Portland General Electric Company
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October 18, 2021

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 1708: Cadmus' Evaluations of PGE's Smart Thermostat program Winter 2019/2020 and Summer 2020 for the BYOT and Direct Installation Channels**

Enclosed are evaluations of Portland General Electric Company's (PGE's) Direct Load Control Thermostat (DLCT) Pilot for the Winter 2019-2020 and Summer 2020 seasons. PGE contracted with a third-party evaluator, Cadmus, to evaluate the load impacts for the Bring-Your-Own-Thermostat (BYOT) channel of the DLCT Pilot, and the load impacts and customer satisfaction associated with the Direct Install (DI) channel of the DLCT Pilot. Cadmus evaluated and submitted reports for both the BYOT and the DI channels of the DLCT Pilot. These programs are consistent with the terms of PGE's Schedule 5.

Key load impact findings:

Cadmus's evaluation found that by March 2020, PGE had acquired approximately 7 MW of winter demand response capacity and by October 2020, PGE had acquired 17.5 MW of summer demand response capacity from the combined DI channel and BYOT channels. When comparing summer 2020 to summer 2019, both channels provided the same or slightly higher demand response capacity per participant. When comparing winter 2019/2020 to 2018/2019, Cadmus reported a marked increase for both channels in demand response capacity and noted several contributing factors, including shorter event duration, colder event days and limiting events to the morning only. For BYOT, Cadmus also attributes the increase to the unenrollment of customers with ineligible heating equipment leading to higher response per participant.

Key recommendations from the Cadmus evaluations:

- Conduct research aimed at understanding and mitigating customer overriding behavior.
  - **Update:** PGE contracted with Cadmus to analyze customer overriding for both channels in the summer 2021 season.
- Call afternoon events in future winter seasons to continue to evaluate this resource.
  - **Update**: The program will test at least two afternoon events in Winter 2021/2022.

Key customer experience findings:
PGE's DLCT Pilot customer satisfaction rating for the DI channel was high in both seasons but decreased by 6 percentage points in summer 2020 over the previous summer. Overall average ratings were 8 or greater on a 10-point scale.

Key recommendations from the Cadmus evaluations:

- Consider developing and testing pre-event notifications to determine whether increased communication about events increases customer engagement and satisfaction.
    - **Update**: PGE tested event notifications in the Summer 2021 season and will use a randomized treatment and control experimental design to evaluate kW impact and customer satisfaction.
- Reiterate the 50% event participation minimum requirement as part of customer education and ongoing customer communications to make sure participants are aware of minimum requirements and as a result reduce overriding behavior.
    - **Update**: PGE includes the 50% event participation minimum requirement in pre-season and mid-season communications, as well as DI leave behind printed material. We updated the DI terms and conditions to clarify this requirement. We will also ensure the requirement is adequately addressed in the customer scheduling and education phases of the DI customer journey.

If you have any questions or require further information, please contact Alina Nestjorkina at (503) 464-2144. Please direct all formal correspondence and requests to the following e-mail address pge.opuc.filings@pgn.com.

Sincerely,

/s/ Jaki Ferchland

Jaki Ferchland
Manager, Revenue Requirement

CADMUS

Memorandum

To: Portland General Electric

From: Cadmus

Subject: Impact Evaluation of PGE Bring-Your-Own Thermostat Pilot Program, Winter 2019/2020 and Summer 2020

Date: September 9, 2021 (revised)

This memo presents the results of the impact evaluation of Portland General Electric's Bring-Your-Own-Thermostat (BYOT) demand response pilot program during winter 2019/2020 and summer 2020 event seasons.

Key Findings and Conclusions

Overall, the BYOT pilot program performed as expected, with demand savings approximately equal to PGE's planning values of 1.2 kW per enrolled customer in winter and 1.0 kW per enrolled customer in summer. However, as this evaluation shows, the pilot load impacts varied significantly before, during, and after the demand response events.

PGE plans to eventually transition the BYOT pilot program to a full-scale program, so it is important for PGE system operators to understand the demand response properties of smart thermostats to have full confidence in the capabilities of this product as a capacity resource. This evaluation reports different program performance metrics that should help system operators better understand the demand response capabilities of residential smart thermostats. Also, though the program delivered the expected savings, PGE has opportunities to improve performance by addressing the reasons customers override demand response events and possibly discouraging such behavior.

The following are key findings of Cadmus' evaluation regarding the performance of the BYOT pilot program during the winter 2019/2020 and summer 2020 event seasons.

- **BYOT savings were similar to those in the previous summer and much higher than those in the previous winter.** In summer 2020, the BYOT pilot achieved average demand savings per treatment group customer of approximately 0.82 kW (=30% of baseline demand), which was approximately equal to the summer 2019 savings of 0.87 kW (35%). In winter 2019/2020, the BYOT pilot achieved average demand savings per treatment group home of approximately 0.83 kW (31%), which was about twice as large as the savings (0.39 kW, 15%) in winter 2018/2019. The difference is attributable to several factors, including in winter 2019/2020 dispatching events only in the morning, dispatching shorter events, dispatching on colder event days, and removing enrolled customers with ineligible heating equipment. All these differences are expected to increase demand savings per customer.

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- **Savings were greatest during the first event hour.** In summer temperature-indicative events,[1] the average demand savings per customer was 1.03 kW (38%) during the first event hour. Savings then degraded by about 30% in each successive event hour relative to savings in the previous hour. In winter events that met the indicative temperature threshold, the average demand savings per customer was 0.88 kW (33%) during the first event hour. Savings in the second and third event hours then degraded by 55% and 29%, respectively, relative to savings in the previous hour.
- **Smart thermostat demand response increased demand before and after events.** In summer 2020, precooling increased demand in the hour immediately preceding the event by between 0.3 kW and 0.4 kW per treatment group customer, and snapback increased demand in the hour immediately following the event by 0.2 kW to 0.4 kW, depending on the event start time, event duration, and weather conditions. In winter, preheating increased demand by between 0.3 kW and 0.5 kW per treatment group home, and post-event snapback increased demand by between 0.3 kW and 0.6 kW.
- **In summer 2020, BYOT demand savings increased with outside temperature.** For every 1°F increase in event hour temperature, the average demand savings per treatment group customer increased by about 0.015 kW. Event temperatures ranged from about 89°F to 97°F.
- **Event overriding was common among BYOT participants.** In summer 2020, 27% to 33% of BYOT customers overrode events, depending on the event. Nearly 70% of the overrides occurred by the end of the first event hour.[2] Overriding reduced the demand response savings from the pilot.

Program Description

Through the BYOT demand response pilot program, PGE can directly manage residential summer and winter peak electricity demand. By working with demand response service providers, PGE can reduce the cooling and heating loads of participating customers by remotely adjusting the setpoints of their smart thermostats (either through fixed degree setback or variable based on thermostat settings). Participating customers must own a qualified smart thermostat (Nest, ecobee, or Honeywell) and heat or cool their homes using central, electrically fueled HVAC systems. Customers who meet the participation requirements receive a check (or on-bill credit, starting in summer 2020) at the end of the heating and cooling seasons.

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1 "Indicative temperature" is a PGE criterion to designate temperature thresholds that may trigger demand response events. These are set at or above 90°F in summer and 32°F or below in winter. In summer 2020, all but one event were temperature indicative. In winter 2019/2020, two of four events were temperature indicative.

2 Analysis of the timing of event overrides reflects BYOT and DI customers combined, as these data were not available at the program track level.

PGE contracted with the smart thermostat demand response service providers Nest and Resideo in winter 2019/2020 and Resideo in summer 2020.

Evaluation

The BYOT pilot program was evaluated as a randomized controlled trial. At the beginning of each season, program enrollees were randomly assigned to a treatment group or control group. Treatment group customers experienced demand response events, while control group customers did not. The control group provided the baseline for measuring the demand response impacts. Customers who enrolled during the season were also randomly assigned to the evaluation treatment group or control group. Tables showing the analysis sample counts and figures demonstrating the statistical equivalence of the randomized treatment and control groups are provided in *Appendix A*.

All demand impacts from BYOT demand response were estimated from difference-in-differences ordinary least squares (OLS) panel regression models. Cadmus aggregated 15-minute interval metered (AMI) consumption data to the hour. The dependent variable was average hourly kW for a participant home and the independent variables included hour-of-the-day dummy variables, cooling degree hour or temperature-humidity index (THI) variables, indicators for assignment to the treatment and control group, and indicators for hours before, during, and after the events. The results from regressions including THI were identical to those from regressions including CDH, so the THI model results are not reported in this memo.

Enrollments

Table 1 presents the BYOT customer, thermostat, and HVAC enrollments and random assignments to the treatment or control group in winter 2019/2020 and summer 2020. Any customer or thermostat enrolled for one or more demand response events was included in the counts.

Table 1. BYOT Program Enrollments by Event Season

Category	Control	Treatment	Total
Winter 2019/2020 Enrollments			
Total Thermostats	583	1,475	2,058
Total HVAC Systems	583	1,474	2,057
Total Customers	562	1,451	2,013
Summer 2020 Enrollments			
Total Thermostats	2,294	13,075	15,369
Total HVAC Systems	2,286	13,030	15,316
Total Customers	2,284	13,014	15,298

Note: Total Thermostats and HVAC Systems represent the number of individual thermostats and HVAC equipment associated with all enrolled participants. Total Customers is the number of unique Service Premise IDs. Winter 2019/2020 enrollments reflect the number of enrolled customers as of March 2020, and summer 2020 enrollments reflect the number of enrolled customers as of September 2020.

Before analyzing the AMI meter data, Cadmus performed several data cleaning steps, which resulted in the exclusion of 0.5% of enrolled customers from the analysis sample. These steps are described in *Appendix A*.

Winter 2019/2020

In winter 2019/2020, PGE dispatched BYOT program thermostats during four events, as listed in Table 2. Each was initiated on a non-holiday, weekday at 7:00 a.m. or 8:00 a.m. and lasted between one and three hours. The average outside temperature during events ranged between 28°F and 34°F.

Table 2. BYOT Demand Response Events – Winter 2019/2020

Event	Date	Avg. Outdoor Temperature (°F)	Start Time	Duration (hours)	Met Indicative Temperature Threshold
1	1/15/2020	33	7:00 AM	2	N
2	2/4/2020	28	7:00 AM	3	Y
3	2/21/2020	31	8:00 AM	1	Y
4	2/27/2020	34	7:00 AM	1	N

Note: Average outdoor temperature is the outdoor temperature recorded in PGE's event log.

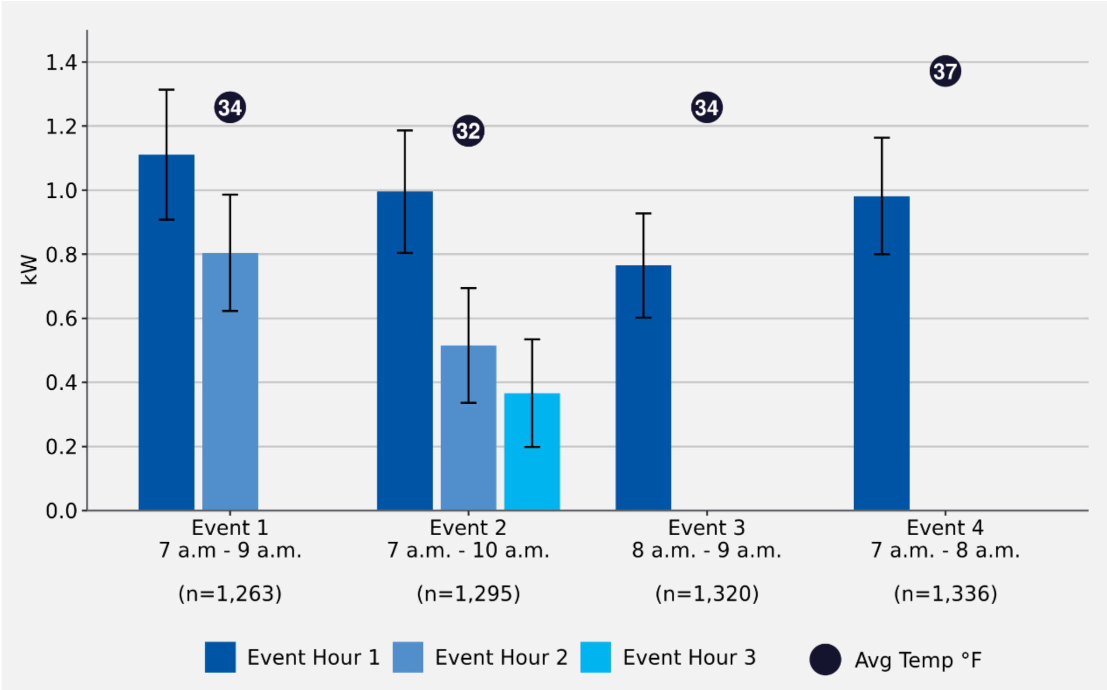
Event 2 and event 3 qualified as temperature-indicative events, with average temperatures below 32°F.

Demand Response Load Impacts

Figure 1 show estimates of the average kW savings per treatment group home for each event hour in winter 2019/2020. The average temperature during the event hours are also displayed.

Savings per treatment group home ranged between about 0.8 kW and 1.1 kW during event hour 1 and 0.5 kW and 0.8 kW during event hour 2. The savings were about 0.4 kW per treatment group home during the third hour of Event 2. All hourly savings estimates were statistically significant at the 5% level.

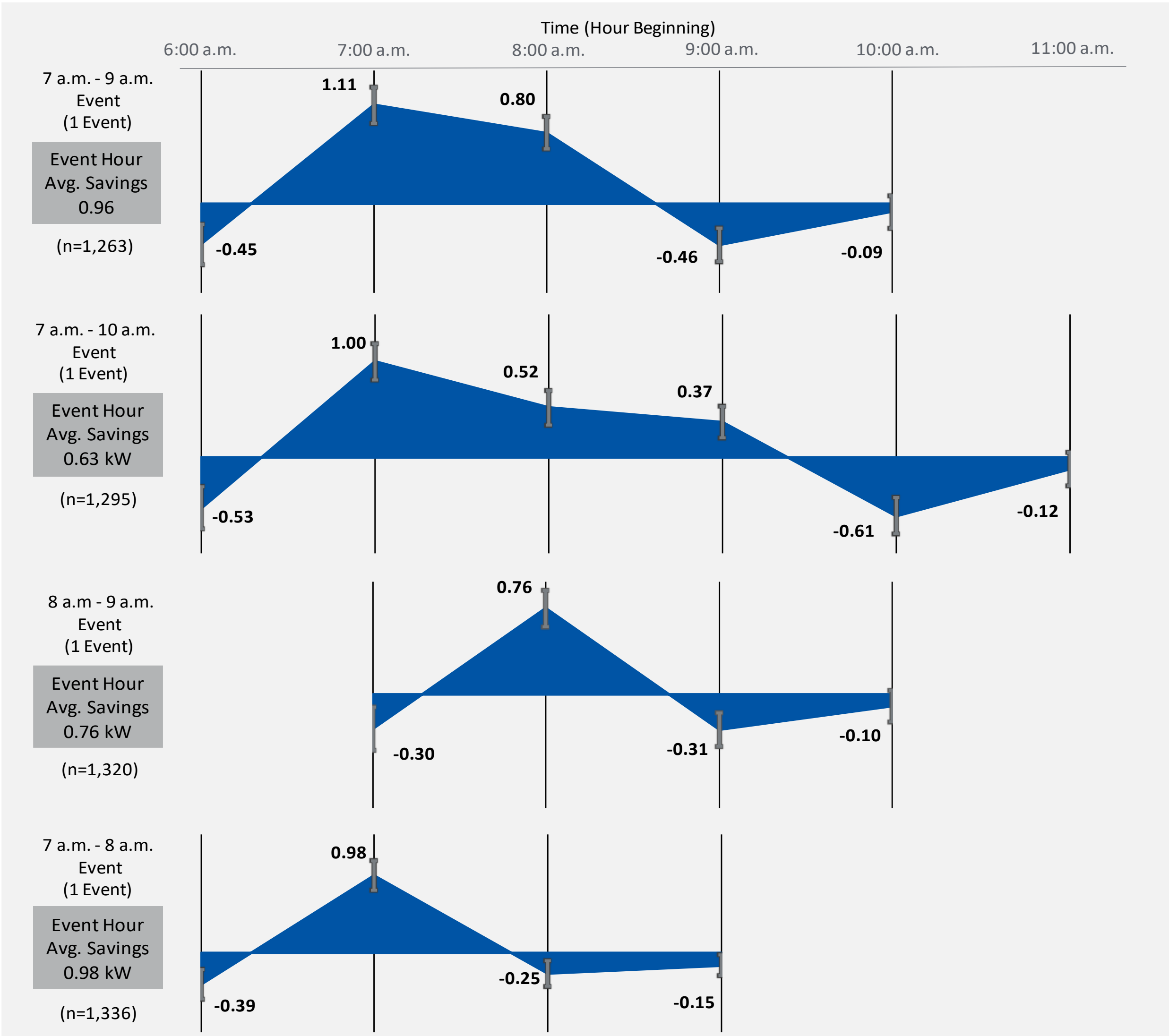
Figure 1. BYOT Demand Savings by Event – Winter 2019/2020



Note: n indicates the number of treatment group customers in the analysis sample for the event. kW savings estimates were obtained from OLS panel regressions of customer metered demand. See text for details. Error bars indicate 95% confidence intervals based on standard errors clustered on homes. Events 2 and 3 met the indicative temperature threshold.

Figure 2 shows the demand impacts before, during, and after each demand response event. Preconditioning during the hour immediately preceding the event increased electricity demand by between 0.3 kW and 0.5 kW per treatment group home. Snapback in the first hour after the event concluded also increased demand by between 0.3 kW and 0.6 kW. After accounting for preconditioning and snapback effects, each event generated a net decrease in energy consumption.

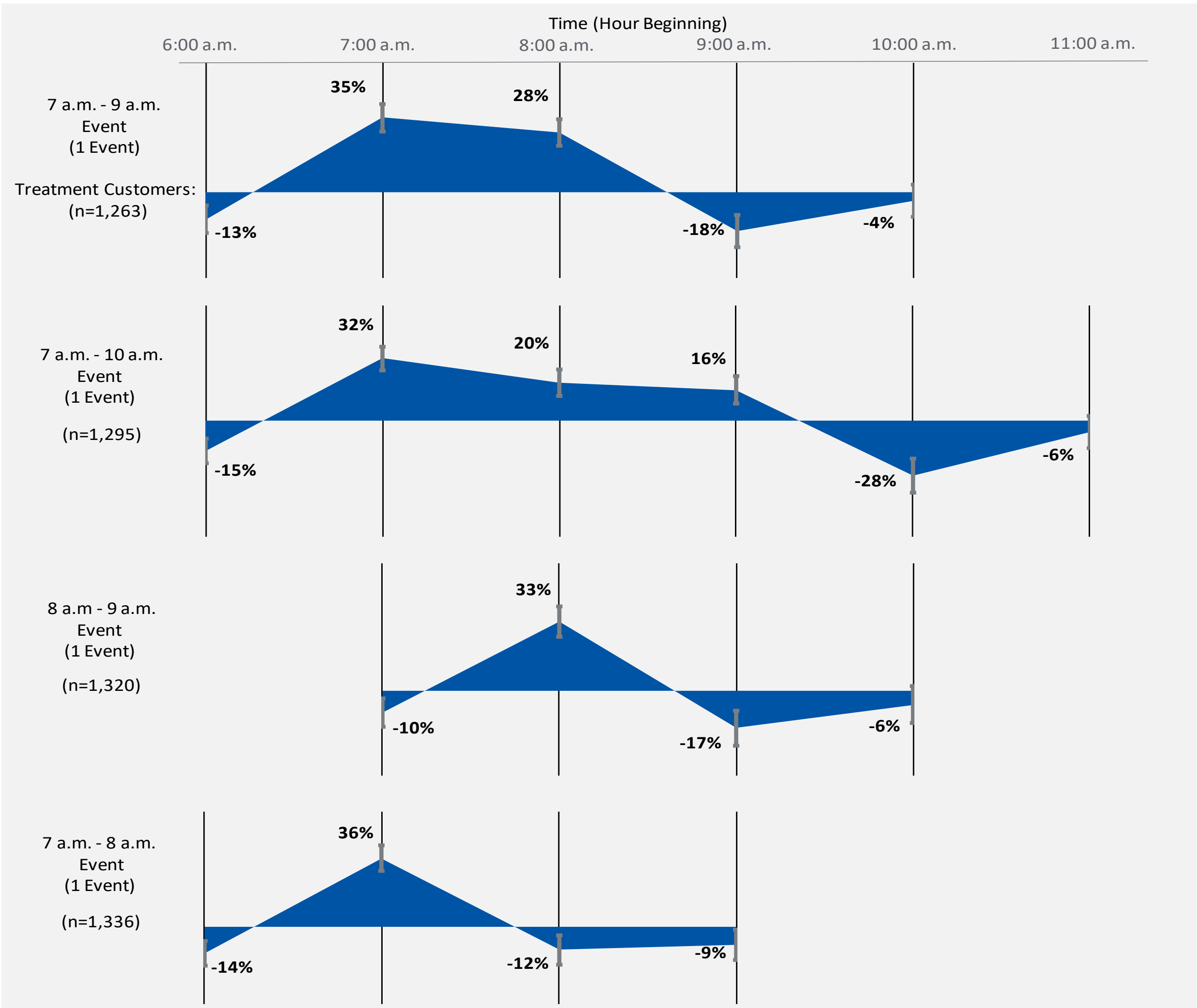
Figure 2. BYOT Average Demand Savings (kW) per Participant – Winter 2019/2020



Note: n indicates treatment group customers in the analysis sample. kW savings estimates were obtained from OLS panel regressions of customer metered demand. See text for details. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

Figure 3 shows the demand impacts as a percentage of baseline demand. Savings during the first event hour ranged between 32% and 36%. In the three-hour event 2, the savings as a percentage of baseline demand decreased from 32% in event hour 1 to about 15% in the last hour.

Figure 3. BYOT Percentage Demand Savings – Winter 2019/2020



Note: n indicates treatment group customers in the analysis sample. Savings estimates were obtained from OLS panel regressions of customer metered demand. See text for details. Error bars indicate 95% confidence intervals based on standard errors clustered on homes. Percentage demand savings calculated as kW savings divided by baseline demand.

Appendix A includes a figure for each event showing the hourly savings as well as the average treatment group customer metered demand, regression model predicted demand, and counterfactual baseline demand.

Program Savings

Table 3 shows the evaluated MW savings for the winter 2019/2020 events. The MW hours for an event were estimated by multiplying the average demand savings per treatment group customer by the number of customers in the treatment group for the event. In addition, the potential demand savings were estimated by multiplying the per-treatment group customer savings estimate by the number of enrolled customers, which included customers who had been randomly assigned to the control group and did not participate in load control in winter 2019/2020.

The evaluated program savings ranged between 0.8 MW and 1.3 MW. The differences across events are driven by both the length of the event—savings during event hours 2 and 3 were smaller than during event hour 1 as the effect of preconditioning diminished —as well as weather, the event day-of-the-week, and event starting hour-of-the-day.

Potential demand savings are the savings that would have been realized during each event if the thermostats of all enrolled customers had been dispatched. Potential demand savings ranged from 1.3 MW to 2.0 MW, and because these savings include control group customers and treatment group customers excluded from the analysis sample, they are slightly higher than the evaluated savings.

Table 3. BYOT Program-Level Savings – Winter 2019/2020

Event	Event Time	Avg. Temp. (°F)	Evaluated Avg. Savings per Treatment Group Customer (kW)	Analysis Sample (n)		Evaluated Demand Savings (MW)	Potential Demand Savings (MW)
				Treatment Customers	Control Customers		
1	7 a.m. – 9 a.m.	34	0.955	1,263	591	1.2	1.9
2	7 a.m. – 10 a.m.	32	0.630	1,295	559	0.8	1.3
3	8 a.m. – 9 a.m.	34	0.760	1,320	534	1.0	1.5
4	7 a.m. – 8 a.m.	37	0.980	1,336	518	1.3	2.0
Average		**34**	**0.831**	**1,304**	**551**	**1.1**	**1.7**

Note: Potential demand is based on total enrolled customers as of March 2020 (N=2,013).

