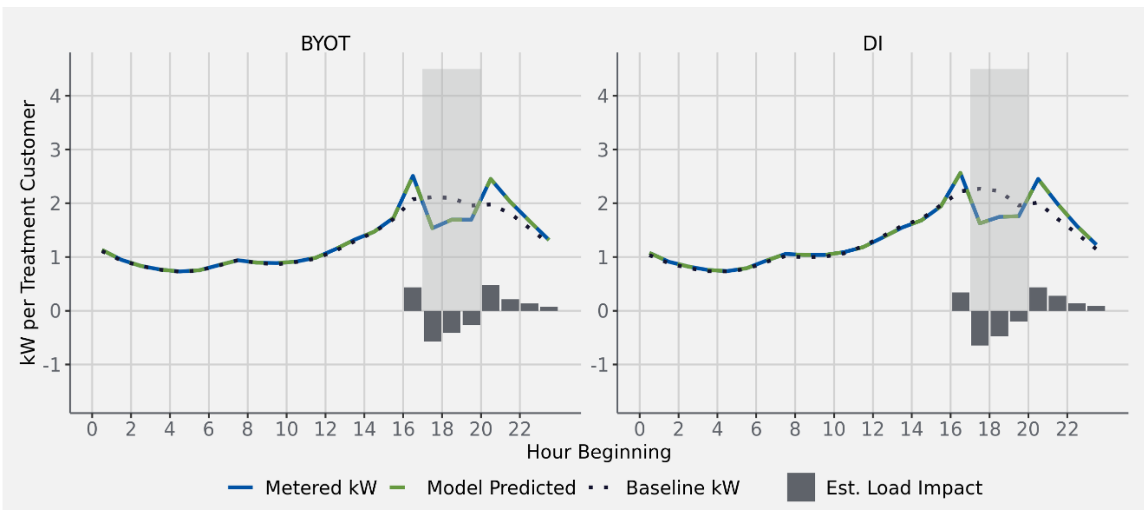
Event 6



Event 7



Event 8

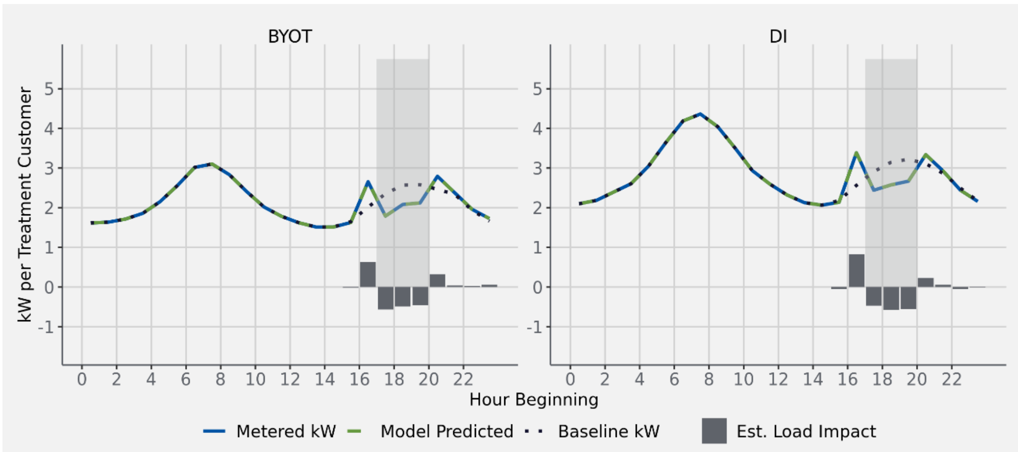


Load Impacts by Event Days – Winter 2021/2022

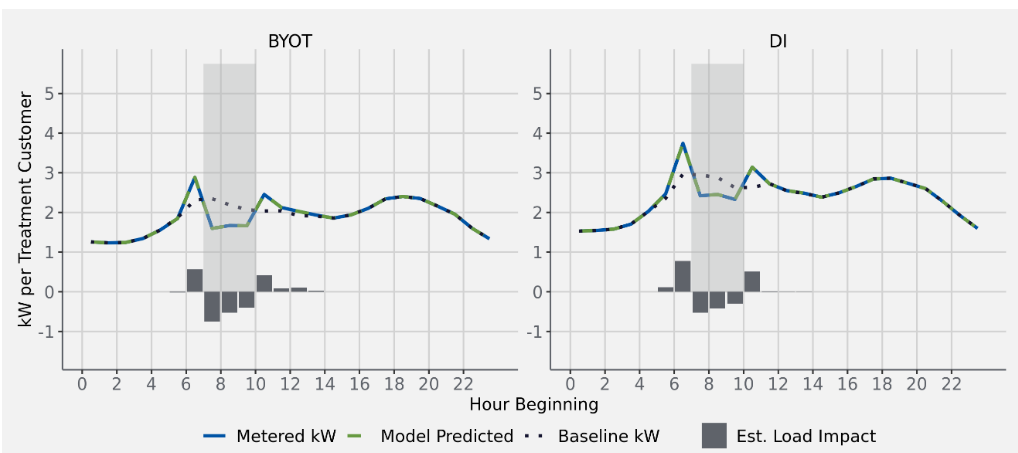
Figure B-3 displays estimates of the average load impacts per participant home for demand response events in winter 2021/2022.

Figure B-3. Average Daily Load Impacts per Participant Home by Event – Winter 2021/2022

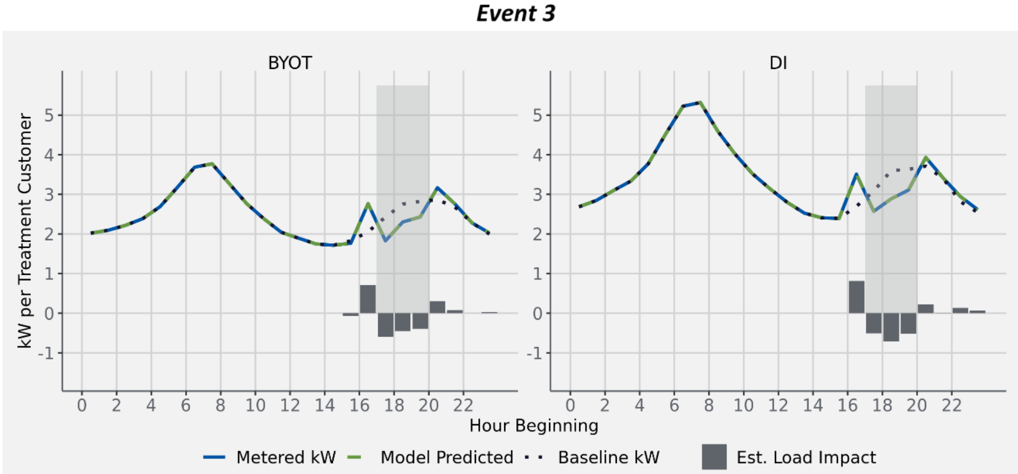
Event 1



Event 2



Event 3



Event Impact Estimates Tables

Table B-1 through Table B-6 show estimated load impacts per treatment customer for each event and event hour, average demand impacts across all event hours, and average energy impact.