Performance Metrics

Table 4 reports key performance metrics for winter residential smart thermostat demand response based on the findings of the winter 2019/2020 evaluation. The metrics were calculated from estimates of the average demand (kW) impacts per treatment group home during pre-event, event, and post-event hours of events that meet the indicative temperature threshold to trigger events (32°F or below). Load impacts as a percentage of baseline demand are shown in parentheses. These performance metrics are intended to help PGE system operators better understand the demand response capabilities of smart thermostats.

Table 4. BYOT Program Performance Metrics – Winter 2019/2020

Key Metrics		Savings per Treatment Group Customer
Average kW Savings	Event Hour 1 (N=2 hours)	0.88 kW (33%)
	Event Hour 2 (N=1)	0.52 kW (20%)
	Event Hour 3 (N=1)	0.37 kW (16%)
Min kW Savings	Event Hour 1 (N=2)	0.76 kW (33%)
	Event Hour 2 (N1)	0.52 kW (20%)
	Event Hour 3 (N=1)	0.37 kW (16%)
Max kW Savings	Event Hour 1 (N=2)	1 kW (32%)
	Event Hour 2 (N=1)	0.52 kW (20%)
	Event Hour 3 (N=1)	0.37 kW (16%)
Average Savings Degradation (difference from previous hour savings)	Event Hour 1 to Event Hour 2 (N=1 hours)	-0.48 kW (55%)
	Event Hour 2 to Event Hour 3 (N=1)	-0.15 kW (29%)
Average Preconditioning (the hour before the event begins)		-0.41 kW (-13%)
Average Snapback (the hour after the event ends)		-0.46 kW (-23%)
Average Event Day Energy Savings		-0.45 kWh

Notes: Average kW savings are the average demand savings per treatment group customer across event hours. Min and max kW savings are the minimum and maximum of the average demand savings per treatment group customer across event hours. Average savings degradation is the difference between the average savings per treatment group customer in an event hour and the average savings in the previous hour. Average preconditioning is the average change in demand per treatment group customer from preconditioning in the hour preceding the start of the event. Average snapback is the increase in demand per treatment group customer in the first hour after the event ends. Average event day conservation is the average change in energy consumption per treatment group customer on event days.

Summer 2020

In summer 2020, PGE dispatched BYOT program thermostats six times. Table 5 summarizes the events. Each event was initiated on a non-holiday, weekday at 4:00 p.m. or 5:00 p.m. and lasted two or three hours. The outside temperature for each event except event 4 averaged more than 90°F and met PGE's indicative temperature threshold.

Table 5. BYOT Demand Response Events – Summer 2020

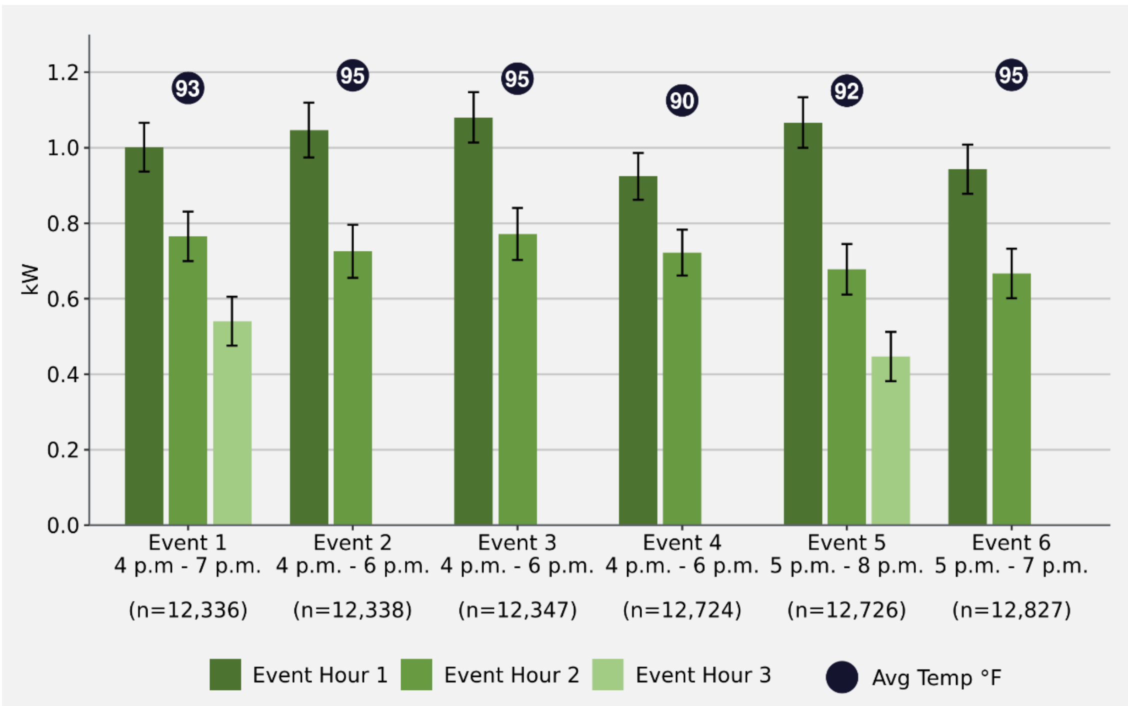
Event	Date	Avg. Outdoor Temperature (°F)	Avg. Temperature Humidity Index	Start Time	Duration (hours)	Met Indicative Temperature Threshold
1	7/20/2020	93	79	4:00 pm	3	Y
2	7/27/2020	98	80	4:00 pm	2	Y
3	7/30/2020	95	81	4:00 pm	2	Y
4	8/10/2020	89	78	4:00 pm	2	N
5	8/17/2020	93	79	5:00 pm	3	Y
6	9/3/2020	94	81	5:00 pm	2	Y

Notes: Average outdoor temperature is the outdoor temperature recorded in PGE's Summer 2020 Event Log. Average temperature humidity index (THI) is the customer weighted average THI of customers included in the analysis.

Demand Response Load Impacts

Figure 4 shows the average kW savings per treatment group customer for each hour of each event during the summer 2020 season as well as the average temperature during each event. Savings during the first event hour ranged from 0.9 kW to 1.1 kW. Savings degraded thereafter during each event, with hour 2 savings ranging between 0.7 kW and 0.8 kW and hour 3 savings between 0.4 kW and 0.5 kW. Savings for all event hours were statistically significant at the 5% significance level.

Figure 4. BYOT Demand Savings by Event – Summer 2020

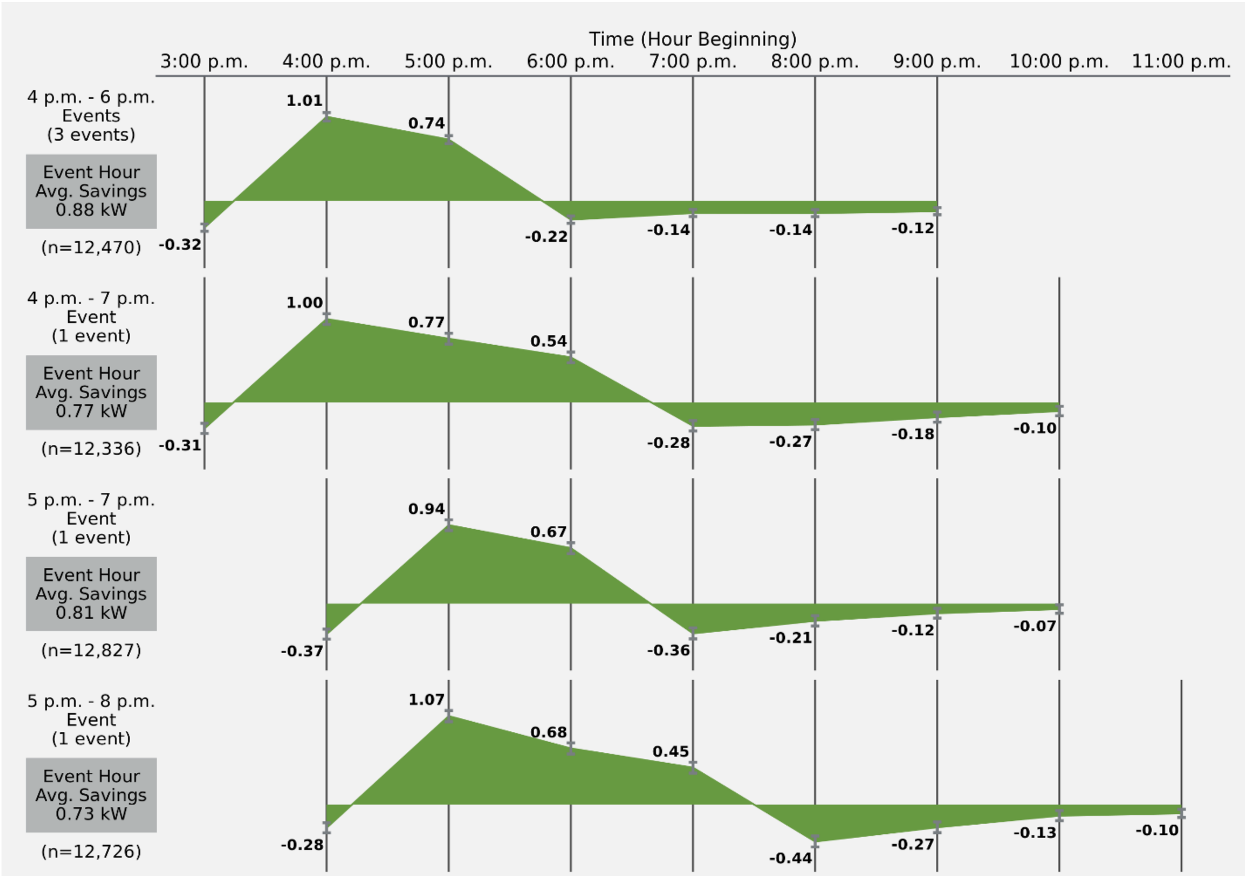


Note: n indicates the number of treatment group customers in the analysis sample for the event. kW savings estimates were obtained from OLS panel regressions of customer metered demand. See text for details. Error bars indicate 95% confidence intervals based on standard errors clustered on homes. Event 4 did not meet the indicative temperature threshold.

Figure 5 displays estimates of the average demand impacts per treatment group home before, during, and after summer 2020 events. Estimates are reported by the starting hour and length of the event. For example, there were three events starting at 4:00 p.m. and lasting two hours. Estimates of the average load impacts for these events are presented in the figure.

Preconditioning increased demand between 0.3 kW and 0.4 kW per treatment group customer, and snapback in the first hour following events increased demand between 0.2 kW and 0.4 kW per treatment group customer. After accounting for preconditioning and snapback effects, each event generated a net decrease in energy consumption. In the figure, this is evident from the larger impact area above the x-axis than below.

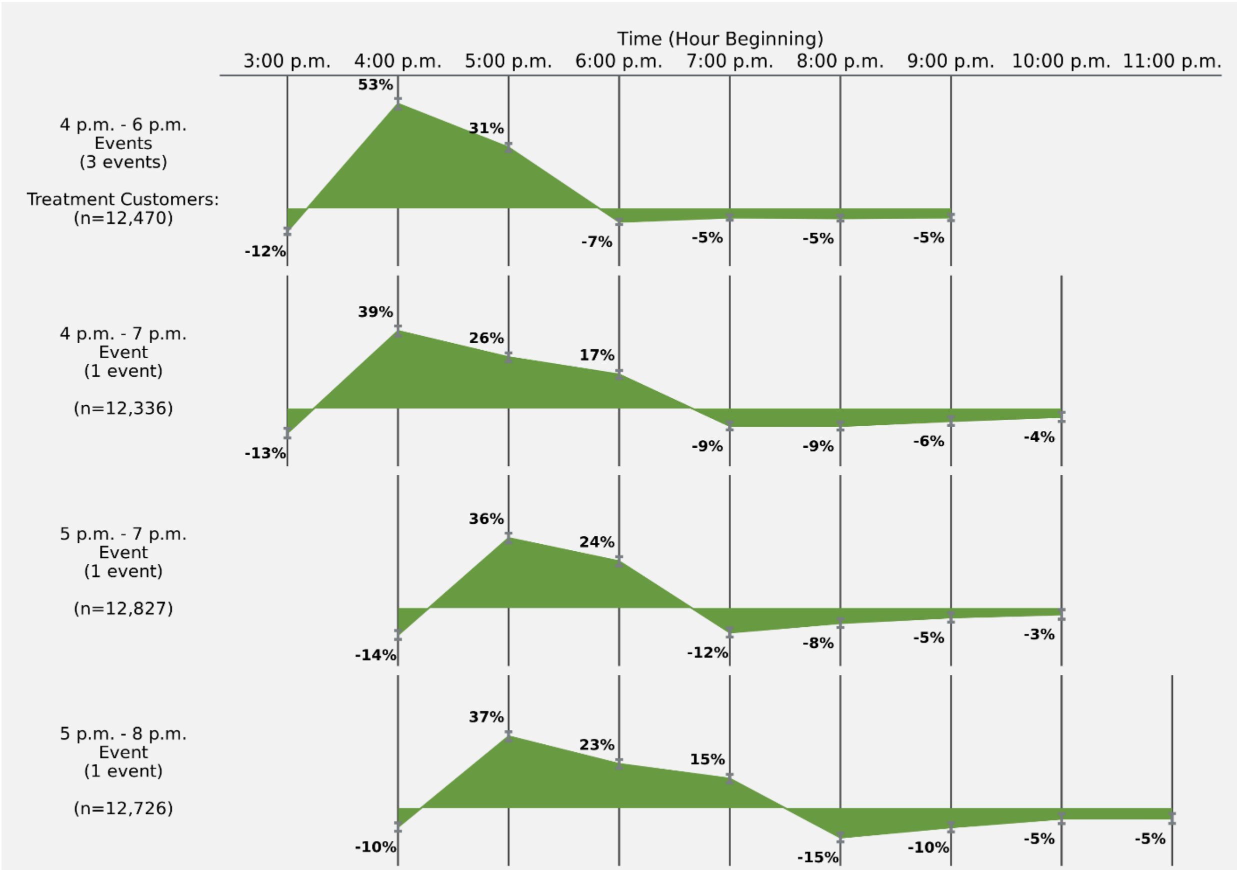
Figure 5. BYOT Average Demand Savings (kW) per Participant – Summer 2020



Note: n indicates treatment group customers in the analysis sample. kW savings estimates were obtained from OLS panel regressions of customer metered demand. See text for details. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

Figure 6 reports the demand impacts as a percentage of baseline demand. Savings during the first event hour ranged from 36% to 53% of baseline demand. In event hour 2, savings as a percentage of baseline demand decreased to between 23% and 36%, and by event hour 3, savings fell to 15% to 17%. As baseline household demand is typically highest during the second and third event hours while demand savings diminish in those hours, the percentage demand savings are highest during event hour 1 (see *Load Impacts by Event Days – Summer 2020*).

Figure 6. BYOT Percentage Demand Savings – Summer 2020



Note: n indicates treatment group customers in the analysis sample. kW savings estimates were obtained from OLS panel regressions of customer metered demand. See text for details. Percentage demand savings calculated as kW savings divided by baseline demand. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

Program Savings

Table 6 summarizes the demand savings generated by the BYOT program during each summer 2020 event. The average savings was 0.82 kW per treatment group customer across all events. Evaluated program savings in MW were calculated by multiplying the average savings per treatment group customer by the number of treatment customers in the analysis sample at the time of the event.[3] Program savings ranged from 9.3 MW to 11.4 MW. Potential program savings estimate the demand savings the program would have achieved if enrolled customers assigned to the control group had also received the direct load control. Potential program savings ranged from 11.2 MW to 14.2 MW.

[3] As the appendix demonstrates, less than 1% of enrolled customers assigned to the treatment group were removed from the analysis because of missing data or other issues.

Table 6. BYOT Program-Level Savings – Summer 2020

Event	Event Time	Avg. Temp. (°F)	Evaluated Avg. Savings per Treatment Group Customer / Event (kW)	Analysis Sample (n)		Evaluated Demand Savings (MW)	Potential Demand Savings (MW)
				Treatment Customers	Control Customers		
1	4 p.m. – 7 p.m.	93	0.769	12,336	2,872	9.5	11.8
2	4 p.m. – 6 p.m.	95	0.886	12,338	2,870	10.9	13.6
3	4 p.m. – 6 p.m.	95	0.926	12,347	2,861	11.4	14.2
4	4 p.m. – 6 p.m.	90	0.823	12,724	2,484	10.5	12.6
5	5 p.m. – 8 p.m.	92	0.731	12,726	2,482	9.3	11.2
6	5 p.m. – 7 p.m.	95	0.805	12,827	2,381	10.3	12.3
Average		**93**	**0.823**	**12,550**	**2,658**	**10.3**	**12.6**

Note: Potential demand is based on total enrolled customers as of September 2020 (N=15,298).

Performance Metrics

Table 7 displays the key performance metrics of the summer 2020 BYOT program evaluation. The metrics summarize the performance of smart thermostats during events with outside temperatures exceeding the indicative temperature threshold (90°F) expected to trigger future summer demand response events. The metrics were calculated using the estimates of kW impacts per treatment group customer before, during, and after events. Demand impacts as a percentage of baseline demand are shown in parentheses.

Table 7. BYOT Program Performance Metrics – Summer 2020

Key Metrics		Savings per Treatment Group Customer
Average kW Savings	Event Hour 1 (N=5 hours)	1.03 kW (38%)
	Event Hour 2 (N=5)	0.72 kW (24%)
	Event Hour 3 (N=2)	0.49 kW (16%)
Min kW Savings	Event Hour 1 (N=5)	0.94 kW (36%)
	Event Hour 2 (N=5)	0.67 kW (24%)
	Event Hour 3 (N=2)	0.45 kW (15%)
Max kW Savings	Event Hour 1 (N=5)	1.08 kW (40%)
	Event Hour 2 (N=5)	0.77 kW (26%)
	Event Hour 3 (N=2)	0.54 kW (17%)
Average Savings Degradation (difference from previous hour savings)	Event Hour 1 to Event Hour 2 (N=5 hours)	-0.31 kW (-30%)
	Event Hour 2 to Event Hour 3 (N=2)	-0.23 kW (-32%)
Average Preconditioning (the hour before the event begins)		-0.32 kW (12%)
Average Snapback (the hour after the event ends)		-0.30 kW (10%)
Average Event Day Energy Savings		0.86 kWh

Notes: Average kW savings are the average demand savings per treatment group customer across event hours. Min and max kW savings are the minimum and maximum of the average demand savings per treatment group customer across event hours. Average savings degradation is the difference between the average savings per treatment group customer in an event hour and the average savings in the previous hour. Average preconditioning is the average change in demand per treatment group customer from preconditioning in the hour preceding the start of the event. Average snapback is the increase in demand per treatment group customer in the first hour after the event ends. Average event day conservation is the average change in energy consumption per treatment group customer on event days.

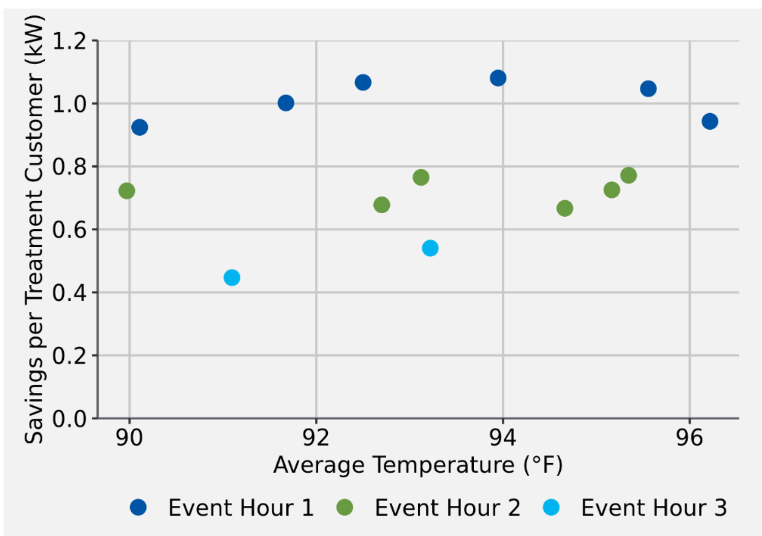
Temperature Response

Air conditioning loads are driven by outside temperature and humidity, and it is expected that demand response savings will be higher on hotter and more humid summer event days. Understanding the relationship between demand response savings and outside temperature and humidity will be important for operationalizing thermostat demand response as a dispatchable resource.

Figure 7 plots estimates of average savings per enrolled customer against outside temperature for event hours in summer 2020. Figure 8 plots hourly savings against the temperature humidity index (THI). Event hours are color-coded by the first, second, and third hours of events, since demand response savings tend to diminish with time since the event start.

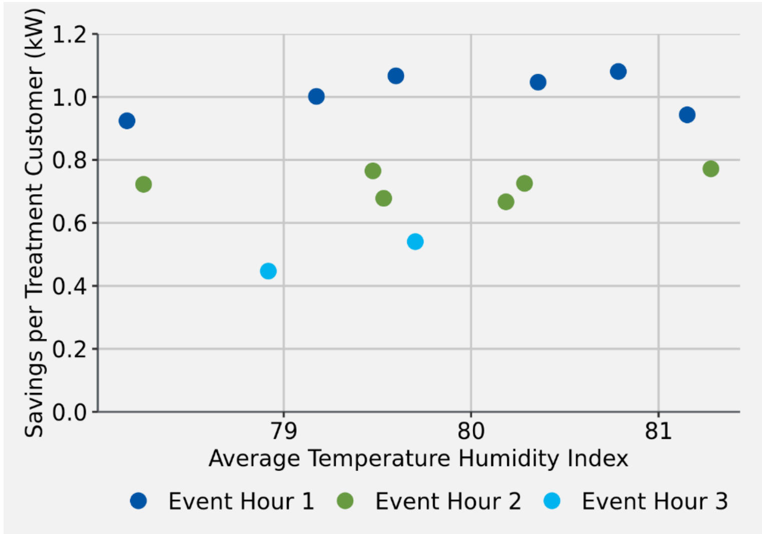
The number of data points is limited to the 14 event hours in summer 2020, but both figures suggest that demand response savings increased with temperature and THI. The relationships are strongest during the first and second event hours.[4]

Figure 7. BYOT Summer 2020 Temperature Response



[4] The highest event hour temperature of 97°F occurred during the first hour of event 6 and shows a small decrease in savings relative to first event hours of other events, but this event may be an anomaly because it occurred in September when residential air conditioning demand typically drops off.

Figure 8. BYOT Summer 2020 Temperature-Humidity Index Response



To investigate the temperature response of savings more thoroughly, Cadmus ran OLS regressions of event hour savings on hour-of-event indicator variables (hour 1, hour 2, hour 3), event hour temperature or THI, and indicator variable for event 6. The results are in Table 8. They show that demand response savings increased by about 0.015 kW/°F and 0.034 kW/THI. Both estimates are statistically significant at the 5% level.

Table 8. Temperature and THI Response Regression Estimates

	Temperature	THI
Regression Coefficient with Standard Error	0.015 (0.007)	0.034 (0.013)
R^2	0.968	0.972
N	14	14

Notes: Temperature response estimates based on OLS regression analysis of event hour savings on hour-of-event indicator variables (hour 1, hour 2, hour 3), event hour temperature (or THI), and indicator variable for event 6. Heteroskedasticity-robust standard errors in parentheses.

A more definitive analysis of the temperature response would incorporate data from previous summer seasons. With more data, it will be possible to predict for each temperature or THI the average demand savings per enrolled customer that PGE can expect from the BYOT pilot. This research is planned for 2021.

Event Overriding

When a customer overrides an event by adjusting the thermostat settings, PGE loses the ability to control the air conditioning unit for the remainder of the event. Depending on when during the event and the magnitude of the changes the customer makes, overriding may cause air conditioning to run longer than would usually occur. Thus, event overriding can lead not just to a loss in savings but an increase in electricity demand for air conditioning.

Table 9 summarizes telemetry data from Resideo about overriding during summer 2020 events.[5] For each event, the table shows total number of thermostats enrolled, percentage that fully participated, percentage that overrode, and the percentages that were offline (not connected to the Wi-Fi), failed to confirm that the event control signal was received, or whose status could otherwise not be confirmed. The data include BYOT and Direct Install (DI) participants. Participants overrode between 22% and 28% of enrolled thermostats during each event.

Table 9. Event Override Summary (BYOT and DI) – Summer 2020

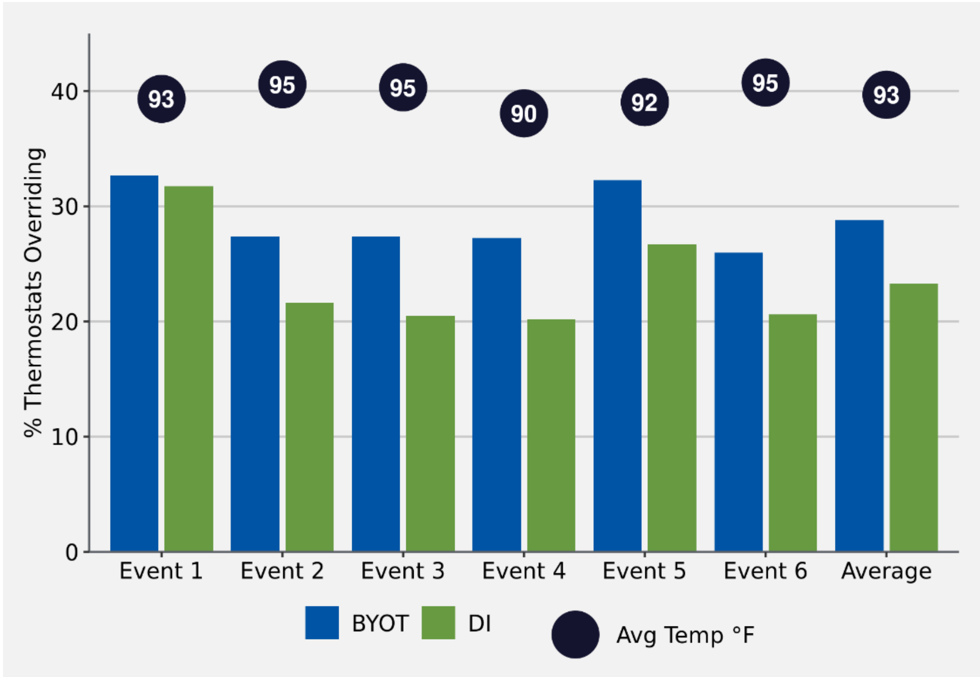
Event	Event Hours	Avg. Outdoor Temperature (°F)	Total Thermostats	Fully Participated	Opted Out	Offline	Failed	Unknown
1	4 p.m. - 7 p.m.	93	17,282	59%	28%	3%	0%	10%
2	4 p.m. - 6 p.m.	98	17,265	65%	23%	3%	0%	10%
3	4 p.m. - 6 p.m.	95	17,265	65%	23%	3%	0%	10%
4	4 p.m. - 6 p.m.	89	17,670	66%	23%	3%	0%	8%
5	5 pm. - 8 p.m.	93	17,507	62%	28%	3%	0%	8%
6	5 p.m. - 7 p.m.	94	18,368	68%	22%	5%	0%	4%

Data source: Resideo summary of overriding and thermostat status.

Figure 9 shows the percentage of thermostats overridden during each demand response for the BYOT and DI pilot programs. This figure excludes offline, failed, and status unknown thermostats. Overriding was more prevalent for BYOT, between 28% and 32% of thermostats, than for DI.

[5] These data were aggregated to the program track (BYOT or DI) or program level, and not reported for individual thermostats.

Figure 9. Event Overrides by Program – Summer 2020



Note: Percentage calculations are based on counts of enrolled thermostats belonging to treatment group customers in each event and exclude off-line, failed, and unknown thermostats.
Data source: Resideo summary of overriding and thermostat status.

The impact of overriding on demand savings depends on when during an event a customer overrides it. If a customer overrides before the beginning of the event (i.e., during the precooling period) or during the first event hour, PGE will forego more electricity demand savings than if the customer overrides during the third event hour.

Figure 10 shows the percentage of enrolled customers who remained in each event (did not override) as a function of minutes since the event start. At the beginning of events (minute zero), approximately 90% of thermostats remained in the event, suggesting that about 10% of participants overrode the thermostat settings during the precooling period. The greatest amount of overriding occurred during the preconditioning period and first event hour. Sixty minutes after the event start, about 80% of thermostats remained. At one hour, the survival curves flatten, suggesting that the rate of overriding decreased thereafter. At the end of three-hour events, about one-third of participants had overridden the event settings.

Figure 10. Event Participation Survival Rates – Summer 2020

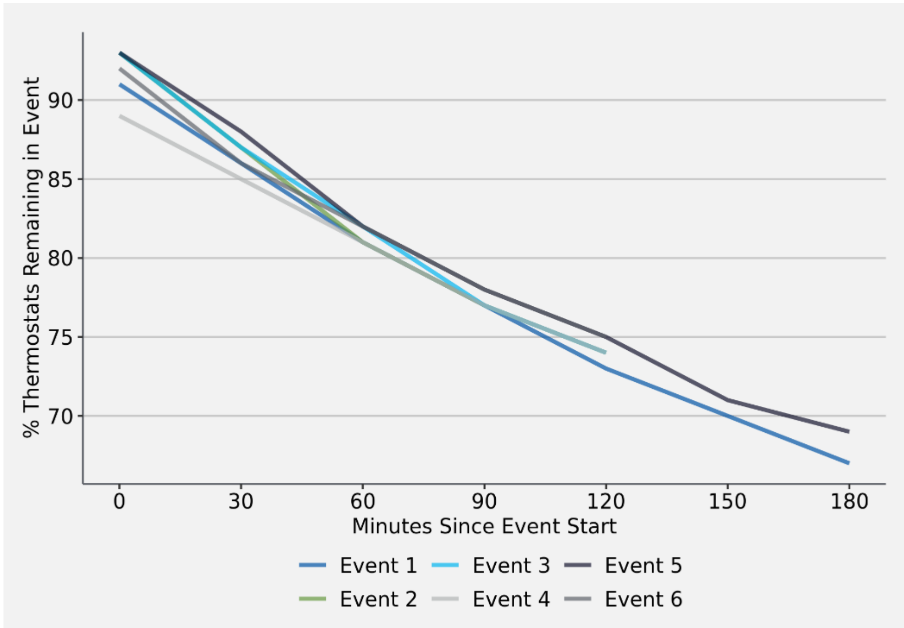
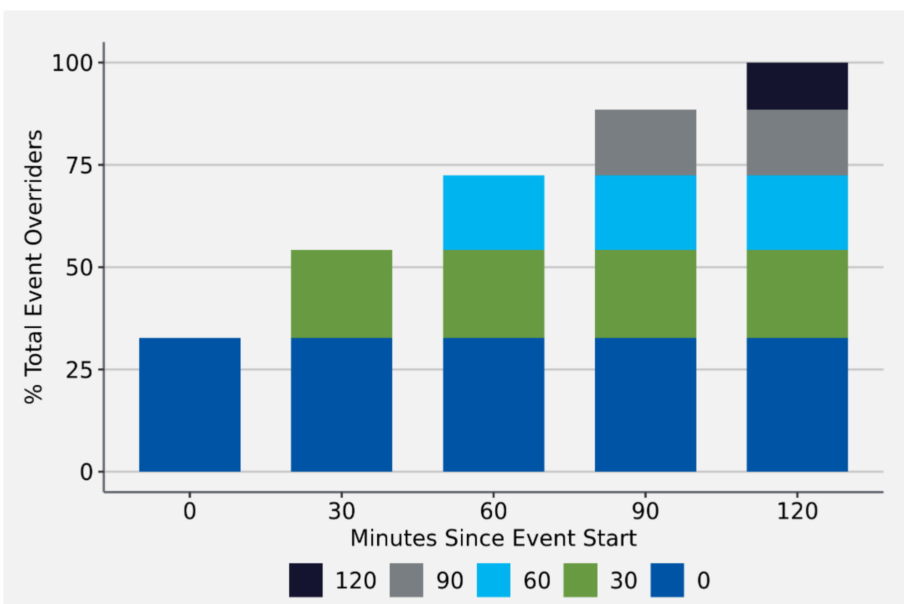


Figure 11 shows another view of overriding by displaying the percentage of overriding that occurred during each 30-minute interval of two-hour events. The figure shows that about two-thirds of all overriding occurs during the preconditioning period or the first event hour. If PGE could take steps to discourage overriding during the preconditioning period or first event hour and delay the overriding until later hours of the event, the savings during the first hour might significantly increase.

Figure 11. Cumulative Overriding by Event Time Elapsed – Summer 2020

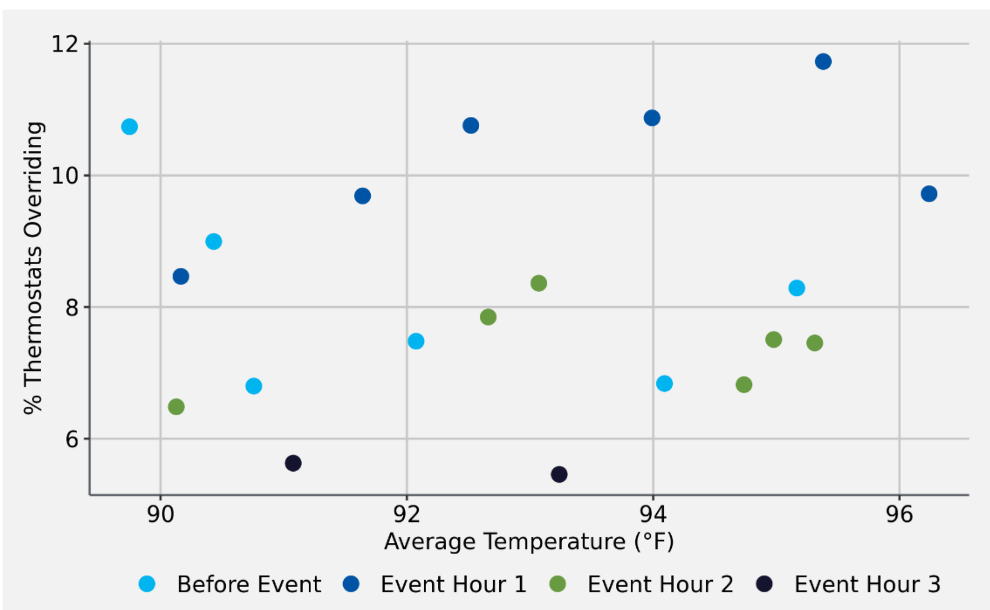


Note: Analysis was limited to four two-hour events in summer 2020 since the percentage of thermostats overriding in each interval is a function of the event length. Percentage of overriders in each interval was averaged across events.

Cadmus also plotted the percentage of enrolled thermostats (excluding failed communications, offline, and unknown status) overridden in each event hour against outside temperature. It is important to differentiate between the preconditioning period and the event period because outside temperature is likely to have opposite effects on overriding. During the preconditioning period, thermostat setpoints are lowered and the air conditioning unit runs more than normal. (The higher electricity demand from preconditioning is depicted in Figure 5 and Figure 6.) Enrolled customers will be more likely to notice the change in home interior temperature and experience thermal discomfort when the outside temperature is cooler. If participants override during the preconditioning period in response to thermal discomfort, we would expect less overriding on warmer days.[6] In contrast, during the event, the air conditioner runs less than normal, and it is expected participants will be less comfortable and more likely to override on warmer days.

Figure 12 shows the percentage of participating thermostats (excluding offline, failed, and status unknown thermostats) overridden plotted against average outdoor temperature during the preconditioning hour and each event hour. As expected, there is some evidence of less overriding before the event on cooler days, as demonstrated by the negative trend of pre-event overrides, and more overriding during the first event hour on hot days, as demonstrated by the positive trend of hour 1 percentage overrides.

Figure 12. Overrides vs. Outside Temperature – Summer 2020



[6] Cadmus' regression analysis of the summer 2020 experience survey data showed that smart thermostat demand response participants who reported thermal discomfort during events were 32 percentage points or 52% more likely to have overridden one or more events. See the winter 2019/2020 and summer 2020 Direct Install smart thermostat demand response evaluation report.

Recommendations

The BYOT pilot evaluation did not include a formal process evaluation of the customer experience or program delivery, so there are a limited number of recommendations for program improvement that Cadmus can make, especially regarding the customer experience. The evaluation of the Smart Thermostat Direct Install Pilot in winter 2019/2020 and summer 2020, which includes a process evaluation, makes a larger number of recommendations, many of which are relevant to the BYOT pilot.

Based on the findings and conclusions of the impact evaluation for the BYOT pilot in winter 2019/2020 and summer 2020, Cadmus makes the following recommendations:

- ***Screening Enrollees for Ineligible HVAC*** – PGE should continue to work with demand response service providers to screen ineligible HVAC equipment from participating in the BYOT pilot. The BYOT demand response savings were much higher in winter 2019/2020 than in winter 2018/2019 in part because of the removal of customers with ineligible heating equipment from the pilot.
- ***Research Aimed at Understanding and Mitigating Customer Overriding*** – PGE is losing significant savings from customers who override demand response events; therefore, it should further research the causes and consider implementing and testing interventions (e.g., encouragement messaging, tiered incentives) to reduce the frequency or delay the onset of overriding. Factors that contribute to overriding may include participation fatigue, lack of understanding of participation requirements, impacts to comfort due to occupancy changes under COVID-19, interaction of customers' conservation efforts, or thermal efficiency of the home envelope. PGE could also consider dispatching events differently to customers with a history of overriding than to customers without such propensities.
- ***Additional Field Testing*** – PGE called only morning events during the winter 2019/2020 season. If PGE plans to use smart thermostat demand response during winter afternoons and evenings, it should call events during these times in future winter seasons.

Appendix A. Additional Impact Evaluation Details

Analysis Sample Counts

Table A-1 and Table A-2 show the number of customers in the tracking data for the winter 2019/2020 and summer 2020 seasons, those removed due to various sources of attrition in the data cleaning process, and the final analysis samples. Only about 0.5% of enrolled customers were excluded from the analysis sample in each season.

Table A-1. Analysis Sample Counts – Winter 2019/2020

Filter	Treatment Group		Control Group	
	Customers	Percent	Customers	Percent
Customers in Tracking Data	1,451	100%	561	100%
Customers with one program enrollment	1,443	99.4%	553	98.6%
Customers with one HVAC System	1,443	99.4%	553	98.6%
Customers in AMI Data	1,443	99.4%	553	98.6%
Customers with ADC < 300 kW	1,443	99.4%	553	98.6%
Customers included in analysis	**1,443**	**99.4%**	**553**	**98.6%**

Table A-2. Analysis Sample Counts – Summer 2020

Filter	Treatment Group		Control Group	
	Customers	Percent	Customers	Percent
Customers in Tracking data	13,014	100%	2,284	100%
Customers in AMI data	12,945	99.5%	2,263	99.1%
Customers with ADC < 300 kW	12,945	99.5%	2,263	99.1%
Customers included in analysis	**12,945**	**99.5%**	**2,263**	**99.1%**

Equivalence of Randomized Treatment and Control Groups

At the beginning of the winter 2019/2020 and summer 2020 seasons, Cadmus randomly assigned enrolled customers to the evaluation treatment group or control group. Figure A-1 and Figure A-2 perform checks of the balance between the randomized treatment and control groups by comparing their hourly demand on non-event, non-holiday weekdays in each season.

The figures plot the average demand per customer by hour of the day and show that the treatment and control groups were well balanced across hours in each season. The 95% confidence interval for the difference in demand between the randomized treatment and control groups includes zero in almost all hours.

Figure A-1. BYOT Consumption Equivalency – Winter 2019/2020

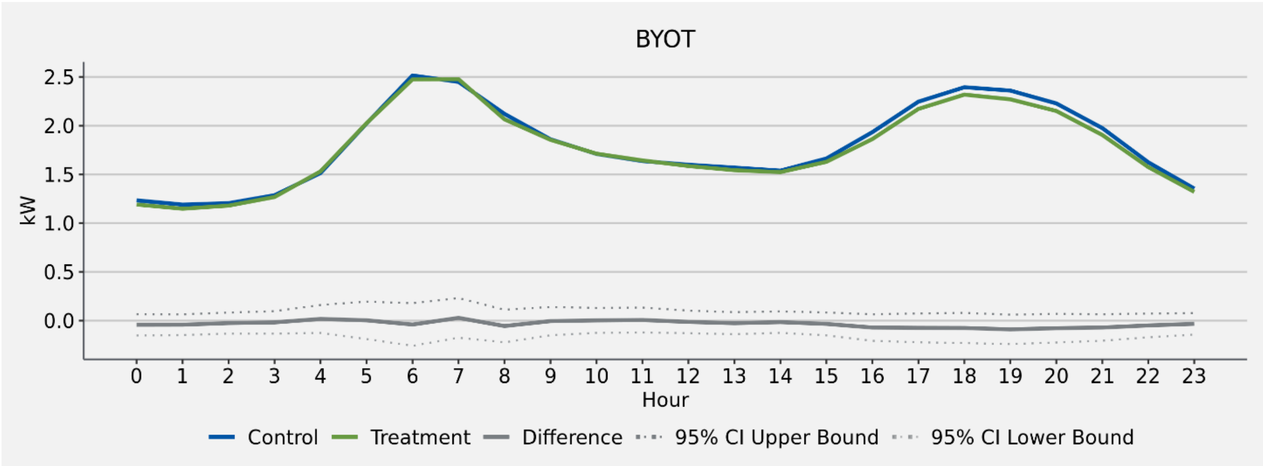
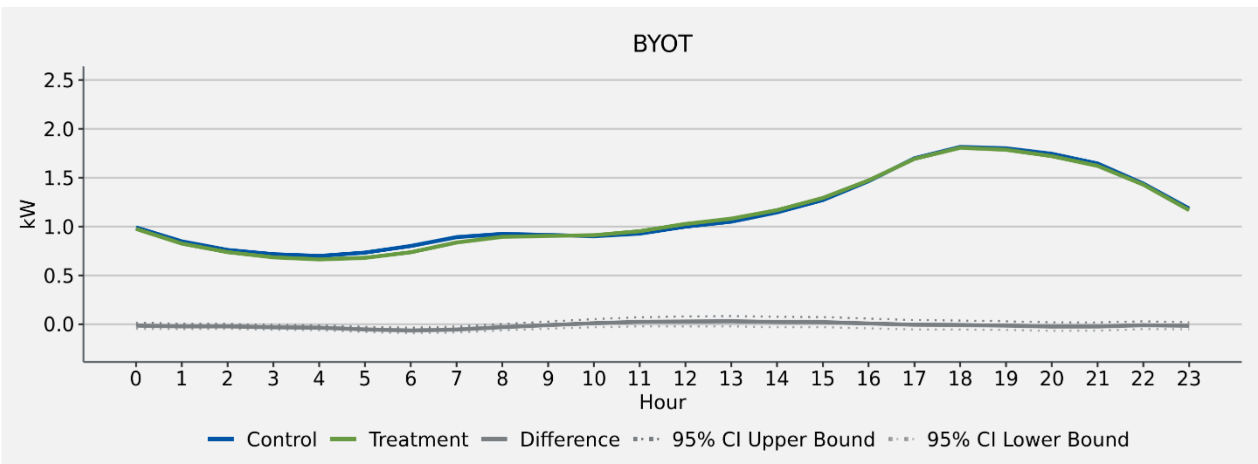


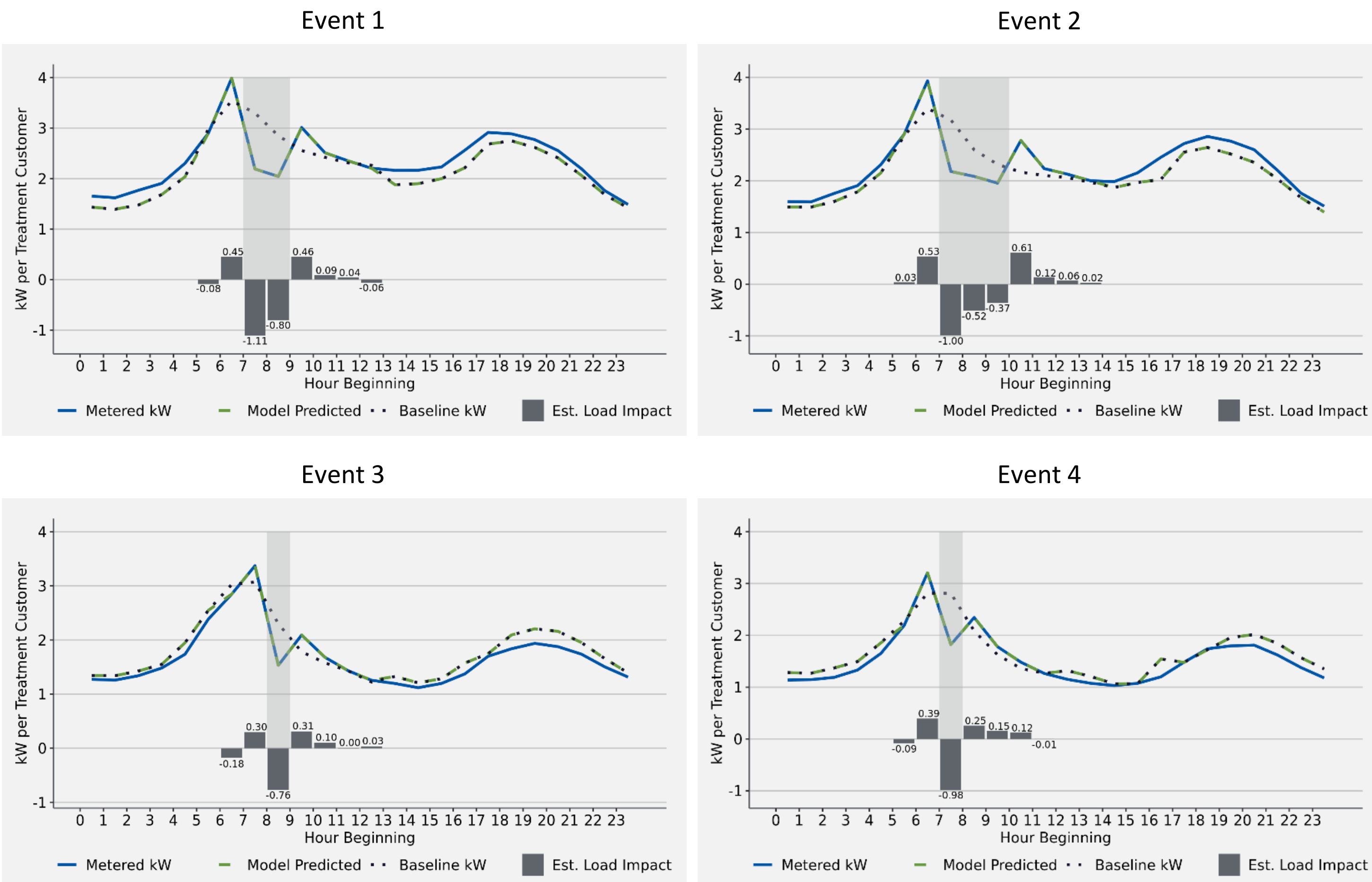
Figure A-2. BYOT Consumption Equivalency – Summer 2020



Load Impacts by Event Days – Winter 2019/2020

Figure A-3 displays estimates of the average load impacts per treatment group customer for demand response events in winter 2019/2020. 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 demanded if the event had not been called.