Table B-1. BYOT Demand Reduction by Event – Winter 2020/2021

Event Hour	Event		
	1	2	3
Event Start Time	7:00 a.m.	7:00 a.m.	7:00 a.m.
Pre-Event Hour 1	0.21***	0.70***	0.94***
Event Hour 1	**-0.41*****	**-0.78*****	**-1.01*****
Event Hour 2	**-0.23*****	**-0.50*****	**-0.62*****
Event Hour 3	**-0.18*****	**-0.26*****	**-0.51*****
Post-Event Hour 1	0.20***	0.64***	0.56***
Post-Event Hour 2	0.20***	0.20***	0.17***
Post-Event Hour 3	0.11**	0.20***	0.03
Post-Event Hour 4	0.09	0.02	-0.04
Event Average Demand Impact (kW)	**-0.27**	**-0.51**	**-0.71**
Average Energy Impact (kWh)	**-0.09**	**0.21**	**-0.47**

Notes: Estimates obtained from Cadmus' panel regression analysis of customer hourly electricity demand. ***, **, * denotes that the estimate is statistically significant at the 1%, 5%, or 10% level, respectively. Cadmus estimated energy impacts by summing the load impacts across the pre-event hour 1, event hours, and post-event hours 1 through 4.

Table B-2. Direct Install Demand Reduction by Event – Winter 2020/2021

Event Hour	Event		
	1	2	3
Event Start Time	7:00 a.m.	7:00 a.m.	7:00 a.m.
Pre-Event Hour 1	0.53***	0.93***	1.25***
Event Hour 1	-0.90***	-1.17***	-1.48***
Event Hour 2	-0.62***	-0.82***	-1.11***
Event Hour 3	-0.43***	-0.57***	-0.74***
Post-Event Hour 1	0.47***	0.71***	1.00***
Post-Event Hour 2	0.11	0.11*	0.29***
Post-Event Hour 3	0.11	0.13**	0.10
Post-Event Hour 4	0.05	0.11*	0.07
Event Average Demand Impact (kW)	**-0.65**	**-0.85**	**-1.11**
Average Energy Impact (kWh)	**-0.95**	**-0.56**	**-0.80**

Notes: Estimates obtained from Cadmus' panel regression analysis of customer hourly electricity demand. ***, **, * denotes that the estimate is statistically significant at the 1%, 5%, or 10% level, respectively. Cadmus estimated energy impacts by summing the load impacts across the pre-event hour 1, event hours, and post-event hours 1 through 4.

Table B-3. BYOT Demand Reduction by Event – Summer 2021

Event Hour	Event							
	1	2	3	4	5	6	7	8
Event Start Time	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.
Pre-Event Hour 1	0.40***	0.29***	0.34***	0.38***	0.33***	0.29***	0.38***	0.43***
Event Hour 1	**-0.92*** **	**-0.73*** **	**-0.97*** **	**-0.87*** **	**-0.94*** **	**-1.01*** **	**-0.88*** **	**-0.58*** **
Event Hour 2	**-0.55*** **	**-0.37*** **	**-0.78*** **	**-0.70*** **	**-0.78*** **	**-0.78*** **	**-0.68*** **	**-0.40*** **
Event Hour 3	**-0.31*** **	**-0.19*** **	**-0.54*** **	**-0.51*** **	**-0.56*** **	**-0.57*** **	**-0.51*** **	**-0.26*** **
Post-Event Hour 1	0.35***	0.21***	0.32***	0.37***	0.35***	0.23***	0.33***	0.47***
Post-Event Hour 2	0.25***	0.14***	0.24***	0.24***	0.24***	0.18***	0.22***	0.22***
Post-Event Hour 3	0.17***	0.06***	0.14***	0.15***	0.15***	0.10***	0.15***	0.13***
Post-Event Hour 4	0.12***	0.07***	0.13***	0.11***	0.12***	0.11***	0.10***	0.07***
Event Average Demand Impact (kW)	**-0.59**	**-0.43**	**-0.77**	**-0.69**	**-0.76**	**-0.79**	**-0.69**	**-0.41**
Average Energy Impact (kWh)	**-0.49**	**-0.51**	**-1.13**	**-0.82**	**-1.08**	**-1.45**	**-0.88**	**0.08**

Notes: Estimates obtained from Cadmus' panel regression analysis of customer hourly electricity demand. ***, **, * denotes that the estimate is statistically significant at the 1%, 5%, or 10% level, respectively. Cadmus estimated energy impacts by summing the load impacts across the pre-event hour 1, event hours, and post-event hours 1 through 4 (demonstrating significance).

Table B-4. Direct Install Demand Reduction by Event – Summer 2021

Event Hour	Event							
	1	2	3	4	5	6	7	8
Event Start Time	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.	5:00 p.m.
Pre-Event Hour 1	0.24***	0.28***	0.26***	0.31***	0.28***	0.21***	0.31***	0.34***
Event Hour 1	**-0.61*** **	**-0.58*** **	**-1.03*** **	**-0.88*** **	**-0.94*** **	**-1.00*** **	**-0.89*** **	**-0.64*** **
Event Hour 2	**-0.33*** **	**-0.26*** **	**-0.77*** **	**-0.67*** **	**-0.71*** **	**-0.71*** **	**-0.61*** **	**-0.48*** **
Event Hour 3	**-0.11*** **	**-0.19*** **	**-0.52*** **	**-0.52*** **	**-0.54*** **	**-0.53*** **	**-0.47*** **	**-0.20*** **
Post-Event Hour 1	0.28***	0.21***	0.40***	0.39***	0.41***	0.24***	0.39***	0.44***
Post-Event Hour 2	0.15***	0.14***	0.21***	0.22***	0.26***	0.15***	0.18***	0.28***
Post-Event Hour 3	0.10***	0.06**	0.11***	0.07**	0.14***	0.08**	0.07***	0.14***
Post-Event Hour 4	0.07***	0.03	0.04*	0.04	0.09***	0.03	0.01	0.08***
Event Average Demand Impact (kW)	**-0.35**	**-0.34**	**-0.77**	**-0.69**	**-0.73**	**-0.75**	**-0.66**	**-0.44**
Average Energy Impact (kWh)	**-0.20**	**-0.35**	**-1.31**	**-1.09**	**-1.01**	**-1.56**	**-1.02**	**-0.04**

Notes: Estimates obtained from Cadmus' panel regression analysis of customer hourly electricity demand. ***, **, * denotes that the estimate is statistically significant at the 1%, 5%, or 10% level, respectively. Cadmus estimated energy impacts by summing the load impacts across the pre-event hour 1, event hours, and post-event hours 1 through 4 (demonstrating significance).