Figure A-3. Estimated Load Impacts by Event – Winter 2019/2020

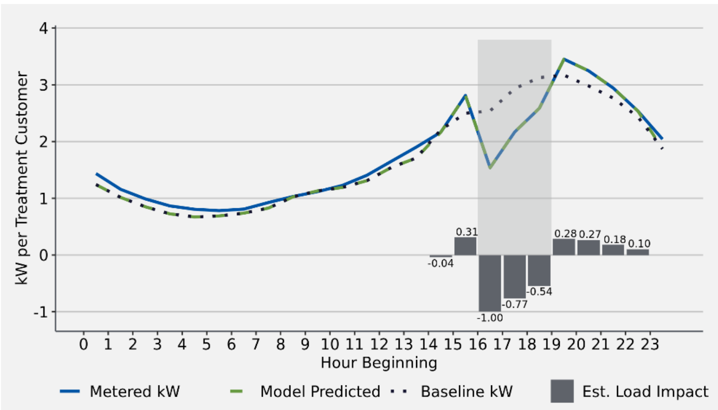


Load Impacts by Event Days – Summer 2020

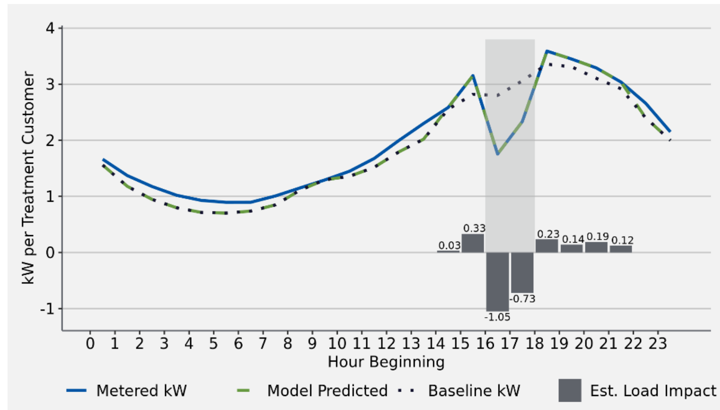
Figure A-4 displays estimates of the average load impacts per treatment group customer for demand response events in winter 2019/2020.

Figure A-4. Estimated Load Impacts by Event – Summer 2020

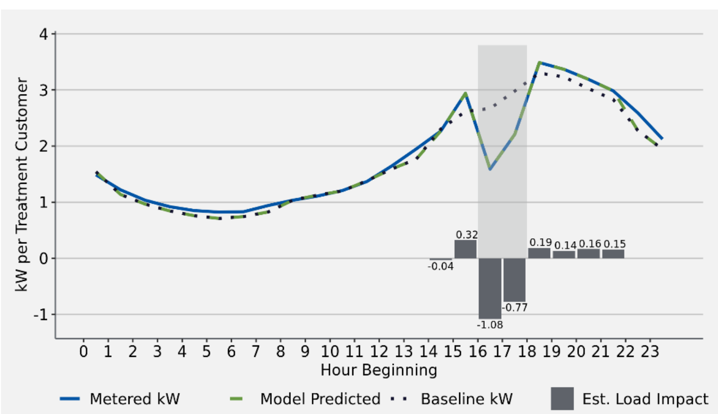
Event 1



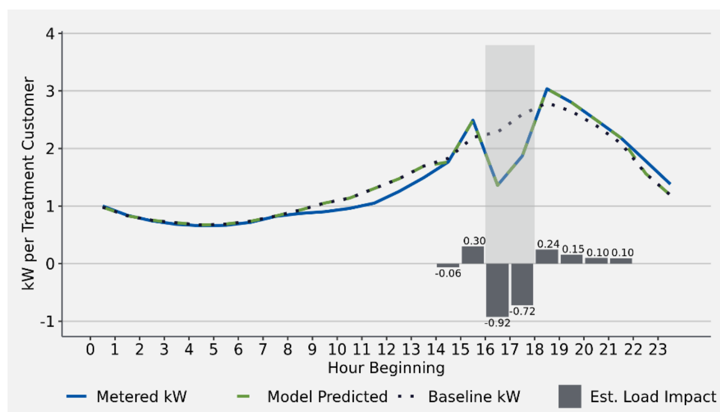
Event 2



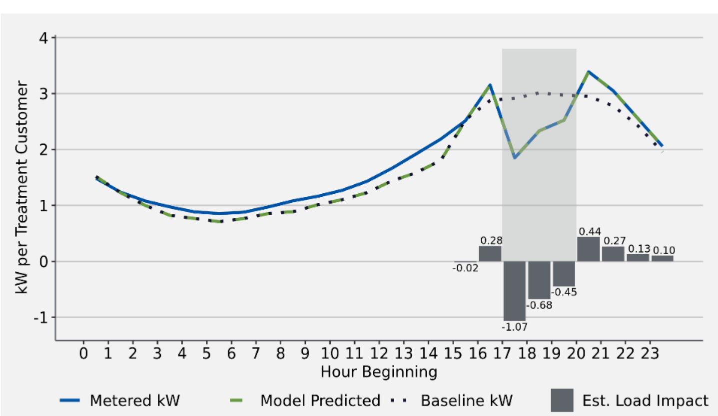
Event 3



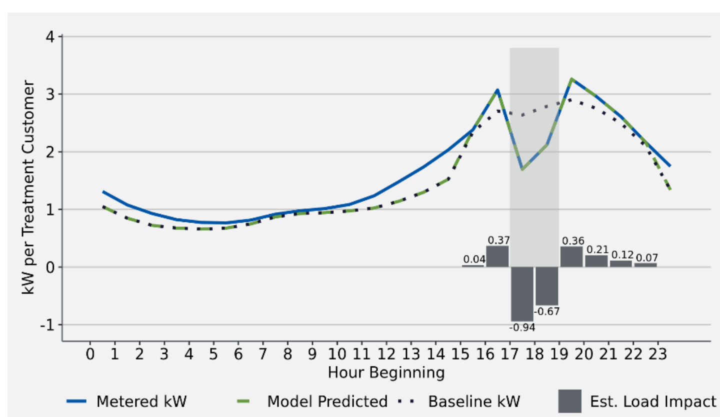
Event 4



Event 5



Event 6

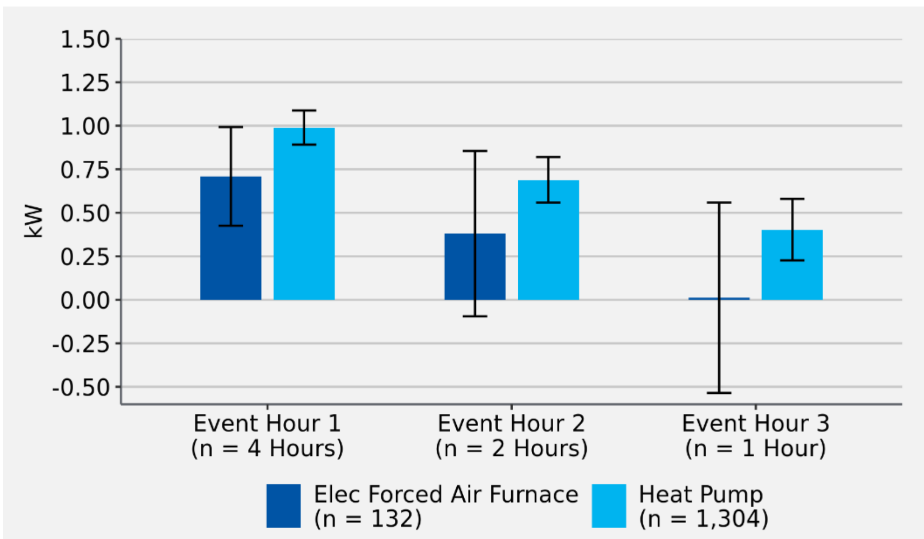


Demand Savings by HVAC Equipment Type – Winter 2019/2020

Cadmus also estimated the demand savings by heating system type. Electric forced air furnaces (EFAFs) are less efficient at heating homes than are heat pumps, so it is expected that savings will be higher in homes with EFAFs due to their higher savings potential.[7] However, at very cold temperatures, heat pumps may operate less efficiently, which can diminish the savings from demand response.

Figure 13 shows the average kW savings per treatment group customer by heating system type and event hour. There were only 132 EFAFs in the analysis sample, so the savings estimates for this system type are not estimated precisely. In winter 2019/2020, homes with heat pumps saved 1.0 kW per treatment group customer in the first event hour, whereas customers with EFAFs saved only 0.7 kW in hour 1. Savings for heat pumps was also higher in the second and third hours. However, none of the differences is statistically significant because EFAF savings estimates are not precise.

Figure 13. BYOT Savings by HVAC System for Event Hours – Winter 2019/2020



Note: Demand impacts by HVAC system type were estimated in separate OLS panel regression models for customers with EFAFs and customers with heat pumps. n indicates the number of treatment group customers in the analysis sample with each heating system type.

In addition to the small number of EFAFs in the sample, a reason to interpret these results with caution is that any difference in savings between home heating equipment types may reflect the impacts of not just home heating equipment but also other home features or customer behaviors correlated with having a particular heating equipment type. For example, homes with heat pumps may have higher savings because they were newer and therefore better insulated than homes with EFAFs.

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[7] It is also important to keep in mind that heat pump homes may have different features and energy use behaviors that affect their thermal efficiency, heating energy demand, and the savings from demand response. For example, home heating equipment type could be correlated with home size and thermal efficiency of the home envelope.

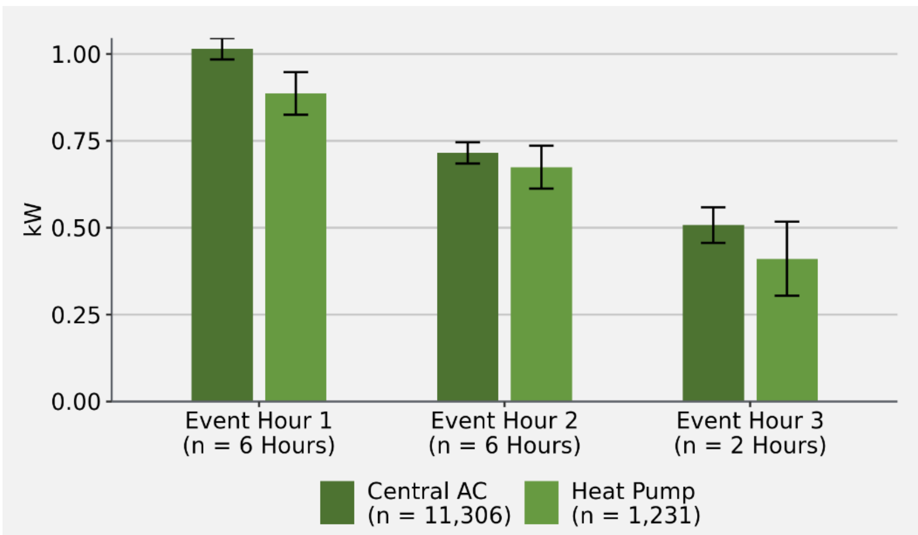
Demand Savings by HVAC Equipment Type – Summer 2020

Cadmus also estimated summer 2020 savings by cooling system type. Since heat pumps in cooling mode operate similar to central air conditioners (CACs), it was expected there would not be large differences in savings between customers by HVAC system type.

Figure 14 shows the average kW savings per treatment group customer for each event hour by cooling system. Customers with CACs achieved slightly higher savings than customers with heat pumps, but the differences were small and not statistically significant.

During the first hour of events, CAC homes saved 1.0 kW, while heat pump homes saved 0.9 kW. These differences persisted in event hour 2 and event hour 3. Though CAC customers saved more than heat pump customers, the differences may be due not to the cooling equipment type but rather to other home features or energy consumption behaviors correlated with having a particular system type.

Figure 14. BYOT Savings by HVAC System for Event Hours – Summer 2020



Note: Demand impacts by HVAC system type were estimated in separate OLS panel regression models for customers with EFAFs and customers with heat pumps. n indicates the number of treatment group customers in the analysis sample with each heating system type.

CADMUS

Direct Install Smart Thermostat Pilot

Evaluation Report

September 2021

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Acronyms, Terms, and Definitions

Acronym/Term	Definition
ADC	Average daily consumption
AMI	Advanced metering infrastructure
BYOT	Bring-your-own thermostat
Control Group	Control group refers to Direct Install customers randomly assigned *not* to receive the thermostat control signals during demand response events. The electricity demand of the control group provided a baseline for measuring the demand response event impacts. Enrolled customers were randomly assigned to the evaluation treatment or control groups at the beginning of each season.
DRMS	Demand response management service
DLC	Direct load control
Event Overrider	An enrolled customer who adjusts the thermostat settings during the pre-conditioning or temperature setback phases of a demand response event and terminates the control of their thermostat by the DRMS provider for the remainder of the event.
Event Over-Ride	Occurs when a customer overrides the control of the thermostat by DRMS provider by adjusting the thermostat settings. PGE loses the ability to control the air conditioning unit for the remainder of the event
Event Persistence	Occurs when a customer does not adjust the thermostat settings during a demand response event and allows the DRMS provider to retain control.
HVAC	Heating, ventilation, and air conditioning
IDR	Intelligent Demand Response
Indicative Temperature	The term “indicative temperature” refers to a PGE designated temperature threshold that may trigger a demand response event. The indicative temperature is set at or above 90°F in summer and 32°F or below in winter.
ITT	Intent to treat treatment effect – the average kW impact per customer (or other relevant unit of analysis) for customers that the program intends to treat
kW	Kilowatt
kWh	Kilowatt-hour
Micro-segment	Five PGE customer segments used in characterizing residential customer demand response potential: Big Impactors, Fast Growers, Middle Movers, Borderliners, and Low Engagers. See the Table C-2 for additional descriptions.
MW	Megawatt
MWa	Average Megawatt
NOAA	National Oceanic and Atmospheric Administration
OLS	Ordinary least squares
PGE	Portland General Electric
RCT	Randomized controlled trial
Treatment Group	Treatment group refers to enrolled customers who were randomly assigned to receive the thermostat control signals during demand response events. Enrolled customers were randomly assigned to the evaluation treatment or control groups at the beginning of each season.
THI	Temperature-humidity index
TOT	Treatment effect on the treated – the average impact per treated customer

Executive Summary

In 2016, the Oregon Public Utility Commission (OPUC) directed Portland General Electric (PGE) to obtain 77 MWs and 69 MWs of, respectively, winter and summer peaking demand response capacity across its full-service territory by 2021.[1] This demand response capacity was intended to help to replace capacity lost from the planned closure of the Boardman facility. Since the OPUC's order, PGE has implemented several demand response pilot programs including smart thermostat direct load control (DLC) that enrolls thousands of PGE residential customers and now provides over 13.7 MW of peak capacity.[2]

PGE's Smart Thermostat pilot enables the direct management of residential customer summer and winter peak space-conditioning electricity demand. Through demand response management service (DRMS) providers, PGE can manage the cooling and heating loads of thousands of participating customers during demand response events by remotely adjusting the setpoints of their smart thermostats.

Over a learning phase of the Smart Thermostat pilot lasting from 2018 to 2020, PGE operated separate tracks—Direct Install and Bring-Your-Own-Thermostat (BYOT)—to understand key market characteristics and the grid services affecting the overall resource value. PGE plans to eventually transition the pilot and its two tracks to a full-scale program and to begin integrating the program with grid operations. This evaluation seeks to help identify and measure the performance of this demand response resource and to provide performance metrics to PGE grid operators so they can have full confidence in the capabilities of this product as a capacity resource.

This evaluation focuses on the Direct Install track. In 2018, PGE launched Direct Install, offering customers a free or discounted smart thermostat device with a complimentary installation from a technician to remove the barriers of the hardware cost, installation cost, and the difficulty of self-installation.[3]

PGE initiated four load control events in winter 2019/2020 and six in summer 2020. Through analysis of individual-customer hourly AMI meter data, interviews with program staff, customer surveys, and a review of the logic model, the evaluation assessed the Direct Install load impacts, program delivery, and customer experience.

---

1 PGE has increased its demand response goals to 141 MW in winter and 211 MW in summer by 2025. See PGE 2019 Integrated Resource Plan, July 2019. Filed by PGE with the Oregon Public Utility Commission, July 19, 2019. https://edocs.puc.state.or.us/efdocs/HAA/lc73haa162516.pdf

2 PGE Flexible Load Plan, December 2020. p. 28. Filed by PGE with the Oregon Public Utility Commission, December 23, 2020. https://edocs.puc.state.or.us/efdocs/HAA/haa125814.pdf

3 PGE launched the Smart Thermostat Demand Response pilot with the BYOT track in 2015. Customers who already own a smart thermostat can participate in the pilot program through the BYOT track. The demand impacts of the BYOT track are reported in a separate memo to PGE (February 2021).

The evaluation covered these objectives:

- Estimate the average kilowatt impact per treatment group customer before, during, and after the load control events
- Assess the impact of events on customer comfort
- Assess the impacts of participation on customer satisfaction with the program and PGE
- Compare Direct Install and BYOT load impacts
- Identify opportunities for improving program delivery, program performance, cost-effectiveness, and customer satisfaction

To measure the demand impacts in winter and summer, PGE implemented a field experiment in which program enrollees were randomly assigned to a treatment group or control group. Control group customers did not experience the demand response events and provided the baseline for measuring the demand impacts for treatment group customers. The demand impact estimates were obtained from panel regression analysis of individual-customer, hour-interval AMI meter consumption data.

Key Findings

As of October 2020, PGE had enrolled a total of 5,902 customers in the Direct Install track, comprising approximately 2,842 winter-eligible and 5,386 summer-eligible customers (with 2,326 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 4.63 MW of winter demand response capacity and 5.06 MW of summer demand response capacity from Direct Install. These capacity values reflect the average savings across all event hours and therefore savings degradation after the first event hour.[5]

Table 1 presents Direct Install demand response event savings and customer satisfaction findings from the evaluation for winter 2019/2020 and summer 2020. In winter, the hourly demand savings per treatment group customer averaged 1.63 kW. Eighty-seven percent of customers were satisfied with the pilot, as measured by the percentage of customers rating their satisfaction as six or higher on 0-10 scale. In summer, the program achieved average demand savings per treatment group customer of 0.94 kW with 86% of customer satisfied.

---

4 Winter 2019/2020 enrollments reflect the number of enrolled customers as of March 2020, and summer 2020 enrollments reflect the number of enrolled customers as of September 2020.

5 To calculate demand response capacity, Cadmus used the average demand savings per enrolled thermostat across all event hours for each season (1.63 kW in 2019/2020 winter and 0.94 kW in 2020 summer). Though it used this straightforward average, Cadmus recognizes that demand response resources have many attributes and can be used in different ways. Demand response capacity can be calculated for events that are triggered for specific outside temperatures, PGE system load, or market condition thresholds, for subpopulations, or at different durations and dispatch times. PGE's demand response capacity depends on how it plans to use demand response.

Table 1. Direct Install Demand Savings and Satisfaction Results

	Winter 2019/2020	Summer 2020
kW Savings*		
Planned kW	1.2	1.0
Evaluated kW	**1.63**	**0.94**
Evaluated kW for events meeting indicative temperature threshold	**1.46**	**0.97**
Satisfaction**		
Satisfied (6-10)	87%	86%
Delighted (9-10)	62%	55%

* Savings values equal the average kW demand reduction per treatment group customer during events; **blue** font indicates significance at 5% level.
** Satisfaction values equal the percentage of survey respondents who rated their program satisfaction on a 0 to 10 rating scale.

Table 1 also shows the average demand savings per treatment group customer for demand response events with weather conditions that meet indicative temperature thresholds. Indicative temperature thresholds refer to PGE designated temperatures that may trigger a demand response event. These were set at or above 90°F in summer and 32°F or below in winter. In summer 2020, all except one event were temperature indicative. In winter 2019/2020, two of four events were temperature indicative.

Table 2 reports key performance metrics for Direct Install for winter 2019/2020 and summer 2020. The metrics summarize the performance of smart thermostats before, during, and after events meeting the indicative temperature thresholds. The metrics were calculated from estimates of the average demand (kW) impacts per treatment group customer. Load impacts as a percentage of metered baseline demand are shown in parentheses.

Table 2. Direct Install Performance Metrics

Key Metrics		Winter Savings (kW) 2019/2020	Summer Savings (kW) 2020
Average kW Savings	Event Hour 1 (Winter N=2 hours, Summer N=5 hours)	1.81 kW (45%)	1.21 kW (39%)
	Event Hour 2 (Winter N=1, Summer N=5)	1.21 kW (31%)	0.85 kW (26%)
	Event Hour 3 (Winter N=1, Summer N=2)	0.83 kW (23%)	0.52 kW (16%)
Min kW Savings	Event Hour 1 (Winter N=2, Summer N=5)	1.54 kW (45%)	1.19 kW (39%)
	Event Hour 2 (Winter N=1, Summer N=5)	1.21 kW (31%)	0.8 kW (24%)
	Event Hour 3 (Winter N=1, Summer N=2)	0.83 kW (23%)	0.5 kW (15%)
Max kW Savings	Event Hour 1 (Winter N=2, Summer N=5)	2.08 kW (46%)	1.27 kW (41%)
	Event Hour 2 (Winter N=1, Summer N=5)	1.21 kW (31%)	0.9 kW (27%)
	Event Hour 3 (Winter N=1, Summer N=2)	0.83 kW (23%)	0.55 kW (17%)
Average Savings Degradation (difference from previous hour savings)	Event Hour 1 to Event Hour 2 (Winter N=1 hour, Summer N = 5 hours)	-0.87 kW (48%)	-0.36 kW (-30%)
	Event Hour 2 to Event Hour 3 (Winter N=1, Summer N = 2)	-0.38 kW (31%)	-0.28 kW (-33%)
Average Preconditioning (the hour before the event begins)		-0.66 kW (15%)	-0.21 kW (7%)
Average Snapback (the hour after the event ends)		-1.01 kW (33%)	-0.34 kW (10%)
Average Event Day Conservation		1.16 kWh	1.23 kWh

Notes: Average kW savings are the average demand savings per treatment group customer across event hours. N refers to the number of events or event hours meeting indicative temperature thresholds. Min and max kW savings are the minimum and maximum of the average demand savings per treatment group customer across events. Average savings degradation is the difference between the average savings per treatment group customer in an event hour and the average savings in the previous hour. Average preconditioning is the average change in savings from preconditioning in the hour preceding the start of the event. Average snapback is the savings in the first hour after the event ends. Average event day conservation is the average energy savings per treatment group customer on event days.

Conclusions

Based on the evaluation findings for winter 2019/2020 and summer 2020, Cadmus came to the following conclusions about the delivery and performance of PGE's Direct Install.

Program Delivery

PGE encountered several changes and challenges with Direct Install, which stifled enrollment. Winter 2019/2020 and summer 2020 were challenging for PGE for two major reasons: the COVID-19 pandemic, which paused marketing and installations, and the transition from two demand response service providers to one. The Smart Thermostat pilot transitioned from having two DRMS service providers to one, which meant events could be managed more efficiently but also resulted in the loss of 16% of enrollees who contracted with a provider that left the program. The remaining provider could only accept customers from the departing provider once those customers accepted new terms and conditions. They were able to re-obtain load control permissions for 84% of them. Despite the challenges and changes, PGE and its implementers still managed to deliver on planned activities during the winter 2019/2020 and summer 2020 season.

To adapt to the pandemic, PGE developed virtual install assistance and delivered a positive customer experience. From mid-July to mid-October 2020, PGE and the installation implementer tested a virtual install assistance in which an online video app is used to remotely guide customers through the installation of a Nest or ecobee thermostat. The installation implementer completed 91 virtual installs during the three-month testing period. Cadmus conducted a survey of customers who participated in virtual install and gathered feedback from 10 respondents. All 10 respondents were delighted with their overall experience with virtual install, giving a satisfaction rating of 9 or 10 and gave highly favorable ratings on various aspects of their experience. The pilot continues to use the online video app to conduct a limited number of virtual installs and to remotely troubleshoot any customer calls that require technical assistance.