Table B-5. BYOT Demand Reduction by Event – Winter 2021/2022

Event Hour	Event		
	1	2	3
Event Start Time	5:00 p.m.	7:00 a.m.	5:00 p.m.
Pre-Event Hour 1	0.64***	0.57***	0.71***
Event Hour 1	-0.56***	-0.75***	-0.60***
Event Hour 2	-0.49***	-0.52***	-0.45***
Event Hour 3	-0.46***	-0.41***	-0.39***
Post-Event Hour 1	0.33***	0.42***	0.30***
Post-Event Hour 2	0.04	0.08	0.08
Post-Event Hour 3	0.02	0.11**	0.00
Post-Event Hour 4	0.06*	0.03	0.03
Event Average Demand Impact (kW)	**-0.50**	**-0.56**	**-0.48**
Average Energy Impact (kWh)	**-0.48**	**-0.58**	**-0.43**

Notes: Estimates obtained from Cadmus' panel regression analysis of customer hourly electricity demand. ***, **, * denotes that the estimate is statistically significant at the 1%, 5%, or 10% level, respectively. Cadmus estimated energy impacts by summing the load impacts across the pre-event hour 1, event hours, and post-event hours 1 through 4.

Table B-6. Direct Install Demand Reduction by Event – Winter 2021/2022

Event Hour	Event		
	1	2	3
Event Start Time	5:00 p.m.	7:00 a.m.	5:00 p.m.
Pre-Event Hour 1	0.82***	0.77***	0.81***
Event Hour 1	-0.47***	-0.53***	-0.51***
Event Hour 2	-0.57***	-0.43***	-0.71***
Event Hour 3	-0.55***	-0.30***	-0.52***
Post-Event Hour 1	0.23***	0.51***	0.22***
Post-Event Hour 2	0.06	0.00	0.01
Post-Event Hour 3	-0.05	0.01	0.13*
Post-Event Hour 4	-0.01	0.01	0.07
Event Average Demand Impact (kW)	**-0.53**	**-0.42**	**-0.58**
Average Energy Impact (kWh)	**-0.54**	**0.03**	**-0.58**

Notes: Estimates obtained from Cadmus' panel regression analysis of customer hourly electricity demand. ***, **, * denotes that the estimate is statistically significant at the 1%, 5%, or 10% level, respectively. Cadmus estimated energy impacts by summing the load impacts across the pre-event hour 1, event hours, and post-event hours 1 through 4.

Appendix C. Summer 2021 Survey Regression Analysis

This appendix outlines Cadmus' approach and the results of our summer 2021 survey regression analysis.

Approach

Cadmus used linear probability models to assess the relationships between customers' event awareness, thermal comfort before and during demand response events, and satisfaction with the pilot and PGE as reported by respondents in the summer 2021 customer surveys.

Results

Table C-1 and Table C-2 report results from the analysis. Cadmus estimated the eight linear probability models (each corresponding to an outcome) using OLS, and the standard errors were heteroskedasticity-robust standard errors based on White (1980).[25] All regressions included control variables for the customer treatment group, thermostat track (BYOT or Direct Install), and demand response micro-segment (see Table C-3 for additional detail). Since the models are linear probability models, the estimated coefficients can be interpreted as the marginal effects of the independent variables (indicated by the row headings) on the modeled outcome (indicated by the column heading). For example, in Table C-2 model 1, the coefficient on Notification Treatment indicates that survey respondents in that treatment group were 25.5 percentage points, or 86% (0.255/0.297), more likely to be aware of events than respondents in the standard demand response treatment group.

[25] White, Halbert (1980). "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity." *Econometrica* (48): 817–838.

Table C-1. Summer 2021 Intelligent Demand Response Experiment Regression Analysis Output

	(1) Event Awareness	(2) Comfort before Event	(3) Comfort during Event	(4) Program Satisfaction	(5) PGE Satisfaction
Intercept	0.671***	0.864***	0.945***	0.874***	0.910***
	(0.102)	(0.131)	(0090)	(0.076)	(0.055)
IDR Treatment	-0.0645*	0.015	-0.027	0.043	0.000
	(0.037)	(0.043)	(0.056)	(0.037)	(0.028)
Big Impactor	0.085	0.001	-0.308***	-0.131	-0.072
	(0.106)	(0.137)	(0.095)	(0.082)	(0.062)
Fast Grower	0.103	-0.043	-0.293***	-0.098	-0.055
	(0.105)	(0.136)	(0.091)	(0.079)	(0.059)
Middle Mover	0.059	0.041	-0.359***	-0.073	-0.019
	(0.109)	(0.137)	(0.099)	(0.082)	(0.060)
Borderliner	0.117	0.078	-0.354***	-0.081	-0.028
	(0.111)	(0.140)	(0.112)	(0.089)	(0.063)
BYOT	0.058*	-0.054*	-0.108**	-0.025	0.030
	(0.030)	(0.033)	(0.044)	(0.029)	(0.023)
N	835	532	532	834	830

Notes: All regressions were linear probability models estimated with data from the summer 2021 surveys and by OLS, with robust standard errors in parentheses. The column headings show the model dependent variable and the row names represent the independent variables. All independent and dependent variables are 0-1 indicator variables and defined as follows: IDR Treatment equals 1 if the respondent was assigned the IDR treatment and equals 0 otherwise. Big Impactor, Fast Grower, Middle Mover, and Borderliner are 0-1 indicator variables for the demand response micro-segments. Event Awareness equals 1 if the respondent reported being aware of the event and equals 0 otherwise. Comfort before Event equals 1 if the respondent rated their thermal comfort before the event as a 6 or higher on a 0-10 scale and equals 0 if the respondent rated their comfort below a 6. Comfort during Event pertains to thermal comfort during the event and is defined analogously. Program Satisfaction equals 1 if the respondent rated their satisfaction as a 6 or higher on a 0-10 scale. PGE Satisfaction is defined analogously. The omitted category is customers who were assigned to the standard demand response control group, were low engagers, and were in the Direct Install track. ***, **, and * denote that the estimated coefficient is statistically significant at the 1%, 5%, and 10% levels, respectively.

Table C-2. Summer 2021 Event Notification Experiment Regression Analysis Output

	(1)	(2)	(3)
	Event Awareness	Pilot Satisfaction	PGE Satisfaction
Intercept	0.297***	1.032***	0.976***
	(0.137)	(0.037)	(0.033)
Notification Treatment	0.255***	-0.008	0.001
	(0.054)	(0.050)	(0.036)
Big Impactor	0.241*	-0.215***	-0.069
	(0.142)	(0.052)	(0.042)
Fast Grower	0.223	-0.223***	-0.072*
	(0.142)	(0.047)	(0.038)
Middle Mover	0.271*	-0.178***	-0.080**
	(0.148)	(0.053)	(0.038)
Borderliner	0.190	-0.247***	-0.103
	(0.164)	(0.091)	(0.066)
BYOT	0.108**	-0.034	0.008
	(0.048)	(0.043)	(0.032)
N	420	420	419

Notes: All regressions were linear probability models estimated with data from the summer 2021 surveys and by OLS, with robust standard errors in parentheses. The column headings show the model dependent variable and the row names represent the independent variables. All independent and dependent variables are 0-1 indicator variables and defined as follows: IDR Treatment equals 1 if the respondent was assigned the IDR treatment and equals 0 otherwise. Big Impactor, Fast Grower, Middle Mover, and Borderliner are 0-1 indicator variables for the demand response micro-segments. Event Awareness equals 1 if the respondent reported being aware of the event and equals 0 otherwise. Comfort before Event equals 1 if the respondent rated their thermal comfort before the event as a 6 or higher on a 0-10 scale and equals 0 if the respondent rated their comfort below a 6. Comfort during Event pertains to thermal comfort during the event and is defined analogously. Pilot Satisfaction equals 1 if the respondent rated their satisfaction as a 6 or higher on a 0-10 scale. PGE Satisfaction is defined analogously. The omitted category is customers who were assigned to the standard demand response control group, were low engagers, and were in the Direct Install track. ***, **, and * denote that the estimated coefficient is statistically significant at the 1%, 5%, and 10% levels, respectively.

Table C-3. Residential Demand Response Micro-Segments

Micro-Segments	Description
Big Impactors (highest potential)	Larger single-family dwellings, high income ranges, highest energy bills, busy households, and typically have digital subscription activity
Fast Growers	Tends to track tightly with Big Impactors, except for being the most engaged with technology behaviors; also the most likely to make online purchases
Middle Movers	Will track with Fast Growers, with proportionally lower values on housing sizes and income but notably close with respect to technology
Borderliners	Some individuals in this group tend by value to lean into Low Engagers while some are aligned more with Middle Movers; these are potential Middle Movers who tend to rent
Low Engagers (lowest potential)	Most likely to interact with newspapers, flyers, and traditional media; least technologically engaged; tend to live in smaller square foot housing, have lower household income, and have a comparatively older demographic with fewer children living at home

Source: PGE

Appendix D. Staff Interview Guides

During fall 2021, Cadmus conducted one interview each with PGE, Resideo, and CLEAResult to understand the pilot's winter 2020/2021 and summer 2021 operations and pilot delivery successes and challenges. In spring 2022, Cadmus interviewed PGE staff to learn about the pilot's winter 2021/2022 operations and pilot delivery successes and challenges.

The interview guides are provided on the following pages.

CADMUS

PGE Residential Smart Thermostat Program

Process Evaluation Interview Guide for PGE Staff

Respondent name:

Interview date: Interviewer initials:

Topics	Corresponding Items
Program Management	Section A
Program Goals	Section B
Marketing and Recruitment	Section C
Enrollment and Installation	Section D
Event Implementation	Section E
Customer Retention	Section F
Risks and Challenges Moving Forward	Section G
Wrap Up	Section H

Introduction: Thank you for making time for this interview. This interview is to help us understand how the Residential Smart Thermostat Program operated in 2021 and is critical to informing the evaluation. This is also a chance for you to provide your perspectives on how the program is working and where implementation can improve.

A. Program Management

A1. It's been one year since we last spoke. Has PGE staff for the Residential Smart Thermostat Program remained the same since last year or has there been changes to staffing? [Probe about any staff/management changes]

   A. Who is the marketing lead for Smart Thermostats?

A2. How has it been working with Resideo this year?

   A. Are you satisfied with Resideo's management of the program? (i.e., the timing, coordination, and communication)
   B. Why or why not?

A3. How has it been working with CLEAResult this year?

   A. Are you satisfied with CLEAResult's management of the program? (i.e., the timing, coordination, and communication)
   B. Why or why not?

B. Program Goals

Next, I'd like to ask you questions about the program goals and status to date.

B1. What is your capacity goal for 2021?
   A. Are you still combining BYOT and Direct Install together?

B2. Do you think you met your capacity goal for 2021?
   A. Why or why not?

B3. What is your enrollment goal for 2021 and your overall enrollment goal?
   A. How many new thermostats enrolled in 2021 and how many thermostats are enrolled to date?

B4. Were there any other goals beside capacity and enrollment for 2021?

C. Marketing and Recruitment

These next questions are about marketing and customer recruitment.

C1. During 2021, how did PGE market the BYOT and Direct Install program?
   A. Did PGE work with the thermostat manufacturers (ecobee, Honeywell, and Nest) on customer recruitment? If so, please describe the work you did.

C2. During 2021, did PGE work with ETO to recruit customers?
   A. What is the current ETO smart thermostat coupon offering?
   B. How effective was the ETO coupon in recruiting customers for the program?

C3. How did you use the Marketplace to recruit customers in 2021?
   A. Was this an effective way to recruit customers?
   B. Why or why not?
   C. Are there any enrollment targets for this channel?
   D. How many enrollees signed up via Marketplace?

C4. Overall, what marketing channels or strategies have been effective in recruiting customers in 2021?

C5. How, if at all, has the Smart Thermostats and Peak Time Rebates programs worked together to promote participant migration?

C6. What marketing challenges did you encounter in 2021, if any?
   A. [If any] Did you work to resolve these challenges?
   B. [If yes] What was the outcome of the solution you implemented?

D. Enrollment and Installation

Let's discuss the enrollment process.

D1. Have there been any changes to the customer enrollment process for BYOT and Direct Install this year and how have those changes impacted enrollments?

D2. For the BYOT track, are you still encountering issues with the accuracy of identifying the customer's HVAC system?

A. [If Yes] Have you implemented any changes to improve the accuracy?
B. [If Yes] Have those changes been effective?

D3. For the Direct Install track, how is CLEAResult performing on operating the customer self-scheduling portal and completing installations?

A. Is CLEAResult installing at the rate you were expecting?

D4. Last year you worked with CLEAResult to introduce Virtual Install. What has happened to Virtual Install in 2021?

A. [If VI is active] How many virtual installs have you completed this year?
B. [If VI is active] What successes and challenges have you experienced with Virtual Install this year?
C. [If VI is not active] Why did Virtual Install go away?

E. Event Implementation

My next set of questions for you are about event implementation.

E1. You called six events this recent summer. Did you have a minimum number of events to call?