Although Direct Install provides in-person education to customers about how the program works, key information about event overrides was missing. PGE provided its installation implementer with a leave-behind factsheet that covers how PGE's Smart Thermostat pilot works. This factsheet did not explain the five-year commitment listed in the program terms and conditions or clearly tie the commitment to the 50% event minimum participation requirement referenced in the factsheet, which the installation implementer said customers frequently had questions about during the installation process. The evaluation found similar comments in the summer 2020 customer experience survey open-ends, with respondents mentioning the lack of communication regarding program participation requirements (8%, n=360).

Nevertheless, the evaluation found that 67% of respondents (n=571) were aware of the event participation requirement and 56% could correctly recall the event participation requirement (n=571). A regression analysis found that those who understood the event participation requirement were 24% less likely to override events. These findings point to the opportunity for PGE to decrease the likelihood of overrides if the event participation requirement is more clearly communicated to customers.

Customers seek pre-event and post-event communication and information. Currently, PGE does not send pre-event notifications directly to customers nor does it provide customers a way to review their event participation history. Hence, customers do not know how many events have taken place nor how many events they fully participated in vs. overrode. When asked if they were interested in receiving notifications before the start of an event, 73% of respondents said they were (n=572). Survey open-end comments showed that 8% of respondents (n=360) expressed negative sentiment about the Smart Thermostat pilot due to a lack of information transparency.

These respondents frequently asked for clear information about the 50% event participation minimum requirement, direct pre-event notifications, and communication on the number of overrides. One unknown risk about providing customers with pre-event notifications and communication about the number of overrides is that customers may decide not to participate in an event prior to its occurrence or that once a customer reaches their 50% event participation goal, the customer may not participate in the remaining events.

During summer 2020, PGE tested an encouragement email designed to remind customers about the 50% event participation minimum requirement and to encourage them not to override the remaining events in the season. One encouragement email was sent to approximately 200 Direct Install customers with an ecobee thermostat who overrode the first two summer 2020 events. Cadmus surveyed the encouragement email recipients and found that 50% of respondents (n=66) remembered receiving the encouragement email. Of the respondents who remembered the encouragement email (n=33), 42% said they felt more motivated to participate in future events after receiving the email. However, without an RCT comparison group, the evaluation could not determine how effective the encouragement email was in reducing overrides. A future test of the encouragement email should consider an RCT design.

Load Impacts

Direct Install savings in winter 2019/2020 exceeded PGE's planned savings values for smart thermostat demand response savings per treatment group customer of 1.2 kW in winter, while summer 2020 savings came in just under the 1.0 kW summer planning value. Direct Install achieved average demand savings of 0.94 kW (=30% of baseline demand) in summer and 1.63 kW (41%) in winter.

Direct Install savings were slightly higher than those in the previous summer and much higher than those in the previous winter. Direct Install achieved savings of 0.84 kW (28%) in summer 2019 and 0.97 kW (31%) in winter 2018/2019. The greater kW and percentage savings may have been attributable to colder event temperatures in winter 2019/2020 than winter 2018/2019 and dispatching all morning events. The higher performance in summer 2020 may have been due to warmer event temperatures and reduced dispatch failures than in summer 2019.[6]

Savings were greatest during the first event hour. Summer first event hour average customer demand savings were 1.21 kW (39%); savings degraded 30% to 33% in each successive event hour relative to savings in the previous hour. For winter these average savings were 1.91 kW (46%). Second and third event hour savings degraded 45% and 30%, respectively, relative to the previous hour.

Precooling and event snapback increased demand before and after summer 2020 and winter 2019/20 events. Summer precooling increased demand 0.16 kW to 0.32 kW per treatment group participant, and snapback in the first hour following events increased demand 0.20 kW to 0.49 kW, depending on the event start time, event duration, and weather conditions. In temperature indicative events, statistically significant snapback effects ranging from 0.06 kW to 0.11 kW were detected four hours after the event window. Winter preheating increased demand 0.38 kW to 0.75 kW per treatment group customer, and post-event snapback increased demand 0.51 kW to 1.38 kW. Snapback persistence was shorter following winter events; a statistically significant increase in demand among treatment group participants lasting longer than one hour was only detected in one event (0.2 kW in the second post-event hour). PGE grid operators should be aware of the potential for very significant snapback in demand upon conclusion of the demand response event.

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[6] The July 26, 2019 event failed to dispatch to ecobee thermostats due to a widespread ecobee service connection issue.

Summer 2020 Direct Install demand savings increased with outside event temperature. For every 1°F increase in event hour temperature, the average demand savings per treatment group customer increased by about 0.042 kW. The effect of outdoor temperature increases expected demand savings by 21% when comparing modeled outcomes for the minimum and maximum event temperatures (90°F and 96°F, respectively). This dynamic resource characteristic will prove valuable to capacity and grid planners who can adjust their expectations about the available capacity from smart thermostats based on outside temperature.

Event overriding was widespread among Direct Install customers. In summer 2020, between 18% and 27% of customers overrode each event. Most overrides (70%) occurred during the preconditioning period or during the first event hour.[7] Overriding reduced the demand response savings from the pilot.

Customer Experience

Direct Install continued to achieve high customer satisfaction but saw a significant decrease in satisfaction in summer 2020. Overall, winter 2019/2020 and summer 2020 achieved high program satisfaction results. In winter 2019/2020, 87% of participants (n=165) reported being satisfied, a level similar to that achieved in winter 2018/2019 (88% satisfied, n=165). However, in summer 2020, there was a small but statistically significant decrease in program satisfaction (86% satisfied, n=571) from summer 2019 (92%, n=224). Notably, summer 2020 showed a significant decrease in the percentage of *delighted* respondents (55%, n=571) from summer 2019 (73%, n=224) and had the lowest percentage of *delighted* respondents of any season.

The decrease in customer satisfaction in summer 2020 may be tied to thermal comfort and the factors impacting comfort. Survey respondents' comfort rating during the events was significantly lower than their comfort before the events. This degradation in comfort was especially acute in the summer seasons (14 to 19 percentage points) compared to the winter seasons (10 to 12 percentage points). Also, summer 2020 resulted in greater degradation in comfort compared to the previous season. A combination of factors could have exacerbated customers' discomfort, including summer 2020 was warmer, more customers were at home due to pandemic, the energy efficiency settings from thermostat manufacturers changed, and the event strategies changed.

Customers' thermal comfort and their understanding of the event participation requirement were the biggest drivers of overriding the demand response events. As stated earlier, a regression analysis showed that customers who understood the 50% event participation minimum requirement were 24% less likely to override events. Also, feeling comfortable during an event reduced the likelihood of

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7 Analysis of the timing of event overrides reflects BYOT and Direct Install customers combined, as these data were not available at the program track level.

overriding by 32 percentage points or 52% relative to those who report feeling uncomfortable. Neither the thermostat brand nor the customer's micro-segment had any bearing on overriding the events.[8]

Thermal discomfort, which increased the probability of overriding, also negatively affected customers' satisfaction with the pilot program and satisfaction with PGE. Through regression analysis, the evaluation found that thermal comfort affected customer satisfaction with the pilot program and PGE. Feeling comfortable during an event increased the likelihood of being satisfied with the program by 22 percentage points, or 34%, and being satisfied with PGE by 10 percentage points, or 13%. This finding suggests that PGE can increase satisfaction and reduce overriding by increasing customer thermal comfort during events. There were no statistically significant differences in the likelihood of being satisfied (with the program and PGE) between thermostat brands or micro-segments.

Recommendations

Based on the evaluation findings and conclusions, Cadmus makes the following recommendations.

Customer Education and Experience

- Reiterate the 50% event participation minimum requirement as part of customer education and ongoing customer communications to get the information to stick and reduce overriding behavior.
- Consider developing and testing pre-event notifications to see if increasing communication about events increases customer engagement and satisfaction. In the notification message, include a short and simple recap of the 50% event participation minimum requirement along with words of encouragement. Use a randomized controlled trial (RCT) design, in which some customers receive the notifications and others do not, to ensure that the effects of the pre-event notifications can be accurately assessed.
- Work with the DRMS provider, thermostat manufacturers, and installation implementer to find ways to increase customer thermal comfort.
    - Consider making customer setback a dynamic function of the customer's previous overriding behavior. If overriding is a sign of discomfort and the customer overrode the previous event, the provider could reduce the amount of setback during the next event or set back the thermostat for one hour instead of two or three hours.
    - Consider educating customers about ways they can increase comfort (but that does not increase their energy use during the event) by frequently providing behavioral tips such as adjusting windows, blinds, curtains, and air circulation. PGE currently sends tips to customers in the season-ready communications; these tips could also be sent in any test notifications and mid-season communications.

[8] Micro-segments refer to five PGE customer segments used in characterizing residential customer demand response potential: Big Impactors, Fast Growers, Middle Movers, Borderliners, and Low Engagers. See the Table C-2 for additional detail.

Event Management

- Vary winter event times to include afternoons. PGE called only morning events during the winter 2019/2020 season. If PGE plans to use smart thermostat demand response during winter afternoons and evenings, it should call events during these times in future winter seasons.

Savings Optimization / Performance

- Conduct research aimed at assessing motivations and mitigation strategies for customer overriding behavior. PGE is losing significant savings from customers who override demand response events. Also, overriding likely has several causes, as suggested by the fact that customers override during the pre-conditioning and temperature setback phases of demand response events; therefore, PGE should further research the causes and consider implementing and testing interventions (such as offering tiered incentives) to reduce the frequency or delay the onset of overriding. Factors that contribute to overriding may include participation fatigue, lack of understanding of participation requirements, impacts to comfort due to occupancy changes under COVID-19, interaction with smart thermostat conservation programs (e.g., Google Nest's Seasonal Savings or ecobee's eco+), or thermal efficiency of the home envelope. PGE could also consider dispatching events differently to customers with a history of overriding than to customers without such propensities.
- Conduct field tests to mitigate snapback. When demand response events end, snapback causes demand to increase above baseline levels and can increase PGE's costs of supply. It may be possible for PGE to reduce the amount of snapback without sacrificing demand savings by working with DRMS providers to adjust the thermostat control algorithms. For example, it may be possible to reduce snapback by staggering the event ending times of participants.
- Evaluate further the relationship between load impacts and weather. This evaluation identified a positive correlation between demand savings and outside temperature during summer event hours. Future evaluations should build on this research to refine the measurement of this relationship to support program planning and operational applications. Specifically, guidance regarding incremental load reductions in reference to indicative weather temperatures (90°F in summer and 32°F in winter) will provide grid operators with better information about load savings potential at various temperatures.

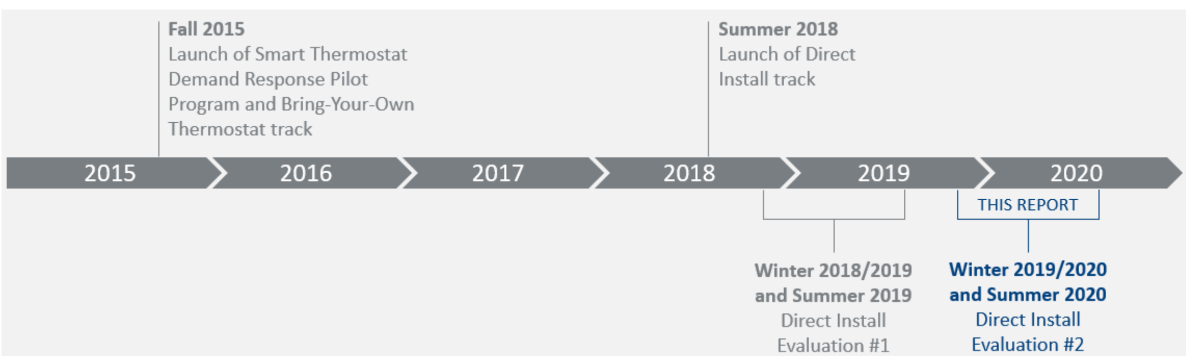
Introduction

In 2016, the Oregon Public Utility Commission (OPUC) directed Portland General Electric (PGE) to obtain 77 MWs and 69 MWs of, respectively, winter and summer peaking demand response capacity across its full-service territory by 2021. This demand response capacity was intended to help replace capacity lost from the planned closure of the Boardman facility. Since the OPUC's order, PGE has implemented several demand response pilot programs including smart thermostat direct load control (DLC) that enrolls thousands of PGE residential customers and now provides over 13.7 MW of peak capacity.[9]

Residential smart thermostat demand response is an important source of PGE's future demand response capacity. Such programs use control of home thermostat setpoints to reduce demand during periods when it is costly for the utility to supply or distribute electricity or to manage intermittent renewable energy supply. Through its Smart Thermostat pilot, PGE can control the cooling and heating loads of participating customers.

Customers who already own a smart thermostat can participate in the pilot program through the Bring-Your-Own Thermostat (BYOT) track. Customers for whom smart thermostat installation or cost pose a challenge can participate through the Direct Install track. Cadmus previously conducted an evaluation of the Direct Install track for winter 2018/2019 and summer 2019 seasons.[10] The current evaluation covers the winter 2019/2020 and summer 2020 seasons of delivery (Figure 1).

Figure 1. Timeline of Direct Install Smart Thermostat Pilot and Evaluation



For this evaluation, Cadmus assessed program design and delivery, load impacts, and customer experiences for each event season. This evaluation provides PGE with valuable information about the Smart Thermostat pilot's performance and presents insights that can be used to optimize PGE's future demand response program offerings.

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9 PGE Flexible Load Plan, December 2020. p. 28. Filed by PGE with the Oregon Public Utility Commission, December 23, 2020. https://edocs.puc.state.or.us/efdocs/HAA/haa125814.pdf

10 Portland General Electric. September 11, 2020. "Re: UM 1708: Cadmus' Evaluations of PGE's Residential Smart Thermostat program Winter 2018/2019 and Summer 2019 for the BYOT and Direct Installation Channels." Filing to The Public Utility Commission of Oregon. https://edocs.puc.state.or.us/efdocs/HAH/um1708hah16326.pdf

Evaluation Objectives and Approach

PGE specified the following objectives for the Direct Install evaluation:[11]

1. Estimate the average kilowatt impact per treatment group customer before, during, and after the load control events
2. Assess the impact of events on customer comfort
3. Assess the impacts of participation on customer satisfaction with the program and PGE
4. Compare Direct Install load impacts to BYOT
5. Identify opportunities for improving program delivery, program performance, cost-effectiveness, and customer satisfaction

Table 3 lists these evaluation activities and how they address the evaluation objectives. The evaluation presented in this report covers winter 2019/2020 and summer 2020 event seasons for Direct Install. *Appendix A. Evaluation Methodology* presents more details about the randomized controlled trial (RCT) and the evaluation activities, including the impact analysis, staff interviews, and customer surveys.

Table 3. Direct Install Evaluation Activities

Activity	Description	Corresponding Evaluation Objective(s)	Outcome
Research Design	RCT: pre-season random assignment of customers to treatment or control group	1, 2, 3, 4	Accurate and precise estimates of impacts
Data Collection and Preparation	Collect and prepare analysis of individual customer advanced metering infrastructure (AMI) meter interval consumption data	1, 2, 3, 4	Final analysis sample for estimation of load impacts
Load Impact Analysis	Regression analysis of individual customer AMI meter interval consumption data	1, 2	Estimates of event savings
Staff Interviews	Interviews with PGE and implementation program staff to understand program implementation processes, successes, and challenges	5	Thorough understanding and documentation of the program design and implementation
Customer Surveys	Seasonal experience surveys with customers	3, 4, 5	Findings on customer engagement, event awareness, comfort, override behavior, and satisfaction
Logic Model Review	Assessment of whether Direct Install operated as expected and produced results as theorized	5	Documentation of what is and what is not producing the theorized results

[11] In the course of this evaluation, several other research topics became priorities and received focus—these included impacts of the COVID-19 pandemic on savings, factors contributing to savings degradation (e.g., event overriders), and curtailment performance relative to various conditions (e.g., temperature/THI). There is opportunity to fully investigate these in subsequent research.

Direct Install Description and Activities

In 2018, PGE launched the Direct Install track of the Smart Thermostat pilot, offering customers a free or discounted smart thermostat with a complimentary installation from a technician. PGE designed the pilot program to manage residential summer and winter loads during hours of peak electricity demand. PGE can control cooling and heating loads of participating customers through the smart thermostat device. The Direct Install track was specifically designed to overcome the customer cost and installation barriers, to accelerate the replacement of older thermostats, which typically only happens when HVAC systems are replaced, and to address the challenges with heating/cooling system verification encountered with the BYOT track. Customers in Direct Install received a free or discounted smart thermostat and a complimentary installation for participating.

Figure 2 summarizes the program design and changes to delivery over the years. Direct Install saw many changes in summer 2020. These changes are described in detail in subsequent sections.

Figure 2. Direct Install Smart Thermostat Pilot Design Over the Years

	Winter 2018/2019	Summer 2019	Winter 2019/2020	Summer 2020
Thermostat Brand	Nest and ecobee	Nest and ecobee	Nest and ecobee	Nest and ecobee
Enrollment Incentive	Free/discounted device and complimentary installation from technician	Free/discounted device and complimentary installation from technician	Free/discounted device and complimentary installation from technician	Free/discounted device and virtual install assistance with technician
DRMS Provider	Google Nest for Nest devices Resideo for ecobee and Honeywell devices	Google Nest for Nest devices Resideo for ecobee and Honeywell devices	Google Nest for Nest devices Resideo for ecobee and Honeywell devices	Resideo for Nest, ecobee, and Honeywell devices
Pre-Event Notification	Not sent directly to customers; notifications pop up on device panel or app right before event	Not sent directly to customers; notifications pop up on device panel or app right before event	Not sent directly to customers; notifications pop up on device panel or app right before event	Not sent directly to customers; notifications pop up on device panel or app right before event
Encouragement Email	None	None	None	Email sent to subset of overriders
Participation Incentive	None; customers agree to five-year commitment and incur a fee if they opt out of program early	None; customers agree to five-year commitment and incur a fee if they opt out of program early	None; customers agree to five-year commitment and incur a fee if they opt out of program early	None; customers agree to five-year commitment and may incur a fee if they opt out of program early

Goals and Objectives

PGE set the following goals and objectives for internal purposes:

- A combined Direct Install and BYOT capacity goal of 7.4 MW in winter and 25.8 MW in summer
- A combined Direct Install and BYOT enrollment goal of 27,307 thermostats by end of 2020

- Obtain customer participation in at least 50% of event hours per season
- Achieve positive customer experiences and high customer satisfaction

Program Eligibility Requirements

Program eligibility requirements have remained the same since the launch of Direct Install in 2018. To be eligible for Direct Install, a customer must meet these requirements:

- Be a PGE residential customer with an active account
- Have a central air conditioner, ducted heat pump, or electric forced-air furnace HVAC system
- Have a Wi-Fi network in the home

Customers with a ducted heat pump could participate in both 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 could participate in the summer season and customers with only an electric forced-air furnace could participate in the winter season.

In exchange for enrollment, customers either receive a smart thermostat free of charge or pay a $50 or $150 copay, depending on their HVAC system and choice of thermostat model. Customers also agree to remain in the pilot program for at least five years and are asked to participate in at least 50% of the events per season, meaning they do not override more than 50% of the events. If a customer opts out before the end of the five-year period, then PGE may charge the customer for the cost of the installed smart thermostat. Customers do not incur any financial penalties for not meeting the 50% event participation requirement.

Roles and Responsibilities

Several staff and role management changes took place in 2020. PGE brought on a new product manager for the Smart Thermostat pilot. CLEAResult continued to serve in the recruitment, scheduling, and installation roles for the Direct Install track. Resideo and Google Nest continued to provide the demand response management system and aggregation services through winter 2019/2020; however, in spring 2020, Google Nest notified PGE it would no longer provide demand response services directly to utilities. PGE made the transition to Resideo as the sole DRMS provider.

Marketing

PGE conducts all program marketing activities for Direct Install, promoting it to customers directly through mail and email (outbound marketing) and indirectly on the PGE website (inbound marketing). In 2020, PGE conducted very little marketing of Direct Install due to the COVID-19 pandemic. All outbound marketing was paused from March through September 2020 as in-person installations could not take place. PGE resumed outbound marketing activities in October 2020, though sparingly.

Installation and Enrollment Process

Prior to the COVID-19 pandemic, interested customers either contacted the Direct Install call center or went online to the Direct Install scheduling web portal listed in the marketing pieces. CLEAResult operated the call center and web portal, which screened the customer for program eligibility. Once determined to be eligible, the customer could self-schedule an installation appointment through the web portal. After successful installation of the smart thermostat device, technicians enrolled the customer in the program online.

COVID-19 Effect on Implementation

From January to early March 2020, CLEAResult operated the scheduling portal, call center, and in-home installations as usual. In mid-March when the COVID-19 pandemic prompted stay-at-home orders, PGE directed CLEAResult to shut down the scheduling portal and halt installations but keep the call center operating to support customers with recently installed thermostats. All previously scheduled installation appointments were cancelled.

During the pause period, PGE and CLEAResult developed COVID-19 health and safety protocols for installation work, following the guidelines recommended by the Center for Disease Control. CLEAResult also worked on devising ideas on how Direct Install could adapt to the new COVID-19 environment. One idea that emerged and was tested was a virtual install assistance.

Virtual Install

During a three-month period, from mid-July to mid-October, PGE tested a virtual install assistance in which CLEAResult used an online video app to remotely guide customers through the installation of Nest or ecobee thermostats. PGE was the first utility for which CLEAResult tested virtual install. CLEAResult already had a partnership with Stream, a Portland-based software company that provides virtual assessments. CLEAResult worked with Stream to use the existing video technology to customize a virtual install assistance for PGE.

When CLEAResult halted in-person installations due to the COVID-19 pandemic, around 350 appointments were cancelled. Starting in mid-July, CLEAResult phoned these 350 customers to see if they would qualify and would be interested in the virtual install assistance. The following summarizes the steps CLEAResult took from start to completion of the virtual install assistance:

1. CLEAResult screened the customer for safety and technical feasibility such as having access to the breaker box, good lighting, necessary tools, comfort/familiarity with electrical wiring, and ability to interact through an online video app.
2. If the customer passed the screener, CLEAResult scheduled an appointment for a technician to guide the customer through the installation process via Stream's video app.
3. One to two days before the online appointment, CLEAResult dropped off the thermostat at the customer's home along with a small screwdriver and leave-behind materials on the thermostat and the Smart Thermostat pilot.
4. Prior to the start of the online appointment, CLEAResult made a reminder phone call and sent a text so the customer would be prepared for the online session.
5. During the online session, the technician guided the customer through the installation process step by step using the app's interactive features such as marking, pointing, and screenshots.

6. After the thermostat was successfully installed, CLEAResult enrolled the customer in the Smart Thermostat pilot through the website.

PGE and CLEAResult ended the virtual install assistance in mid-October 2020 once in-the-field installation jobs resumed. CLEAResult still uses the online video app to conduct a limited number of virtual installs and to remotely troubleshoot any customer calls that require technical assistance.

Return to the Field

In mid-October 2020, CLEAResult reinstated the scheduling portal and returned to conducting in-person installation jobs with new COVID-19 health and safety protocols in place. These new health and safety protocols included requiring the installation technician to wear a mask and gloves when entering the customer's home and to practice social distancing.

Education

PGE continued to focus customer education on the thermostat and the program during the installation process. Before the COVID-19 pandemic, the installation technician educated the customer directly on how to use the thermostat device and how PGE's Smart Thermostat program works and also gave the customer hard copy factsheets. During virtual installs, the technician educated the customer during the phone call and through the online video app and dropped off hard copy factsheets in a bag.