A. What factors triggered the events?

E2. How did Resideo perform on dispatching the events (e.g., communication failures) and managing the load for summer?

A. Did Resideo perform to your expectations?

E3. IDR strategies and the pre-event notification emails were tested during the summer. How effective were these?

A. Did you see any noticeable impacts to load or the customer experience?
B. Did you observe any decrease in the number of overrides?
C. Are you looking to test IDR strategies and the pre-event notification emails for the upcoming winter season? Why or why not?

E4. Regarding planned uses for IDR in PGE power operations:

A. What, if anything, changed to test IDR now?
B. Did Power Ops or other stakeholders request curtailment leveling at the resource level?
C. How should we or PGE assess performance of curtailment smoothing? [Any target parameters for variation? At what interval [1, 5, 15, 60 min]?]

E5. We'd like to know more about pre-event notifications, any strategies you may have for them, and challenges with sending these notifications. First...

A. Pre-event notifications emails were sent to subset of participants this summer. What outcomes were you hoping to see [reduce opt-out rates, improve program satisfaction, program retention, ….]?
B. If successful, do you anticipate any challenges rolling-out pre-event email notifications to all participants?
C. Will you consider other channels for pre-event notifications?
D. What forms of support and challenges [i.e., DRMS provider capabilities, OEM & legal restrictions, etc.] would the program face with implementing various pre-event notifications?

E6. Besides the pre-event notification emails, was there any customer education on how the program works and reducing overrides? If yes, please describe.

E7. Back in June of this year, there was the historic extreme heat wave and PGE called several events during that extreme heat wave. How did the program perform during those extreme heat wave days?

A. What concerns, if any, did you have about calling events on the extremely hot days?
B. What did you learn from the extreme heat wave and how will you use this information moving forward for the program?

E8. Did you encounter any other issues with managing events during 2021? If yes, please describe.

A. [If yes] Were the issues resolved and if so, how were they resolved?
B. [If A = No] Are you working on finding a solution to this issue?

F. Customer Retention

Another major topic of concern I'd like to discuss about is customer retention.

F1. How many customers did the program lose so far this year and how does it compare to last year?

A. About what percentage of theses are due to customers opting out of the program vs. service account closures?
B. Are there any other significant factors contributing to customers dropping out of the program?

F2. Have you done anything this year to make up for the program drop-outs? If yes, please describe.

F3. What does PGE do with enrolled thermostats that become disconnected from the internet and remain that way?

G. Risks and Challenges Moving Forward

These next questions are about the future of the program.

G1. Is the program ready to move to full deployment? Why or why not?

A. What questions, if any, must be answered before the program can be fully deployed?

G2. What are the biggest challenges and risks moving forward for the program?

A. Do you have solutions in place to manage these risks and overcome the challenges? If yes, please describe.
B. Is the program cost-effective and is this a barrier for moving forward?
C. [If yes] Are there any ideas or plans to make the program more cost-effective? If yes, please describe.
D. What concerns do you have about how thermostat manufacturer data privacy rules will affect the program implementation and evaluation?
E. As Time of Day pricing rolls out, do you have any concerns that it may cannibalize some of Smart Thermostat's savings for dual-enrolled households?
F. [If yes] Are there any strategies you are considering to deal with this challenge?

G3. Do you have any changes or improvements in store for the program in this upcoming winter and summer seasons? If yes, please describe.

G4. For the IDR group, Resideo used Honeywell's load-cycling feature—restricting the amount of time AC units' cycle during event windows—which help deliver more savings on the hottest days when thermostat setbacks produced little/no savings. Load-cycling invariably caused many of these households to experience indoor warming greater than the program's stated 2-degree setback. What strategies would the program consider for load-cycling households? For example, different program communications or increased incentives.

G5. Resideo's IDR strategy improves curtailment smoothing and event opt-out rates by dispatching higher override households later in events. This results in scenarios where higher opt-out households may receive end of season incentives by participating in fewer event hours than households dispatched at beginning of events. Do you plan to address this disparity in any way?

A. Any concerns that lower hourly participation threshold for higher opt-out households may encourage these households to remain in the program?

H. Wrap Up

I have a few final questions for you to wrap up.

H1. Overall, what would you say are your program successes for 2021?

H2. What are the biggest areas to improve on?

H3. What are you hoping to learn from this year's evaluation?

H4. Those were all the questions we had. Is there anything else Cadmus should know about that may help with the evaluation?

Thank you for your time!

CADMUS

PGE Residential Smart Thermostat Program

Process Evaluation Interview Guide for Resideo

Interviewee:

Interview Date: Interviewer:

Topics	Corresponding Items
Program Management	Section A
Customer Recruitment and Enrollment	Section B
Event Implementation	Section C
Wrap Up	Section D

Introduction: Thank you for making time for this interview. This interview is to help us understand how PGE's Smart Thermostat Program operated in 2021 and is critical to informing the evaluation. This is also a chance for you to provide your perspectives on how PGE's Smart Thermostat Program is working and where implementation can improve.

A. Program Management

A1. It's been one year since we last spoke to the Resideo team. Can you remind me of your roles and responsibilities with PGE's Smart Thermostat Program?

A2. Has the Resideo team for PGE's Smart Thermostat Program remained the same since last year or has there been changes to staffing? [Probe about any staff/management changes]

B. Customer Recruitment and Enrollment

Next, I'd like to ask you questions about customer recruitment and enrollment.

B1. During 2021, did you work with the thermostat manufacturers (ecobee, Honeywell, and Nest) on customer recruitment? If so, please describe the work you did.

B2. How are customer enrollments coming along this year?

B3. Have there been any changes to the customer enrollment process and experience this year and how have those changes impacted enrollments?

B4. How is the customer's HVAC system identified?

A. This year, have you encountered any issues with the accuracy of the HVAC identification?
B. [If A = Yes] Have you implemented any changes to improve the accuracy?
C. [If B = Yes] Have those changes been effective?

C. Event Implementation

My next set of questions for you are about how you implemented the events during 2021.

C1. Last year, you mentioned how ecobee Plus changed the way events were dispatched on some thermostats. To your knowledge, have there been any changes to the way events are dispatched?

A. [If yes] Please describe.
B. [If yes] What was the outcome of the changes?

C2. What load management strategies did you implement this past winter and summer?

A. How effective were each of these strategies? [Probe about overrides]
B. Which strategies had the best outcome for PGE's Smart Thermostat Program? (Standard DR vs. Flat IDR)
C. I understand that with Honeywell thermostats, you can cycle the AC unit on and off rather than adjust the set points. And that you deployed the Honeywell load cycling this past summer. For which events did you deploy the load cycling and how did it perform?
D. What levels of cycling were employed? (Might be length of time or a percentage)

C3. How are households selected for the various start times across an event window?