Event Management

PGE initiated the load control events and coordinated with Google Nest and Resideo to implement the events. Several changes occurred in 2020, including changes to the DRMS providers, event strategies, and customer outreach.

DRMS Providers

PGE had previously called demand response events through Google Nest and Resideo. For the winter 2019/2020 season, Google Nest continued to dispatch events and aggregate data on Nest thermostats, while Resideo continued to dispatch events and aggregate data on ecobee thermostats. In April, PGE made the transition to one DRMS provider, Resideo. For the summer 2020 season, Resideo dispatched events and aggregated data on all thermostats.

As part of the transition to a single DRMS provider, customers with a Nest thermostat were informed and given the opportunity to accept new terms and conditions. Of the customers with a Nest thermostat enrolled in PGE's Smart Thermostat pilot, 84% accepted the new terms and conditions. Customers who did not accept the terms and conditions were unenrolled from the pilot.

Schedule of Load Control Events

Table 4 shows the schedule of load control events that PGE initiated. The winter 2019/2020 event season ran from December 1, 2019, through February 28, 2020. The summer 2020 event season ran from June 1, 2020, through September 30, 2020. PGE called four events in winter 2019/2020 and six events in summer 2020. Events lasted one to three consecutive hours and occurred on weekday (non-holiday) afternoons or mornings, typically when electricity demand for space conditioning was greatest (that is, on cold days during winter and hot days during summer). PGE could have called one more event in summer 2020 but decided not to due to the Oregon wildfires and ensuing smoke and hazardous air quality.

Table 4. Direct Install Load Control Events

Season	Event	Date	Avg. Outdoor Temp.	Start Time	Duration (hours)	Met Indicative Temperature Threshold
Winter 2019/2020	1	1/15/2020	33°F	7:00 a.m.	2	N
	2	2/4/2020	28°F	7:00 a.m.	3	Y
	3	2/21/2020	31°F	8:00 a.m.	1	Y
	4	2/27/2020	34°F	7:00 a.m.	1	N
Summer 2020	1	7/20/2020	93°F	4:00 p.m.	3	Y
	2	7/27/2020	98°F	4:00 p.m.	2	Y
	3	7/30/2020	95°F	4:00 p.m.	2	y
	4	8/10/2020	89°F	4:00 p.m.	2	N
	5	8/17/2020	93°F	5:00 p.m.	3	Y
	6	9/3/2020	94°F	5:00 p.m.	2	Y

Note: Average outdoor temperature is the outdoor temperature recorded in PGE's event log. 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 summer and 32°F or below in winter. In summer 2020, all but one event were temperature indicative. In winter 2019/2020, two of four events were temperature indicative.

Event Strategy Details

As part of the RCT design, customers are randomized to treatment and control groups each season. Customers assigned to the treatment group had their thermostats controlled during the events, while customers assigned to the control group did not. During events, controlled devices receive a setback to curb HVAC usage. Once the thermostat exceeds the temperature setback, HVAC systems automatically resume and may not persist through a full event period, depending on the level of thermal efficiency of the building envelop. Treatment group customers can also override the load control during events by adjusting the thermostat settings or hitting the event cancel button.

Table 5 shows the event implementation details and differences by thermostat brand. Thermostat brands have been anonymized in this report.

Table 5. Direct Install Event Implementation Details

Brand	Pre-Event Notification	Event In-Progress Notification	Preconditioning before Event	Temperature Setback during Event
Brand A	Displayed on thermostat panel and app (not a push notification) two hours prior	Displayed on thermostat screen and on app	No preheating in winter; precooling in summer only for some customers	3°F lower in winter; 3°F higher in summer; some customers had a range of 0-2 degrees
Brand B	Displayed on thermostat panel and app (not a push notification) 10 minutes prior	Displayed on thermostat screen and on app	1°F -3°F preheating in winter; 2°F precooling in summer	3°F lower in winter; 3°F higher in summer

* These pre-event notifications do not appear for all customers and depend on the thermostat manufacturer's and customer's notification settings.

In previous winter and summer seasons, Resideo tested intelligent demand response (IDR) on a small number of thermostat devices.[12] However, for winter 2019/2020 and summer 2020, Resideo did not test any IDR strategies and instead used a standard approach because it did not have access to customers' setpoint data. Furthermore, in 2020 thermostat manufacturers released new energy-saving enablement features (i.e., Nest's Seasonal Savings and ecobee's eco+). These new features impacted how the thermostat functioned during event dispatch. Depending on which features the customer enabled, the demand response features of the thermostat may have been disabled for the event (specific to one of the available settings). After the summer 2020 season, PGE worked with Resideo to make sure event dispatch was not disabled by the energy-saving enablement features.

Encouragement Email

During the summer 2020 season, PGE and Resideo conducted customer outreach via email to maximize event participation. Prior to summer 2020, PGE had not conducted any targeted customer outreach to influence event participation. PGE noted in its own override research from previous winter and summer seasons that 10% of Direct Install customers failed to participate in the required minimum 50% of event hours. This finding led PGE to test an email designed to remind customers about the event participation requirement and encourage them to participate in future events.

After the first two events of summer 2020, PGE had Resideo identify the customers who did not participate in at least 50% of total event hours for these two events (i.e., overrode the events) and send them an encouragement email. Only customers with an ecobee thermostat received the encouragement email.

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12 Intelligent demand response (IDR) customizes the thermostat setback for individual customers based on historical heating or cooling demand and the thermal properties of a home to achieve more consistent and lasting load reductions across event hours. IDR also regulates the dispatch of load control signals to avoid big changes in aggregate loads due to simultaneous preconditioning before the event, the event initiation, or snapback after an event.

Logic Model

A logic model describes how a program should be expected to succeed, given its design, by graphically presenting the relationships between program activities, outputs, and expected outcomes. The logic model is a useful tool for program staff, implementers, and evaluators to determine if the program's activities and outputs are producing the outcomes as theorized.

In 2018, Cadmus developed the logic model for Direct Install using program materials and information obtained from staff interviews. Figure 3 shows the Direct Install logic model. As part of the logic model, Cadmus identified and documented Direct Install's implementation barriers, challenges, and risks to program success. Figure 4 shows the mapping of these barriers, challenges, and risks as well as solutions that PGE and its partners may use to manage and overcome them. The colors used to denote the challenges, risks, and solutions in Figure 4 correspond to the activities, outputs, and impacts in the logic model (Figure 3).

Figure 3. Logic Model of Direct Install Smart Thermostat Pilot

PROGRAM THEORY

PGE's Integrated Resource Plan (2016) calls for the use of demand response (DR) to help manage system peak loads. By offering residential customers financial incentives for participation, PGE's Smart Thermostat Program will realize the goals of **enrolling 27,768 smart thermostats by 2020**. Through the Direct Install path of the program, PGE offers free or discounted smart thermostats with complimentary installation and education to qualified customers. This path attracts new customers not served by the mass-marketed Bring Your Own Thermostat (BYOT) path, including low-income customers, late adopters of smart thermostats, and customers historically uninclined to participate in demand response programs. Directly installing thermostats will overcome HVAC equipment verification issues present in the BYOT path. Mandating a five-year commitment from customers will enhance the cost effectiveness of the program.

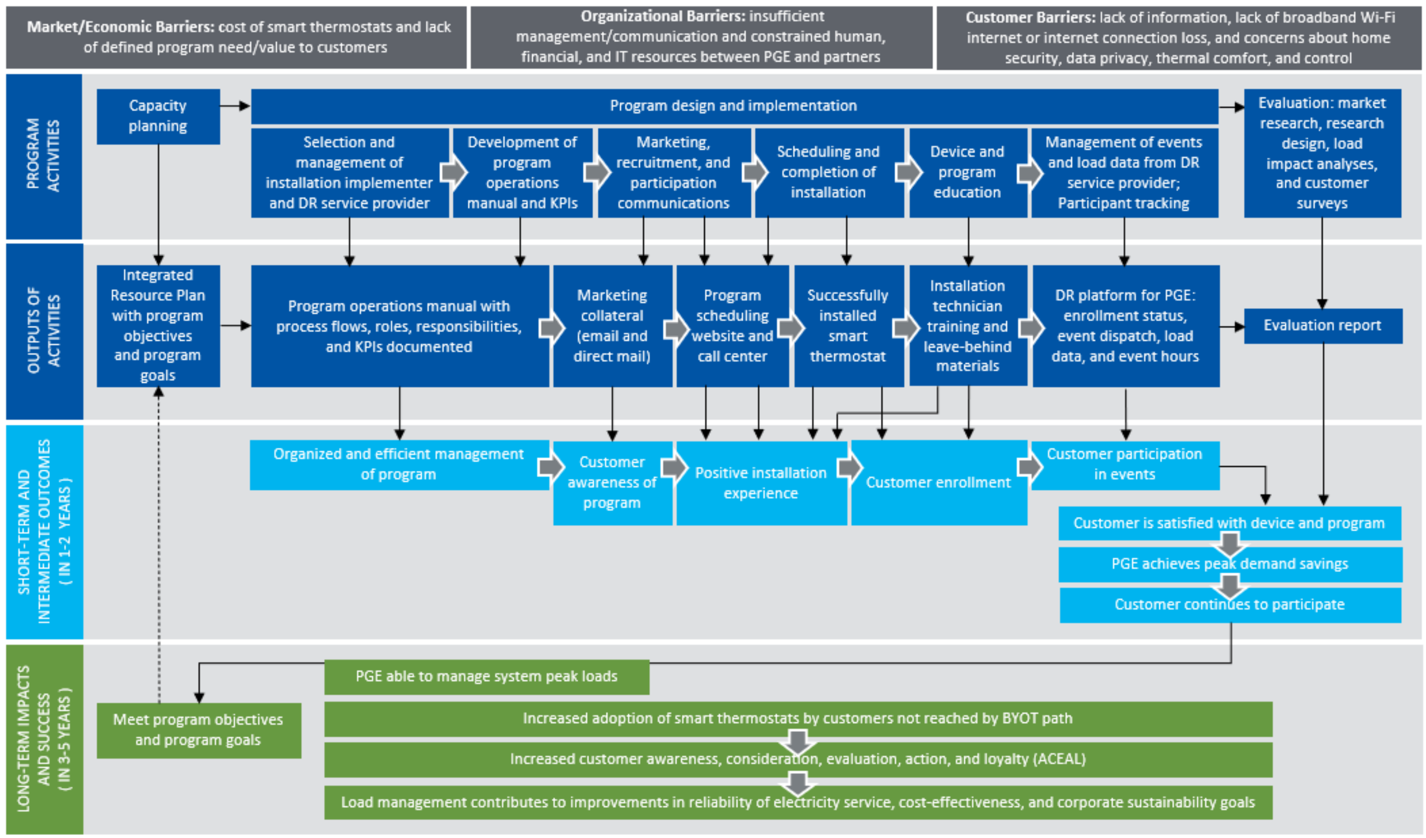
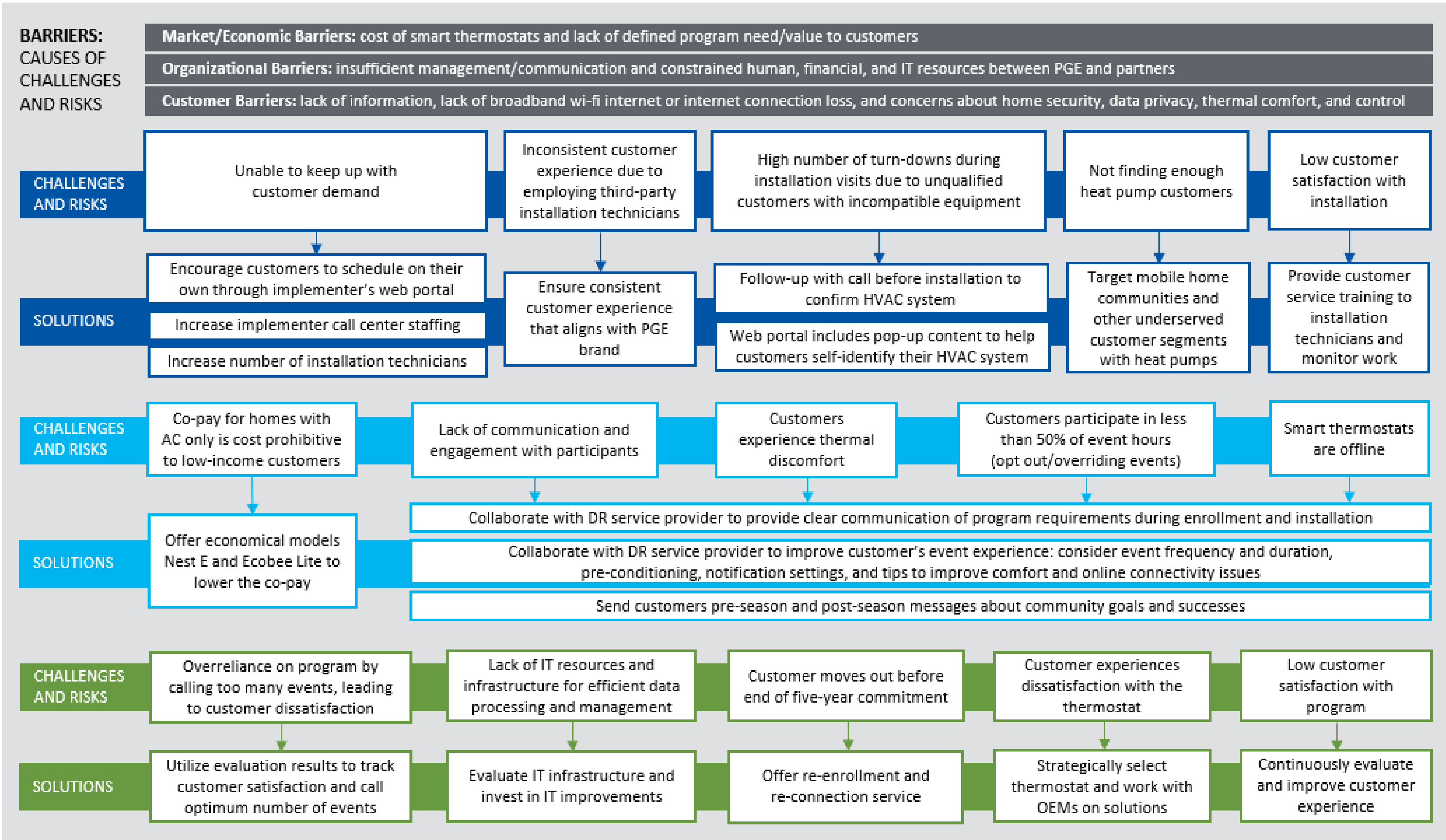


Figure 4. Map of Direct Install Implementation Barriers, Challenges, Risks, and Solutions



Evaluation Findings

This section presents the evaluation findings on the Direct Install track of the Smart Thermostat pilot and is organized according to the following topics:

- Program delivery successes
- Program delivery challenges
- Load impacts
- Customer experience
- Logic model review
- Future changes and considerations

Program Delivery Successes

Overall, Direct Install operated as expected in winter 2019/2020 and summer 2020 and continued to perform well on demand savings. It found a virtual solution to installations for a three-month period during the COVID-19 pandemic.

Demand Savings Performance

Table 6 shows that Direct Install savings were higher in the current seasons than in the previous seasons.

Table 6. Direct Install Demand Savings Compared to Previous Seasons

Season	Demand Savings per Treatment Group Customer	
	Winter	Summer
Current Seasons (winter 2019/2020 and summer 2020)	1.63 kW (41%)	0.94 kW (30%)
Previous Seasons (winter 2018/2019 and summer 2019)	0.97 kW (31%)	0.84 kW (28%)

Note: Average demand savings as a percentage of baseline demand in parentheses. The winter 2018/2019 season included five afternoon events and one morning event, all 3-hour duration.

In winter 2019/2020, Direct Install achieved average demand savings of approximately 1.63 kW (41%) per treatment group customer, which was much larger than the savings of 0.97 kW (31%) in winter 2018/2019. The difference is attributable to several factors, including that in winter 2019/2020 events were dispatched only in the morning, were of shorter duration, and were on colder days.

In summer 2020, Direct Install achieved average demand savings of approximately 0.94 kW (30% of baseline demand) per treatment group customer, slightly higher than the savings of 0.84 kW (28%) in summer 2019. The higher savings in summer 2020 may be due to warmer event temperatures and fewer event dispatch failures. During the third event of summer 2019, the event signal failed to dispatch to ecobee thermostats due to a widespread service connection issue.

More detailed results for winter 2019/2020 and summer 2020 showing the load impact estimates for hour before, during, and after events are presented below.

Virtual Install

PGE and CLEAResult reported that virtual install went very well. CLEAResult completed 91 virtual installs during the three-month testing period from mid-July to mid-October.[13] Cadmus conducted a survey of customers who participated in virtual install and gathered feedback from 10 respondents. All were delighted with their overall experience with virtual install, giving a satisfaction rating of 9 or 10 and gave highly favorable ratings on various aspects of their experience (Figure 5).

Figure 5. Virtual Install Customer Experience Ratings

Overall Satisfaction with Virtual Install	Statement	Response
All 10 delighted (9-10 rating) 7 gave a rating of 10 3 gave a rating of 9	*The installation was easy to follow*	**All 10** agreed 7 strongly agreed 3 somewhat agreed
	The technician communicated instructions to me clearly	**All 10** agreed 10 strongly agreed
	The technician was professional and courteous	**All 10** agreed 10 strongly agreed
	I would be comfortable with doing another similar virtual installation in the future	**All 10** agreed 10 strongly agreed

Source: Summer Experience Survey Questions. "Please rate your overall satisfaction with the virtual installation" and "Please tell us if you agree or disagree with the following statements about your experience with the virtual installation."

Even with high remarks from virtual install participants, PGE and CLEAResult pointed out these limitations and challenges with virtual install that make it difficult to justify its use for the long term:

- Virtual install is suitable only for a small number of customers who are handy with repairs, savvy with heating and cooling equipment, and/or are tech savvy.
- Because of the technical knowledge required, a screening process is necessary and costly to identify the customers who are a good fit for virtual install.
- Virtual install takes longer to complete than a traditional direct install because of the additional setup required online and time to guide the customer through the process.
- Virtual install is not considered to be as cost-efficient as traditional direct install because of the home drop-off delivery method,[14] online appointment delays from customers who are not being prepared, and customers changing their minds at the last minute (which then required a pick-up service to retrieve the thermostat).

[13] Most virtual install customers were enrolled in the Smart Thermostat Demand Response pilot program after the final event of the summer 2020 season and therefore are not reflected in counts of enrolled customers.

[14] CLEAResult wanted to mail the thermostats to customers but could not due to the backlog of mail deliveries and delays from the U.S. Postal Service.

Program Delivery Challenges

PGE encountered program delivery challenges in the areas of enrollments, marketing, installations, and customer education.

Enrollments

PGE set a combined Direct Install and BYOT enrollment goal of 27,768 thermostats by the end of 2020. As of October 2020, the pilot program had enrolled a total of 22,408 thermostats,[15] 26% of which came from the Direct Install track. The Smart Thermostat pilot did not meet its enrollment goal because two challenges slowed down enrollments.

First was the Nest-to-Resideo transition, which resulted in a 15% loss of enrollees originally contracted under Google Nest. The transition required Google Nest customers to sign new terms and conditions before Resideo could access control of their thermostats; the outreach to reobtain load control permission from customers achieved an 85% acceptance rate. Second was the COVID-19 pandemic, which led to a pause in marketing and installations.

Additionally, the rollout of eco+ resulted in some customers selecting thermostat conservation settings (i.e., 1 of a 5-point scale) that unintentionally prevented them from receiving PGE demand response event dispatches. Ecobee discovered and corrected the error that caused this after the summer 2020 season. Though this did not impact enrollment status, it did result in 155 thermostat devices in the treatment group across both Direct Install and BYOT tracks being unable to receive curtailment through PGE's event dispatch in summer 2020. The removed devices constituted 0.9% of the treatment group.

Table 7 shows enrollment during the winter 2019/2020 and summer 2020 seasons.

Table 7. 2020 Direct Install Enrollment by Season

Category	Control	Treatment	Total
Winter 2019/2020 Enrollments			
Total Thermostats	541	2,739	3,280
Total HVAC Systems	541	2,734	3,275
Total Customers	532	2,680	3,212
Summer 2020 Enrollments			
Total Thermostats	1,416	3,864	5,280
Total HVAC Systems	1,417	3,864	5,281
Total Customers	1,415	3,858	5,273

Note: Total Thermostats and HVAC Systems represent the number of individual thermostats and HVAC equipment associated with all enrolled participants. Total Customers is the number of unique Service Premise IDs. Winter 2019/2020 enrollments reflect the number of enrolled customers as of March 2020, and summer 2020 enrollments reflect the number of enrolled customers as of September 2020.

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15 Of the 22,408 thermostats enrolled, 3% are winter-only customers, 77% are summer-only customers, and 20% are dual-season customers.

Marketing

An increase in the smart thermostat rebate amount for the BYOT track and the limitations imposed by the COVID-19 pandemic created challenges to marketing Direct Install in 2020. Prior to the pandemic, CLEAResult said the customer value of Direct Install was challenged ever since Energy Trust of Oregon increased its smart thermostat rebate from $50 to $100 for the BYOT track (effective June 1, 2019). CLEAResult said it subsequently noticed a lower marketing conversion rate for Direct Install and that its staff encountered customers requiring a more convincing value proposition for Direct Install over BYOT. For this current evaluation, Cadmus was not tasked to investigate the marketing conversion rates or customer value propositions between Direct Install and BYOT. Therefore, this evaluation cannot report how much the higher rebate impacted enrollments to Direct Install during 2020. The main reason PGE paused Direct Install marketing for much of 2020 was due to the pandemic.

Installations

Because in-person installations could not take place during the pandemic shutdown, installations came to a halt for most of 2020. As described in the previous section, PGE tested virtual install to make up some ground, though with a small, targeted subset of customers. When CLEAResult was able to return to the field in mid-October 2020, it could not install at the same rate as before. CLEAResult said installation jobs took much longer as a result of the new COVID-19 health and safety protocols. Although CLEAResult said installations have gone well since returning to the field, slower installations have put PGE behind on its overall enrollment goal.

Customer Education

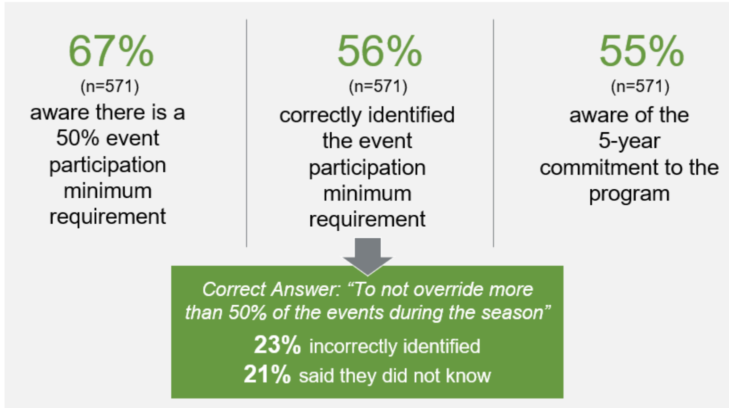
Though customers received in-person or virtual education about how the program works and were provided a factsheet, the evaluation found gaps in customer education that had implications for event overrides.

PGE provided CLEAResult with two leave-behind factsheets to give to customers during the installation process, in-person or virtually. One factsheet covered how PGE's Smart Thermostat pilot program works. The factsheet did not explain the five-year commitment or clearly tie that to the 50% event participation minimum requirement, which CLEAResult said customers frequently asked about during the installation process. Cadmus found similar comments in the summer 2020 customer experience survey about the lack of communication regarding program participation (8% of respondents, n=360).

> *"I do love this initiative and the environmental impact it has...reducing the energy demand and more reliance on renewable resources. However, the conditions of a 5yr commitment or participation in at least 50% of peak events were NOT communicated!"*
> **– Summer 2020 Experience Survey Respondent**

Also in the summer 2020 experience survey, Cadmus asked respondents about their understanding of program participation. As shown in Figure 6, over half were aware and could correctly recall the program participation requirement. Nevertheless, a substantial proportion of respondents were not aware.

Figure 6. Customers' Understanding of Program Participation



Source: Summer Experience Survey Questions. "Were you aware of the 50% event participation minimum requirement?" and "Which statement best describes the 50% event participation minimum requirement?" and "Were you aware of the 5-year commitment to the program?"

Cadmus ran regressions to assess the relationship between respondents' understanding of the 50% event participation minimum requirement and their self-reported overrides. The regression analysis found that understanding the event participation requirement reduced the likelihood of overriding events by 15 percentage points or 24% relative to those who did not understand the requirement. These findings point to the opportunity for PGE to decrease the likelihood of overrides if program participation requirements were more clearly communicated to customers. See *Appendix C* for more detail.

Load Impacts

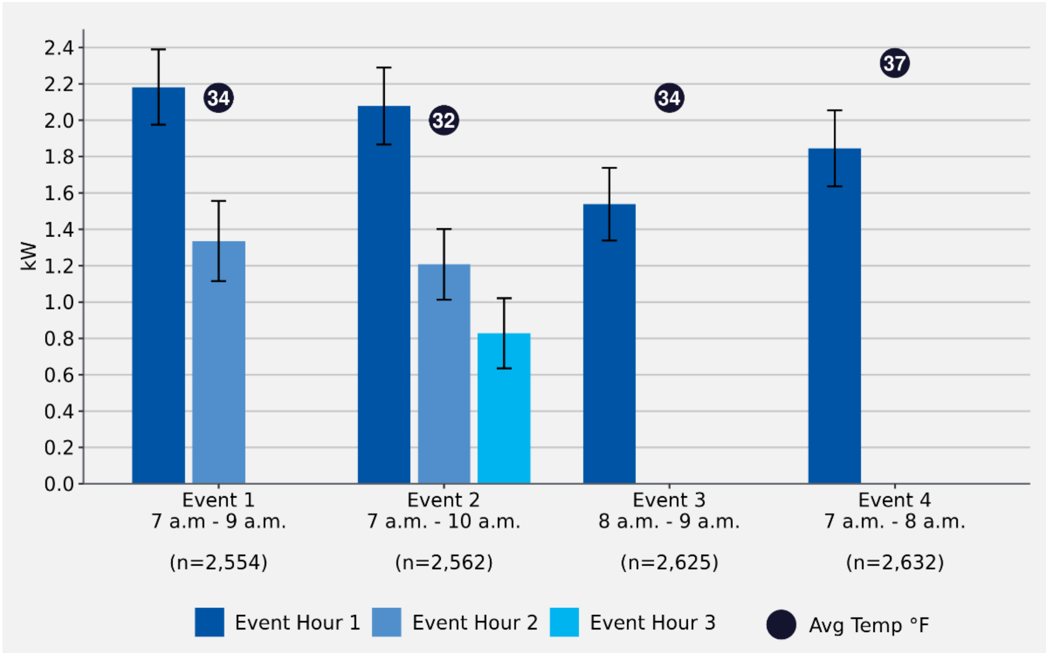
Seasonal Impacts – Winter 2019/2020

During the Direct Install winter 2019/2020 season, PGE launched four events. Each was initiated on a non-holiday, weekday at 7:00 a.m. or 8:00 a.m., and lasted between one and three hours.

Winter Demand Savings Estimates by Event

Figure 7 shows the average demand savings per treatment group customer for each hour of the four winter events. The average temperature during the event hours are also displayed. Savings per treatment group customer ranged between 1.5 kW and 2.2 kW during event hour 1 and between 1.2 kW and 1.3 kW during event hour 2. Savings was about 0.8 kW per treatment group customer during the third hour of Event 2. All hourly savings estimates were statistically significant at the 5% level.

Figure 7. Direct Install Demand Savings by Event and Event Hour – Winter 2019/2020



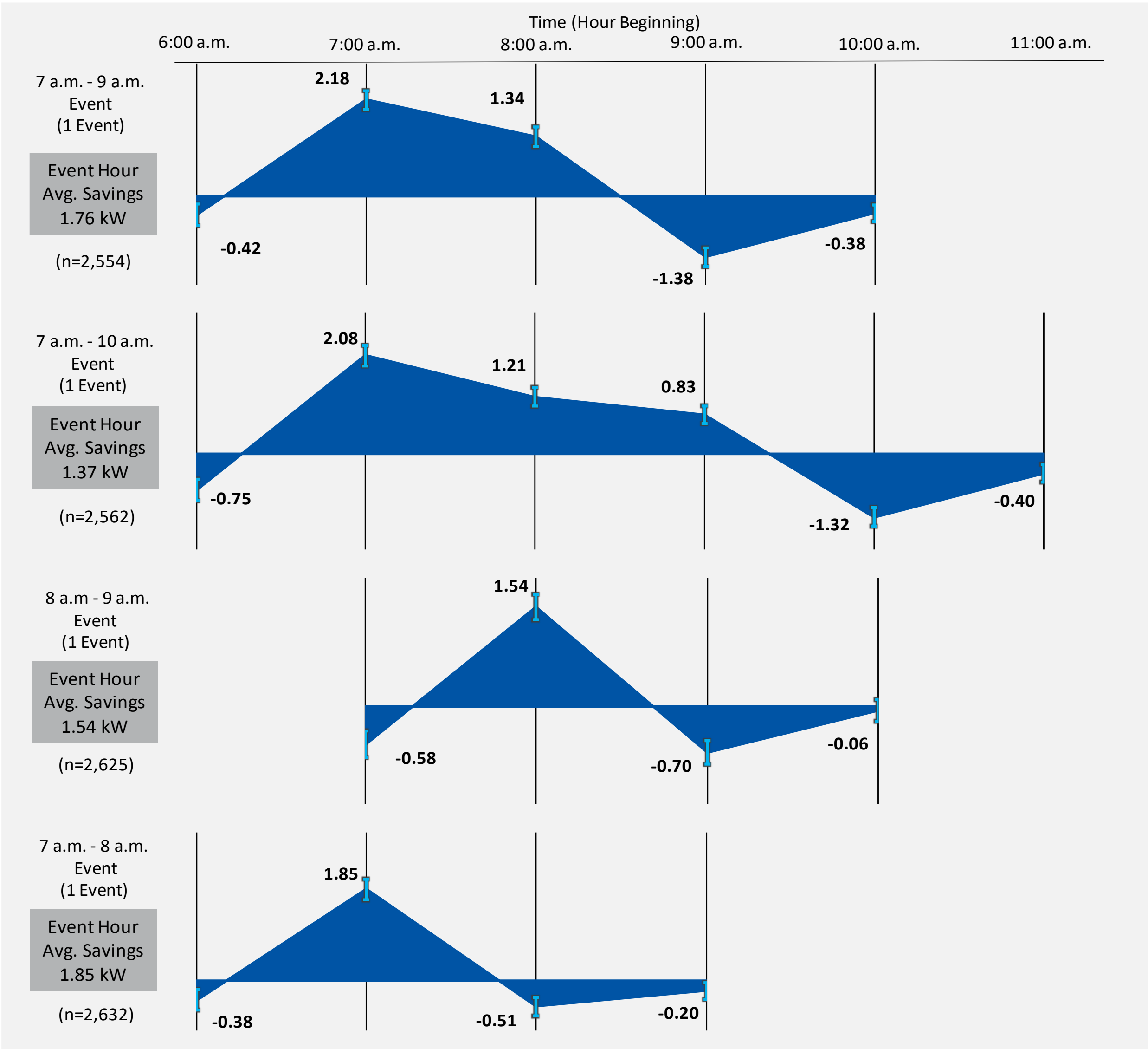
Note: Impacts were estimated using regression analysis of customer AMI meter data. Error bars show 95% confidence intervals estimated from standard errors clustered on customers. *n* indicates the number of treatment group customers in the analysis sample for the event. Average temperatures reported in figures and tables in the *Load Impacts* section are the weighted average of localized weather for customers in the analysis sample during event hours.

Demand savings peaked in the first hour of events. In each event longer than one hour, savings in each hour decreased compared to the previous hour. Savings degraded an average of 0.9 kW per treatment group customer between the first and second hours of an event, and savings degraded by 0.4 kW between the second and third hours for the three-hour event.

Winter Demand Response Load Impacts

Figure 8 shows the demand impacts before, during, and after each demand response event. Preconditioning during the hour immediately preceding the event increased electricity demand by between 0.4 kW and 0.8 kW per treatment group customer. Snapback in the first hour after the event concluded also increased demand by between 0.5 kW and 1.4 kW.

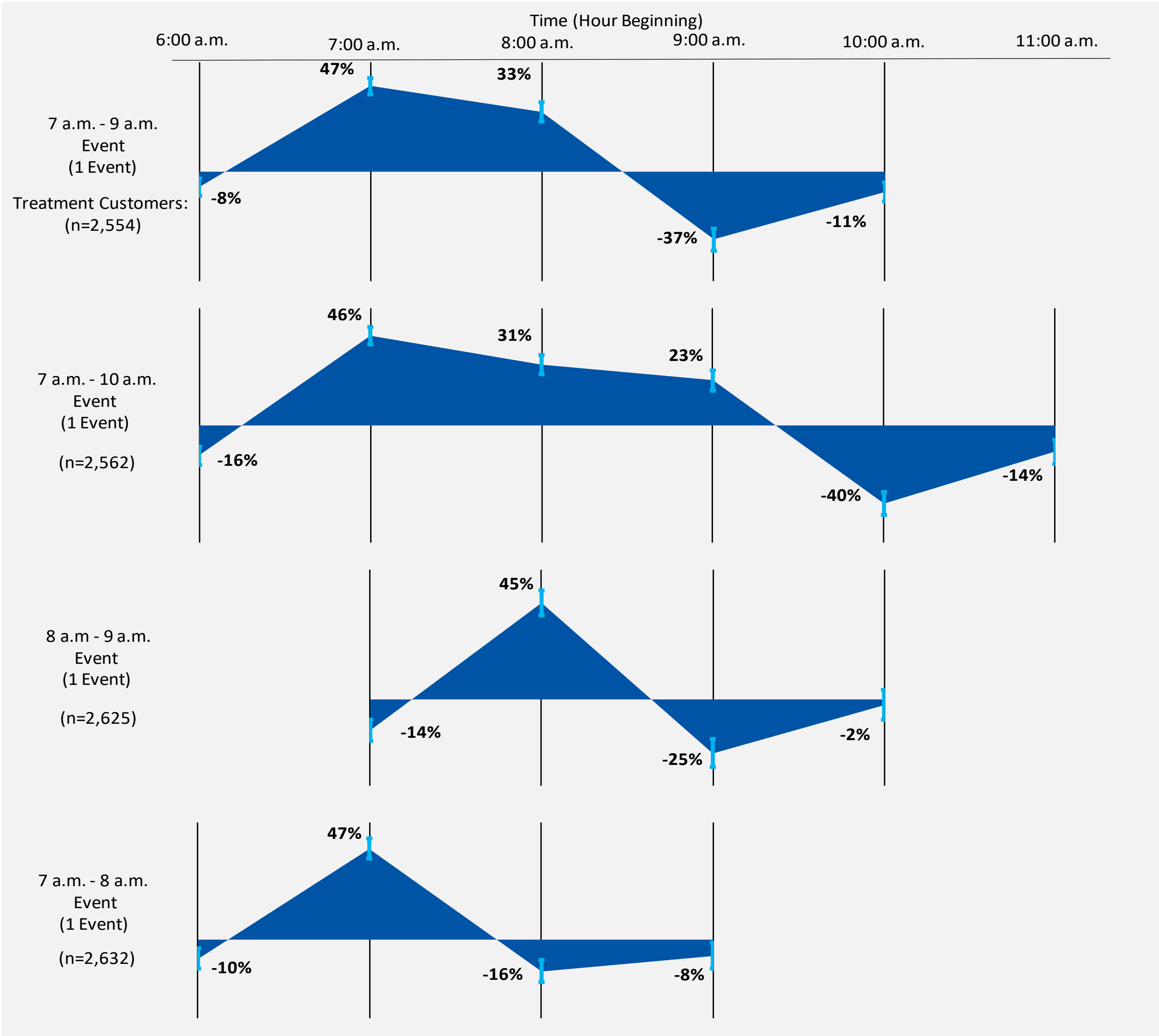
Figure 8. Direct Install Average Demand Savings (kW) – Winter 2019/2020



Note: n indicates treatment group customers in the analysis sample. kW savings estimates were obtained from ordinary least squares (OLS) panel regressions of customer metered demand. See *Appendix A* for details. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

Figure 9 shows the demand impacts as a percentage of baseline demand. Savings during the first event hour ranged between 45% and 47%. In the three-hour event, the savings as a percentage of baseline demand decreased from 46% in event hour 1 to about 23% in the last hour.

Figure 9. Direct Install Percentage Demand Savings – Winter 2019/2020



Note: n indicates treatment group customers in the analysis sample. Savings estimates were obtained from OLS panel regressions of customer metered demand. See *Appendix A* for details. Error bars indicate 95% confidence intervals based on standard errors clustered on homes. Percentage demand savings calculated as kW savings divided by baseline demand.

Winter Total Demand Savings

Table 8 shows the evaluated MW savings for the winter 2019/2020 events. The MW hours for an event were estimated by multiplying the average demand savings per treatment group customer by the number of customers in the treatment group for the event. In addition, the potential demand savings, defined as the savings that would have been realized during each event if the thermostats of all enrolled customers had been dispatched, were estimated by multiplying the per-treatment group customer savings estimate by the number of enrolled customers, which included customers who had been randomly assigned to the control group and did not participate in load control in winter 2019/2020.

The evaluated total savings ranged between 3.5 MW and 4.9 MW. The differences across events are driven both by the length of the event—savings during event hours 2 and 3 were smaller than during event hour 1—as well as by weather, the event day-of-the-week, and event starting hour-of-the-day.

Potential demand savings ranged from 4.3 MW to 5.8 MW, and because these savings include control group customers, they are slightly higher than the evaluated savings.

Table 8. Direct Install Total Demand Savings (MW) – Winter 2019/2020

Event	Event Time	Avg. Temp. (°F)	Evaluated Avg. Savings per Treatment Group Customer / Event (kW)	Analysis Sample (n)		Evaluated Demand Savings (MW)	Potential Demand Savings (MW)
				Treatment Customers	Control Customers		
1	7 a.m. - 9 a.m.	34	1.760	2,554	604	4.5	5.7
2	7 a.m. - 10 a.m.	32	1.373	2,562	596	3.5	4.4
3	8 a.m. - 9 a.m.	34	1.540	2,625	532	4.0	4.9
4	7 a.m. - 8 a.m.	37	1.850	2,632	527	4.9	5.9
Average		**34**	**1.632**	**2,593**	**565**	**4.2**	**5.2**

Note: The average savings per customer across all events is the treatment-group-size weighted average for the individual events. Evaluated MW savings were estimated by multiplying the average per treatment customer demand savings estimates in each event by the number of treatment group participants in the analysis sample. Potential MW savings are based on the total enrolled customers as of March 2020 (N=3,212). The number of treatment and control group customers in the analysis sample varied by event. The analysis sample excludes homes with missing AMI meter data and multiple program enrollments (that may have been assigned to both treatment and control groups). Details regarding the analysis sample and screening are provided in the *Data Collection and Preparation* section.

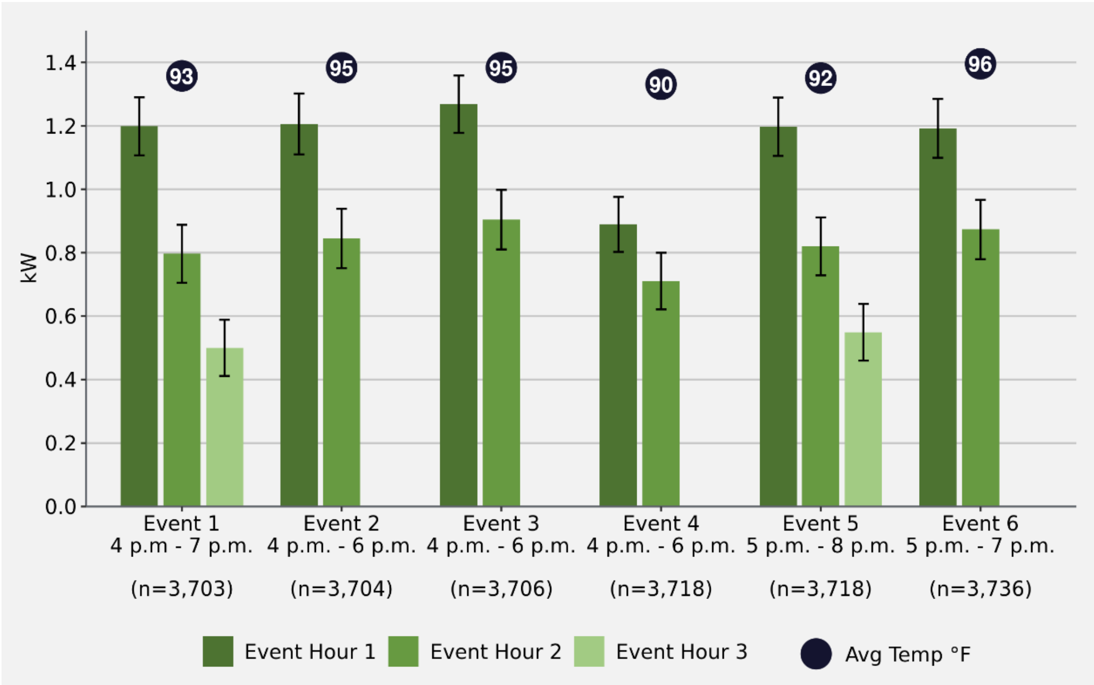
Seasonal Impacts – Summer 2020

During summer 2020, PGE dispatched Direct Install program thermostats six times. Each event was initiated on a non-holiday, weekday at 4:00 p.m. or 5:00 p.m. and lasted two or three hours.

Summer Demand Savings Estimates

Figure 10 shows the average kW savings per treatment group customer for each hour of each event during the summer 2020 season as well as the average temperature during each event. As during winter events, demand savings peaked in the first hour of summer events then diminished through the remaining hours. Savings during the first event hour ranged from 0.9 kW to 1.3 kW. Savings degraded thereafter during each event, with hour 2 savings ranging between 0.7 kW and 0.9 kW and hour 3 savings between 0.5 kW and 0.6 kW. Savings for all event hours were statistically significant at the 5% significance level.

Figure 10. Direct Install Demand Savings by Event and Event Hour– Summer 2020



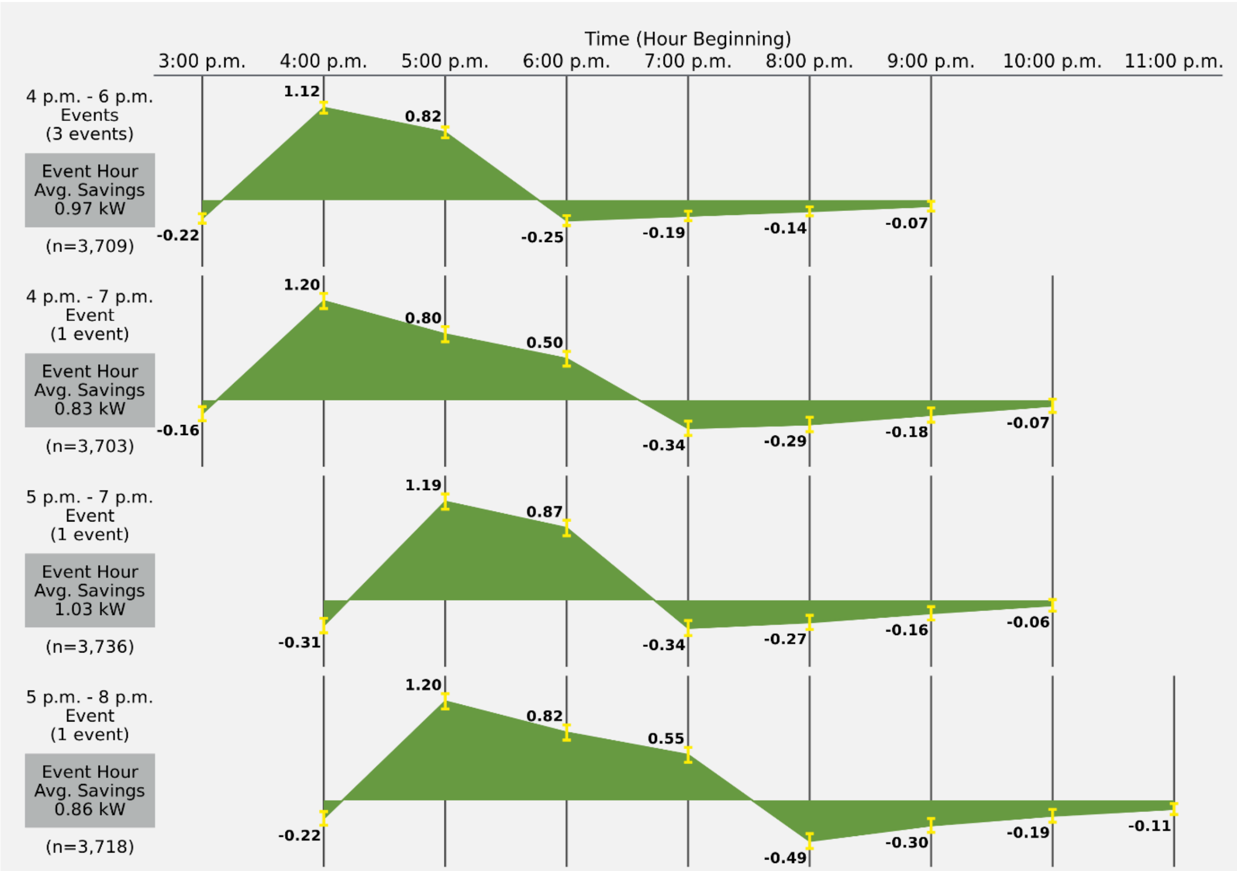
Note: n indicates the number of treatment group customers in the analysis sample for the event. kW savings estimates were obtained from OLS panel regressions of customer metered demand. See *Appendix A* for details. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

Summer Demand Response Load Impacts

Figure 11 displays estimates of the average demand impacts per treatment group home before, during, and after summer 2020 events. Estimates are reported by the starting hour and length of the event. For example, there were three events starting at 4:00 p.m. and lasting two hours. Estimates of the average load impacts for these events are presented in the figure.

Preconditioning increased demand between 0.2 kW and 0.3 kW per treatment group customer, and snapback in the first hour following events increased demand between 0.3 kW and 0.5 kW per treatment group customer. After accounting for preconditioning and snapback effects, each event generated a net decrease in energy consumption. In the figure, this is evident from the larger impact area above the x-axis than below.