A. How does this selection help to smooth curtailment curves and reduce opt-out rates?
B. how are households with higher propensities to opt out of an event handled?

C4. Back in June of this year, there was the extreme heat wave in the Pacific Northwest and PGE called back-to-back events during that extreme heat wave. How did the smart thermostats and load management strategies perform during those extreme heat waves?

A. Did Resideo dispatch the thermostats differently because of the extreme heat?
B. Any performance difference between Honeywell's load cycling units and other OEM's setback controls? If yes, how was this achieved?
C. Have you dispatched events during extreme weather conditions before and how challenging was this heat wave?
D. What did you learn from the heat wave and how will you use this information moving forward for PGE's Smart Thermostat Program?

C5. Has thermostat manufacturer's data privacy policies affected your ability to assist PGE in any way? If yes, please describe.

C6. Last year you reported having very few offline thermostats. Did you have any issues with offline thermostats this year? If yes, please describe.

   A. Did you run a campaign this year to have customers check their smart thermostat's online connection?
   B. [If yes] Any reporting on this metric you can share?

C7. Did you encounter any others issues with managing events during 2021? If yes, please describe.

   A. [If yes] Were the issues resolved and if so, how were they resolved?
   B. [If A = No] Are you working on finding a solution to this issue?

D. *Wrap Up*

I have a few final questions for you to wrap up.

D1. Overall, what would you say are your successes for 2021 with regards to PGE's Smart Thermostat Program?

D2. What areas are you looking to improve on?

D3. Do you have any changes or improvements in store for the program in this upcoming winter and summer seasons? If yes, please describe.

D4. Those were all the questions we had. Is there anything else Cadmus should know about that may help with the evaluation?

Thank you for your time!

CADMUS

PGE Residential Smart Thermostat Program

Process Evaluation Interview Guide for CLEAResult

Interviewee:

Interview Date: Interviewer:

Topics	Corresponding Items
Program Management	Section A
Scheduling and Installation Operations	Section B
Customer Education	Section C
Wrap Up	Section D

Introduction: Thank you for making time for this interview. This interview is to help us understand how PGE's Smart Thermostat Program operated in 2021 and is critical to informing the evaluation. This is also a chance for you to provide your perspectives on how PGE's Smart Thermostat Program is working and where implementation can improve.

A. *Program Management*

A1. It's been one year since we last spoke to the CLEAResult team. How has the CLEAResult team for PGE's Smart Thermostat Program changed since last year? [Probe about any staff/management changes]

A2. Last year when we spoke we were in throes of the pandemic and you had limited number of installers. How many installers do you have now for PGE's Smart Thermostat Program?

A. Are you back to the level you want to be?
B. Why or why not?

B. *Scheduling and Installation Operations*

B1. How are the self-scheduling and installations doing so far in 2021 compared to 2020?

A. Do you have an installation goal for 2021?
B. How many installations have you completed so far in 2021 and at what number do you think you'll close out by the end of the year?
C. How long do customers wait from the time they schedule the appointment to the day of installation?

B2. Have you made any changes to the self-scheduling portal since last year?

A. [If yes] Please describe.
B. [If yes] Why were those changes made?
C. [If yes] How effective have those changes been?

B3. Have you encountered any challenges with the self-scheduling this year?

A. [If yes] Please describe.
B. [If yes] Were these challenges addressed in any way? If so, how were these challenges resolved?

B4. Have you made any changes to the installation process since last year?

A. [If yes] Please describe.
B. [If yes] Why were those changes made?
C. [If yes] How effective have those changes been?

B5. How has COVID changed the way you perform direct installs?

B6. Have you encountered any challenges with the installation process this year?

A. [If yes] Please describe.
B. [If yes] Were these challenges addressed in any way? If so, how were these challenges resolved?

B7. Last year you worked with PGE to introduce Virtual Install. What has happened to Virtual Install in 2021?

A. [If VI is active] For what instances is Virtual Install used and when do you offer customers this option?
B. [If VI is active] How many virtual installs have you completed this year?
C. [If VI is active] Is it still the DIY handy/tech savvy customers who opt to do Virtual Install or are you seeing other types of customers taking up Virtual Install this year?
D. [If VI is active] What successes and challenges have you experienced with Virtual Install this year?
E. [If VI is not active] Why did Virtual Install go away?
F. [If VI is not active] Can Virtual Install be activated quickly should its need arise?

B8. The Pacific Northwest had an extreme heat wave in early summer. Based on the enrollments this past summer, have you noticed any changes to customers' HVAC systems?

A. Have your installers noticed additional AC units or larger AC units in customer homes?
B. Do you think extreme heat has played a role in any way for Direct Install enrollments? If yes, please describe.

C. Customer Education

Next, I'd like to ask you questions about customer education.

C1. Have you made any changes to the way customers are educated about PGE's Smart Thermostat Program? For example, have there been any updates to the leave-behind materials or what the installer says to the customer? [Probe about discouraging overrides]

A. [If yes] Please describe.

B. [If yes] Why were those changes made?
C. [If yes] How effective have those changes been?

C2. Are there areas where customers could use more education on or that PGE should develop more educational materials on?

D. Wrap Up

I have a few final questions for you to wrap up.

D1. Overall, what would you say are your successes for 2021 with regards to PGE's Smart Thermostat Program?

D2. What areas are you looking to improve on?

D3. Do you have any changes or improvements in store for the program later this year or next year? If yes, please describe.

D4. Those were all the questions we had. Is there anything else Cadmus should know about that may help with the evaluation?

Thank you for your time!

CADMUS

PGE Residential Smart Thermostat Pilot Program

Winter 2022 Process Evaluation Interview Guide for PGE Program Manager

Respondent name:

Interview date: Interviewer initials:

Topics	Corresponding Items
Program Goals	Section A
Marketing and Recruitment	Section B
Enrollment and Installation	Section C
Event Implementation	Section D
Customer Retention	Section E
Risks and Challenges Moving Forward	Section F
Wrap Up	Section G

Introduction: Thank you for making time for this interview. This interview is to help us understand how the Residential Smart Thermostat pilot program operated during the winter 2021/2022 season, how the pilot is evolving to transition to full program deployment, and identify what levers PGE can pull to improve program performance and customer delivery.

A. *Program Goals*

Let's start with questions about the program goals and status to date.

A1. What was the capacity goal for winter 2021/2022?

A2. Do you think you met the capacity goal for winter?
   A. Why or why not?

A3. How many thermostats are enrolled to date and where do you stand in terms of your overall enrollment goal?

A4. Were there any other goals for the winter season, such as event participation rates or overrides?
   A. [If yes] What were the goals and how did you do?

B. *Marketing and Recruitment*

These next questions are about marketing and customer recruitment.

B1. Were there any marketing activities for BYOT and Direct Install during the past six months?
   A. Which of the marketing activities were successful at recruiting customers, if any?

B2. In the past six months, were there any marketing challenges you encountered?

A. [If yes] Did you work to resolve these challenges?
B. [If yes] What was the outcome of the solution you implemented?

B3. During the last evaluation interview, you mentioned that Smart Thermostats and Peak Time Rebates programs had worked together to promote participant migration. Have there been any more collaborative marketing/recruitment efforts between the two programs?

C. *Enrollment and Installation*

Let's discuss the enrollment process.

C1. Have there been any changes to the customer enrollment process for BYOT and Direct Install in the past six months?

A. [If yes] How have those changes impacted enrollments?

C2. For the Direct Install track, how is CLEAResult performing on completing installations during the past six months?

A. Is CLEAResult back to installing at a rate similar to pre-pandemic levels?

C3. Is Virtual Install still around as a backup and for troubleshooting use cases?

D. *Event Implementation*

My next set of questions for you are about event implementation.

D1. How many events did PGE call during the winter season?

A. What times did you call these events?
B. What factors triggered the winter events?

D2. Overall, what would you say went well during the winter season?

D3. How did Resideo perform on dispatching the events (e.g., communication failures) and managing the load for winter?

A. Did Resideo perform to your expectations?

D4. Was there any customer education activities or materials you deployed during the winter season?

A. [If yes] Please describe.
B. [If yes] Why did you do the activities or develop these materials?
C. [If yes] Do you think the activities/materials were effective?

D5. Did you encounter any other issues with managing events during the winter season? If yes, please describe.

A. [If yes] Were the issues resolved and if so, how were they resolved?
B. [If A = No] Are you working on finding a solution to this issue?

E. Customer Retention

The next topic I'd like to discuss is customer retention.

E1. Did you see any program attrition during the winter season?
   A. [If yes] What were the reasons for attrition?
   B. How does this attrition compare to the previous winter season?

E2. During the last evaluation interview, you mentioned that you were working on un-enrollment notifications. Has that been developed and did you deploy it?
   A. [If yes] How is that working so far?

F. Risks and Challenges Moving Forward

These next questions are about the future of the program.

F1. How much closer are you to moving the pilot program to full program deployment?
   A. What else needs to happen to get to full deployment?

F2. What are the biggest challenges and risks moving forward for the program?
   A. Do you have solutions in place to manage these risks and overcome the challenges? If yes, please describe.

F3. Is the program cost-effective and is this a barrier for moving forward?
   A. [If yes] Are there any ideas or plans to make the program more cost-effective? If yes, please describe.

F4. Do you have any changes or improvements in store for the program in this upcoming summer and winter seasons? If yes, please describe.

F5. Adam, did you have any questions for Beth about future program design or operational considerations?

G. Wrap Up

G1. Those were all the questions we had. Is there anything else Cadmus should know about that may help with the evaluation?

Thank you for your time!

Appendix E. Survey Instruments

Cadmus designed and administered a summer 2021 survey for Event 4 (fielded on July 31, 2021) and a summer 2021 survey for Event 7 (fielded on August 14, 2021). The same survey instrument was used for both events.

The survey instrument is provided on the following pages.

CADMUS

PGE Smart Thermostat Demand Response Pilot

Summer 2021 Event Survey for BYOT and Direct Install

Research Topics	Corresponding Question
Event Awareness	A1-A6
Pre-Event Notification Test	B1-B7
Thermal Comfort	C1-C4
Event Participation and Overrides	D1-D6
Satisfaction	E1-E4
Research Questions	**Analysis**
What factors influenced the probability a customer was aware of demand response events? How is awareness affected by thermal comfort before event, thermal comfort during event, and micro-segment?	Regression **DV: A1** IV: A2, A3, A5, B1, C1, C2, Track, Microsegment, Notification test, IDR test
How does event comfort depend on event awareness and micro-segment?	Regression **DV: C1, C2** IV: A1, A5, Microsegment
What factors influence the probability of overriding? How do each of the following factors affect overriding: thermal comfort during event, thermal comfort before event, awareness of event, and understanding of program participation?	Regression **DV: D3, D4** IV: A1, A2, A3, A5, B1, B2, C1, C2, C3, D1, D2, Track, Microsegment, Notification test, IDR test
How do the following variables correlate with program satisfaction and PGE satisfaction: event awareness, thermal comfort, and overriding?	Correlation **E1:** A1, A5, B1, B2, C1, C2, C3, D3, D4 **E3:** A1, A5, B1, B2, C1, C2, C3, D3, D4 **E1 : E3**

Group	IDR	Event Notifications
A: IDR	FLAT	NO
B: Event notifications (ecobee and Honeywell only)	STANDARD	YES
C: Control	STANDARD	NO

Target Audience: Customers who are enrolled in the residential Smart Thermostat Demand Response pilot for summer 2021 season

Expected number of completions: 1,070

Estimated timeline for fielding: Between July 13 and September 30, 2021. With PGE directive, an event survey will be administered online within 48 hours of an event. One survey reminder email may be sent after initial email, depending on the number of completes.

Variables to be Pulled into Survey

- Email
- FirstName
- LastName
- Track = BYOT, BYOTRAP, DI, or VI
- EnrollDate
- TestBedStatus = In TB or Out TB
- System = AC or HP
- IDRGroup = a, b, or c
- Microsegment = Big Impactors, Borderliners, Fast Growers, Low Engagers, Middle Movers, or Null
- MigratedFromPTR = Yes or No

Email Invitation

To: [Email]
From: Cadmus on behalf of Portland General Electric
Subject: How was PGE's Smart Thermostat Program?

Dear [FirstName],

You are currently enrolled in the Smart Thermostat Program. On Friday July 30, PGE held a Peak Time Event. Would you take a moment to answer a few questions about Friday's event? We value your input because we use it to improve PGE programs. Your responses will be kept confidential. Thank you for sharing your feedback with us.

Follow this link to the Survey:
[Survey Link]

Or copy and paste this URL into your internet browser:
[Survey Link]

If you have any questions about this survey or any difficulties taking the survey, please contact Masumi Izawa at Cadmus, the research firm conducting this survey on PGE's behalf. You can reach her at (503) 467-7115 or masumi.izawa@cadmusgroup.com.

Sincerely,
Adam Gardels
Smart Thermostat Evaluation Manager, Portland General Electric

Follow the link to opt-out of future emails:
${l://OptOutLink?d=Click here to unsubscribe}

Survey Start Screen

Welcome! This survey will take 7 minutes to complete. Your responses will remain confidential and will only be used for research purposes.

A. Event Awareness

A1. Your smart thermostat works with PGE to shift electricity consumption from times when demand for electricity is highest. Did you know that there was a Peak Time Event on Friday between 5PM to 8PM?

1. Yes
2. No

A2. Were you home during any portion of the Peak Time Event?

1. Yes
2. No
3. Don't know

A3. Was your air conditioner **on** during the Peak Time Event?

1. Yes
2. No [Skip to B1]
3. Don't know [Skip to B1]

[Ask if A1=1 and A3=1]

A4. How did you know the Peak Time Event was happening? Select all that apply. [Randomize 1-4]

1. Display on smart thermostat
2. Notification from smart thermostat app
3. Noticed a change in how the air conditioner was running
4. Noticed a temperature change
5. Received notification email from PGE [Display if IDRGroup=b]
6. Something else (please describe) [Open-end text entry]
7. Don't know [Exclusive answer]

[Ask if A1=1 and A2=1 and A3=1]

A5. To maintain your home's comfort during a Peak Time Event, your smart thermostat may cool your home slightly more than normal about an hour before the start of the event. Did you notice this pre-cooling before Friday's Peak Time Event?

1. Yes
2. No

[Ask if A5=1]

A6. How did you notice the pre-cooling? Select all that apply. [Randomize 1-4]

1. Display on smart thermostat
2. Notification from smart thermostat app
3. Noticed a change in how the air conditioner was running
4. Noticed a temperature change
5. Something else (please describe) [Open-end text entry]
6. Don't know [Exclusive answer]

[Ask section B if IDRGroup = b]

B. *Pre-Event Notification Test*

B1. Do you remember receiving an email from PGE about Friday's Peak Time Event on the day of the event?

1. Yes
2. No

[Ask if B1=1]

B2. The event notification email from PGE said, *"To get credit for participating, make sure no one overrides the settings during pre-cooling or the event."* Did you understand what PGE was asking you to do?

1. Yes
2. No

[Ask if B1=1]

B3. How would you rate the usefulness of the event notification you received?

1. Very useful
2. Somewhat useful
3. Not too useful
4. Not at all useful
5. Don't know

[Ask if B3= 1 or 2]

B4. What was useful about the event notification you received? [Open-end Text Entry]

[Ask if B3= 3 or 4]

B5. What could PGE do to make the event notification more useful for you? [Open-end Text Entry]

[Ask if B1=1]

B6. Would you like to continue receiving these event notifications?

1. Yes
2. No
3. Don't know

[Ask if B6=1]

B7. How would you like to receive these event notifications? Select all that apply. [Randomize 1-3]

1. Text message
2. Email
3. Voice message
4. No preference [Exclusive answer]
5. Don't know [Exclusive answer]

[Ask section C if A2=1 and A3=1]

C. Thermal Comfort

C1. On Friday **before** the Peak Time Event, how comfortable was the interior temperature of your home?

1. 0 – Not at all comfortable
2. 1
3. 2
4. 3
5. 4
6. 5
7. 6
8. 7
9. 8
10. 9
11. 10 – Perfectly comfortable
12. Don't know

C2. On Friday **during** the Peak Time Event, how comfortable was the interior temperature of your home?

1. 0 – Not at all comfortable
2. 1
3. 2
4. 3
5. 4

6. 5
7. 6
8. 7
9. 8
10. 9
11. 10 – Perfectly comfortable
12. Don't know

C3. How did the comfort level you experienced during the event compare to the level of comfort you expected from participating in PGE's Smart Thermostat Program?

1. More comfortable than what I expected
2. Less comfortable than what I expected
3. About what I expected
4. I had no expectations
5. Don't know

C4. What actions, if any, did you take during Friday's Peak Time Event to stay comfortable? Select all that apply. [Randomize 1-7]

1. Used fans to circulate the air
2. Closed the blinds or curtains
3. Turned off or limited the use of lights
4. Drank beverages
5. Took a shower
6. Avoided doing housework or physical activity
7. Left the home
8. Something else (please describe) [Open-end text entry]
9. None of the above [Exclusive answer]
10. Don't know [Exclusive answer]

[Ask section D if A2=1 and A3=1]

D. Event Participation and Overrides

D1. During Friday's Peak Time Event, did you or someone else in your home take any of the following actions? [Response Options: 1=Yes, 2=No, 3=Don't know/Not applicable] [Randomize A-D]

A. Adjusted the thermostat settings directly on the smart thermostat
B. Adjusted the thermostat settings using the smart phone app
C. Switched the smart thermostat to "off" mode
D. Turned off or cut the power to the central air conditioning or heat pump

[Ask if any answers from D1=1]

D2. What made you or someone in your household decide to take that action(s) during the Peak Time Event? Select all that apply. [Randomize 1-6]

1. Temperature was too cool for me or other occupants
2. Temperature was too warm for me or other occupants
3. Time of the event was inconvenient
4. Waste of money to make the home cooler than normal
5. Waste of energy to make the home cooler than normal
6. I prefer to keep my normal temperature settings
7. Something else (please describe) [Open-end text entry]
8. Don't know [Exclusive answer]

D3. During Friday's Peak Time Event, do you remember seeing a warning message on your thermostat or phone that a Peak Time Event was taking place and that you were about to end your participation in the event?

1. Yes
2. No

[Ask if D3=1]

D4. Did you choose to end your participation in Friday's Peak Time Event?

1. Yes
2. No

D5. What could PGE do to make it easier for you to participate in a Peak Time Event? [Open-end text entry]

E. Satisfaction

E1. Please rate your overall satisfaction with PGE's Smart Thermostat Program.

1. 0 – Extremely dissatisfied
2. 1
3. 2
4. 3
5. 4
6. 5
7. 6
8. 7
9. 8
10. 9
11. 10 – Extremely satisfied

E2. How likely would you be to recommend the Smart Thermostat Program to a friend, family member, or colleague?

1. 0 – Extremely unlikely
2. 1
3. 2
4. 3
5. 4
6. 5
7. 6
8. 7
9. 8
10. 9
11. 10 – Extremely likely

E3. Please rate your overall satisfaction with PGE.

1. 0 – Extremely dissatisfied
2. 1
3. 2
4. 3
5. 4
6. 5
7. 6
8. 7
9. 8
10. 9
11. 10 – Extremely satisfied

E4. As our final question, what keeps you motivated to stay enrolled in PGE's Smart Thermostat Program? Select all that apply. [Randomize 1-7]

1. To earn the $25 incentive at the end of the season [Display if Track = BYOT or BYOTRAP]
2. Because I received a free thermostat and installation [Display if Track = DI or VI]
3. To reduce my energy bill
4. To reduce my carbon footprint
5. To help PGE rely more on renewable energy
6. To help keep electricity prices affordable for my community
7. To help the community avoid power outages
8. Something else (please describe) [Open-end text entry]
9. Don't know [Exclusive answer]

End of Survey Message

Your responses have been submitted. Thank you!