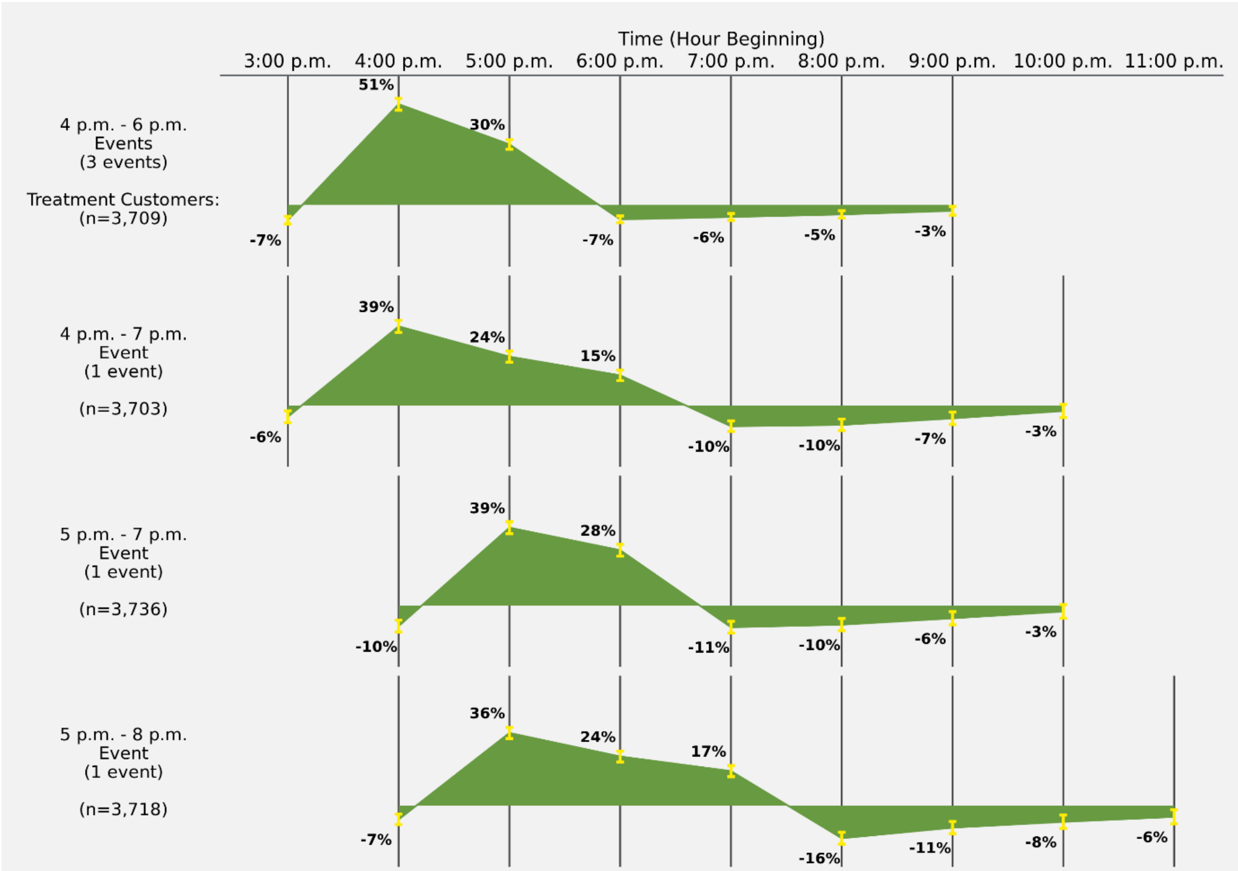
Figure 11. Direct Install Average Demand Savings (kW) – Summer 2020



Note: n indicates treatment group customers in the analysis sample. kW savings estimates were obtained from OLS panel regressions of customer metered demand. See *Appendix A* for details. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

Figure 12 reports the demand impacts as a percentage of baseline demand. Savings during the first event hour ranged from 36% to 51% of baseline demand. In event hour 2, savings as a percentage of baseline demand decreased to between 24% and 30%, and by event hour 3, savings fell to 15% to 17%.

Figure 12. Direct Install Percentage Demand Savings – Summer 2020



Note: n indicates treatment group customers in the analysis sample. kW savings estimates were obtained from OLS panel regressions of customer metered demand. See *Appendix A* for details. Percentage demand savings calculated as kW savings divided by baseline demand. Error bars indicate 95% confidence intervals based on standard errors clustered on homes.

Summer Total Demand Savings

Table 9 summarizes the demand savings generated by the Direct Install program during each summer 2020 event. The average savings was 0.94 kW per treatment group customer across all events. Evaluated total savings in MW were calculated by multiplying the average savings per treatment group customer by the number of treatment customers in the analysis sample at the time of the event.[16] Total savings ranged from 3.0 MW to 4.0 MW. Potential savings are an estimate of the demand savings Direct Install would have achieved if enrolled customers assigned to the control group or dropped from the analysis sample had also received the direct load control. Potential savings ranged from 4.1 MW to 5.6 MW.

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[16] As discussed in *Appendix A*, less than 1% of enrolled customers assigned to the treatment group were removed from the analysis because of missing data or other issues.

Table 9. Direct Install Total Savings (MW) – Summer 2020

Event	Event Time	Avg. Temp. (°F)	Evaluated Avg. Savings per Treatment Group Customer / Event (kW)	Analysis Sample (n)		Evaluated Demand Savings (MW)	Potential Demand Savings (MW)
				Treatment Customers	Control Customers		
1	4 p.m. - 7 p.m.	93	0.832	3,703	1,449	3.1	4.4
2	4 p.m. - 6 p.m.	95	1.025	3,704	1,448	3.8	5.4
3	4 p.m. - 6 p.m.	95	1.086	3,706	1,446	4.0	5.7
4	4 p.m. - 6 p.m.	90	0.800	3,718	1,434	3.0	4.2
5	5 p.m. - 8 p.m.	92	0.856	3,718	1,434	3.2	4.5
6	5 p.m. - 7 p.m.	96	1.033	3,736	1,416	3.9	5.4
Average		**93**	**0.939**	**3,714**	**1,438**	**3.5**	**4.9**

Note: The average savings per customer across all events is the treatment-group-size weighted average for the individual events. Evaluated MW savings were estimated by multiplying the average per treatment customer demand savings estimates in each event by the number of treatment group participants in the analysis sample. Potential MW savings are based on the total enrolled customers as of September 2020 (N=5,273). The number of treatment and control group customers in the analysis sample varied by event. The analysis sample excludes homes with missing AMI meter data and multiple program enrollments (that may have been assigned to both treatment and control groups). Details regarding the analysis sample and screening are provided in the *Data Collection and Preparation* section.

Temperature Response

Air conditioning loads are driven by outside temperature and humidity, and it is expected that demand response savings will be higher on hotter and more humid summer event days. Understanding the relationship between demand response savings and outside temperature and humidity will be important for operationalizing thermostat demand response as a dispatchable resource.

Figure 13 plots estimates of average savings per enrolled customer against outside temperature for event hours in summer 2020. Figure 14 plots hourly savings against the temperature-humidity index (THI). Event hours are color-coded by the first, second, and third hours of events, since demand response savings tend to diminish with time since the start of the event.

The number of data points is limited to the 14 event hours in summer 2020, but both figures suggest that demand response savings increased with temperature and THI. The relationships are strongest during the first and second event hours.[17]

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17 The highest event hour temperature of 97°F occurred during the first hour of event 6 and shows a small decrease in savings relative to the first event hours of other events. However, this event may be an anomaly because it occurred in September when residential air conditioning demand typically drops off.

Figure 13. Direct Install Summer 2020 Temperature Response

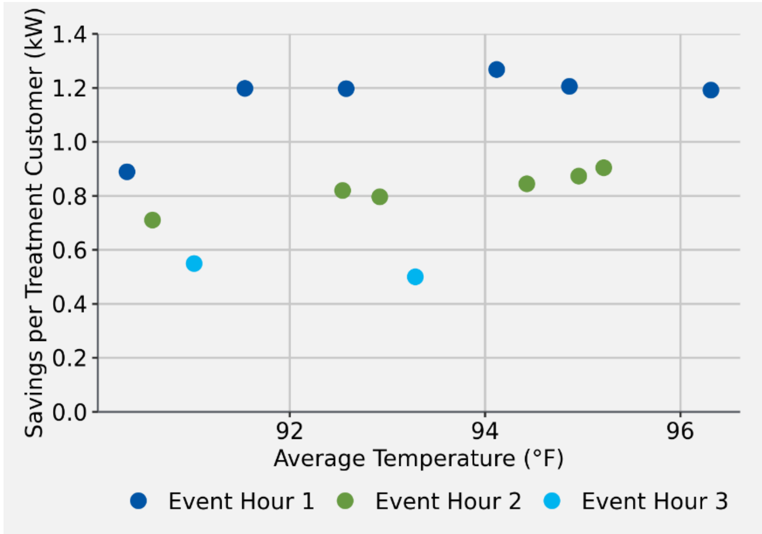
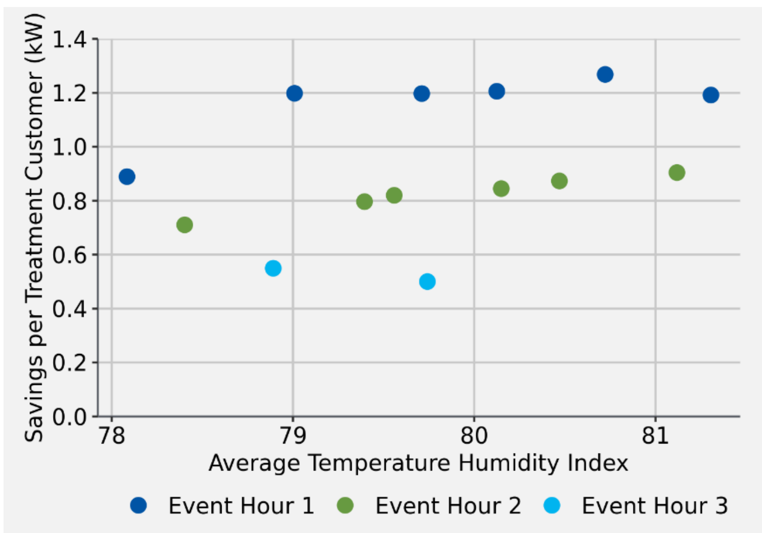


Figure 14. Direct Install Summer 2020 Temperature-Humidity Index Response



To investigate the temperature response of savings more thoroughly, Cadmus ran OLS regressions of event hour savings on hour-of-event indicator variables (hour 1, hour 2, hour 3), event hour temperature or THI, and indicator variable for event 6. The results are shown in Table 10. Demand response savings increased by about 0.042 kW/°F and 0.088 kW/THI. Both estimates are statistically significant at the 5% level.

A more definitive analysis of the temperature response would incorporate data from previous summer seasons. With more data, it will be possible to predict for each temperature or THI the average demand savings per enrolled customer that PGE can expect from Direct Install. This research is planned for 2021.

Table 10. Temperature and THI Response Regression Estimates

	Temperature	THI
Regression Coefficient with Standard Error	0.042 (0.015)	0.088 (0.023)
R^2	0.929	0.949
N	14	14

Notes: Temperature response estimates based on OLS regression analysis of event hour savings on hour-of-event indicator variables (hour 1, hour 2, hour 3), event hour temperature (or THI), and indicator variable for event 6. Heteroskedasticity-robust standard errors are in parentheses.

Event Overriding

When a customer overrides an event by adjusting the thermostat settings, PGE loses the ability to control the air conditioning unit for the remainder of the event. Depending on when during the event and the magnitude of the changes the customer makes, overriding may cause air conditioning to run longer than would usually occur. Thus, event overriding can lead not just to a loss in savings but an increase in electricity demand for air conditioning.

Table 11 summarizes telemetry data from Resideo about overriding among Direct Install customers during summer 2021 events. For each event, the table shows total number of thermostats enrolled, percentage that fully participated, percentage that overrode, and the percentages that were offline (not connected to the Wi-Fi), failed to confirm that the event control signal was received, or whose status could otherwise not be confirmed. Customers overrode between 18% and 27% of enrolled thermostats during each event. Please see the *Impact Evaluation of PGE Bring-Your-Own Thermostat Pilot Program, Winter 2019/2020 and Summer 2020* memorandum for a detailed analysis of event overrides.[18]

Table 11. Direct Install Event Override Summary – Summer 2020

Event	Event Hours	Avg. Outdoor Temperature (°F)	Total Thermostats	Fully Participated	Opted Out	Offline	Failed	Unknown
1	4 p.m. - 7 p.m.	93	3,357	58%	27%	5%	0%	10%
2	4 p.m. - 6 p.m.	98	3,888	69%	19%	4%	0%	7%
3	4 p.m. - 6 p.m.	95	3,888	70%	18%	4%	0%	7%
4	4 p.m. - 6 p.m.	89	3,893	72%	18%	4%	0%	6%
5	5 pm. - 8 p.m.	93	3,862	66%	24%	4%	0%	6%
6	5 p.m. - 7 p.m.	94	4,123	70%	18%	10%	0%	2%

Note: Average outdoor temperature is the outdoor temperature recorded in PGE's event log.

Data source: Resideo summary of overriding and thermostat status.

18 Cadmus. February 2021. *Impact Evaluation of PGE Bring-Your-Own Thermostat Pilot Program, Winter 2019/2020 and Summer 2020*

Load Impact Comparison between Direct Install and BYOT

Table 12 compares the average demand savings per treatment group customer between Direct Install and BYOT. Direct Install savings were higher than BYOT in both seasons. However, the most substantial difference was during winter, when Direct Install achieved demand savings that were approximately 0.8 kW (10 percentage points) greater than BYOT. The difference in percentage savings suggests that the difference in kW savings cannot only be explained by differences in average demand for space heating between Direct Install and BYOT customers.

Table 12. Comparison of Demand Savings Performance by Track and Season

Season	Demand Savings per Treatment Group Customer	
	Direct Install	BYOT
Winter 2019/2020	1.63 kW (41%)	0.83 kW (31%)
Summer 2020	0.94 kW (30%)	0.82 kW (30%)

Note: Average demand savings as a percentage of baseline demand in parentheses.

Figure 15 displays the savings by track for each event in winter 2019/2020. Average hourly savings per Direct Install treatment group customer ranged from 1.37 kW to 1.85 kW, while BYOT savings ranged between 0.63 kW and 0.98 kW. The difference is likely attributable to several factors, including the ability for the Direct Install track to screen out non-electric heating systems from enrollment. Other factors that may contribute include differences in customer demographics, thermal envelope efficiency, mixes of thermostat brands, and HVAC system types.

Figure 15. Demand Savings by Smart Thermostat Pilot Program Track and Event – Winter 2019/2020

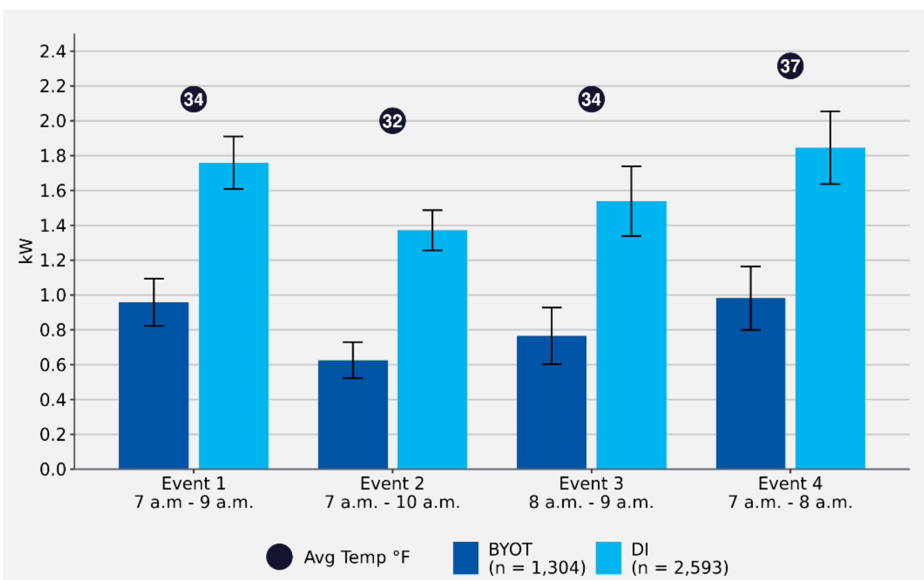


Figure 16 shows the savings by track for summer 2020 events. The BYOT track achieved average hourly savings per treatment group customer between 0.73 kW and 0.93 kW. Savings among Direct Install customers ranged from 0.80 to 1.09 kW per treatment group customer. While there were differences in kW savings for some events, the percentage savings of approximately 30% for each track suggests the BYOT and Direct Install tracks performed similarly in summer.

Figure 16. Demand Savings by Smart Thermostat Pilot Program Track and Event – Summer 2020

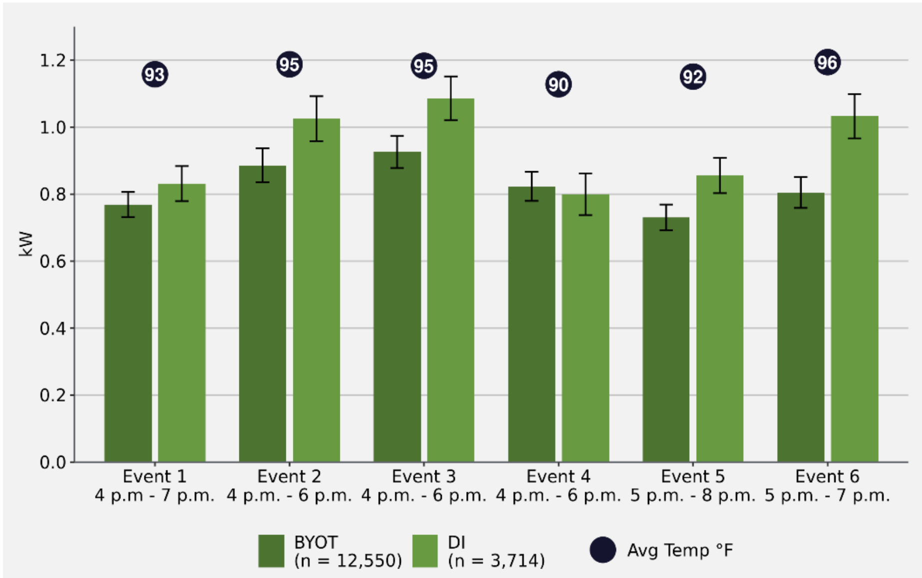


Table 13 and Table 14 compare the demand savings performance metrics for temperature indicative events between tracks for winter 2019/2020 and summer 2020 seasons, respectively. Direct Install achieved consistently higher savings per treatment group customer across all metrics in both seasons. In winter, the demand savings during the first event hour were twice as large for Direct Install (1.81 kW) as BYOT (0.88 kW). In summer, the difference in first event hour savings was much narrower, just 0.18 kW.

Table 13. Comparison of Demand Saving Performance Metrics by Program – Winter 2019/2020

Key Metrics		Winter 2019/2020 – kW Savings	
		Direct Install	BYOT
Average kW Savings	Event Hour 1 (N=2 hours)	1.81 kW (45%)	0.88 kW (33%)
	Event Hour 2 (N=1)	1.21 kW (31%)	0.52 kW (20%)
	Event Hour 3 (N=1)	0.83 kW (23%)	0.37 kW (16%)
Min kW Savings	Event Hour 1 (N=2)	1.54 kW (45%)	0.76 kW (33%)
	Event Hour 2 (N=1)	1.21 kW (31%)	0.52 kW (20%)
	Event Hour 3 (N=1)	0.83 kW (23%)	0.37 kW (16%)
Max kW Savings	Event Hour 1 (N=2)	2.08 kW (46%)	1.00 kW (32%)
	Event Hour 2 (N=1)	1.21 kW (31%)	0.52 kW (20%)
	Event Hour 3 (N=1)	0.83 kW (23%)	0.37 kW (16%)
Average Savings Degradation (difference from previous hour savings)	Event Hour 1 to Event Hour 2 (N=1 hour)	-0.87 kW (48%)	-0.48 kW (55%)
	Event Hour 2 to Event Hour 3 (N=1)	-0.38 kW (31%)	-0.15 kW (29%)
Average Preconditioning (the hour before the event begins)		-0.66 kW (15%)	-0.41 kW (13%)
Average Snapback (the hour after the event ends)		-1.01 kW (33%)	-0.46 kW (23%)
Average Event Day Energy Savings		1.16 kWh	0.45 kWh

Notes: Average kW savings are the average demand savings per treatment group customer across event hours. N refers to the number of events or event hours meeting indicative temperature thresholds. Min and max kW savings are the minimum and maximum of the average demand savings per treatment group customer across event hours. Average savings degradation is the difference between the average savings per treatment group customer in an event hour and the average savings in the previous hour. Average preconditioning is the average change in savings from preconditioning in the hour preceding the start of the event. Average snapback is the savings in the first hour after the event ends. Average event day conservation is the average energy savings per treatment group customer on event days.

Table 14. Comparison of Demand Saving Performance Metrics by Program – Summer 2020

Key Metrics		Summer 2020 – kW Savings	
		Direct Install	BYOT
Average kW Savings	Event Hour 1 (N=5 hours)	1.21 kW (39%)	1.03 kW (38%)
	Event Hour 2 (N=5)	0.85 kW (26%)	0.72 kW (24%)
	Event Hour 3 (N=2)	0.52 kW (16%)	0.49 kW (16%)
Min kW Savings	Event Hour 1 (N=5)	1.19 kW (39%)	0.94 kW (36%)
	Event Hour 2 (N=5)	0.80 kW (24%)	0.67 kW (24%)
	Event Hour 3 (N=2)	0.50 kW (15%)	0.45 kW (15%)
Max kW Savings	Event Hour 1 (N=5)	1.27 kW (41%)	1.08 kW (40%)
	Event Hour 2 (N=5)	0.90 kW (27%)	0.77 kW (26%)
	Event Hour 3 (N=2)	0.55 kW (17%)	0.54 kW (17%)
Average Savings Degradation (difference from previous hour savings)	Event Hour 1 to Event Hour 2 (N=5 hours)	-0.36 kW (-30%)	-0.31 kW (-30%)
	Event Hour 2 to Event Hour 3 (N=2)	-0.28 kW (-33%)	-0.23 kW (-32%)
Average Preconditioning (the hour before the event begins)		-0.21 kW (7%)	-0.32 kW (12%)
Average Snapback (the hour after the event ends)		-0.34 kW (10%)	-0.30 kW (10%)
Average Event Day Energy Savings		1.23 kWh	0.86 kWh

Notes: Average kW savings are the average demand savings per treatment group customer across event hours. N refers to the number of events or event hours meeting indicative temperature thresholds. Min and max kW savings are the minimum and maximum of the average demand savings per treatment group customer across event hours. Average savings degradation is the difference between the average savings per treatment group customer in an event hour and the average savings in the previous hour. Average preconditioning is the average change in savings from preconditioning in the hour preceding the start of the event. Average snapback is the savings in the first hour after the event ends. Average event day conservation is the average energy savings per treatment group customer on event days.

Customer Experience

After the winter 2019/2020 and summer 2020 season, Cadmus administered an online survey to Direct Install customers to assess their experience. The experience surveys asked customers about their event awareness, thermal comfort, override behavior, and satisfaction. The following sections describe key findings from the winter and summer experience surveys. Whenever possible or applicable, survey results from the previously evaluated seasons are provided.

Awareness of Events

The winter and summer customer experience surveys asked respondents how many events they noticed. Figure 17 shows the survey results for each evaluated season.

Figure 17. Event Awareness

	Winter 2018/2019	Summer 2019	Winter 2019/2020	Summer 2020
Number of Events PGE Called	6 events	6 events	4 events	6 events
Percentage Who Noticed the Events	60% (n=162)	67%* (n=235)	65% (n=165)	57%* (n=572)
Average Number of Events Noticed from Those Who Noticed	5.2 events (n=97)	4.0* events (n=158)	3.0 events (n=107)	4.7* events (n=327)

*Difference between seasons is significant with 90% confidence (p≤0.10).
Source: Experience Survey Question. "Your smart thermostat works with PGE to shift electricity consumption from times when demand for electricity is highest. How many high demand events did you notice this past winter/summer?"

For the winter 2019/2020 and summer 2020 seasons, about a third of respondents noticed the events but they tended to notice, on average, a fewer number of events than were called. No statistically significant differences emerged in customer awareness of the events between the two winter seasons.

However, the two summer seasons significantly differed. Interestingly, fewer respondents from summer 2020 noticed the events compared to respondents from summer 2019, but the average number of events noticed was higher in summer 2019 than in summer 2020. The significant differences in customer awareness of the summer events may be due to a combination of factors identified in Table 15. As described in subsequent sections, these factors may have affected various aspects of customer experience in addition to awareness of the event.

Table 15. Factors that Could Have Impacted Customer Experience

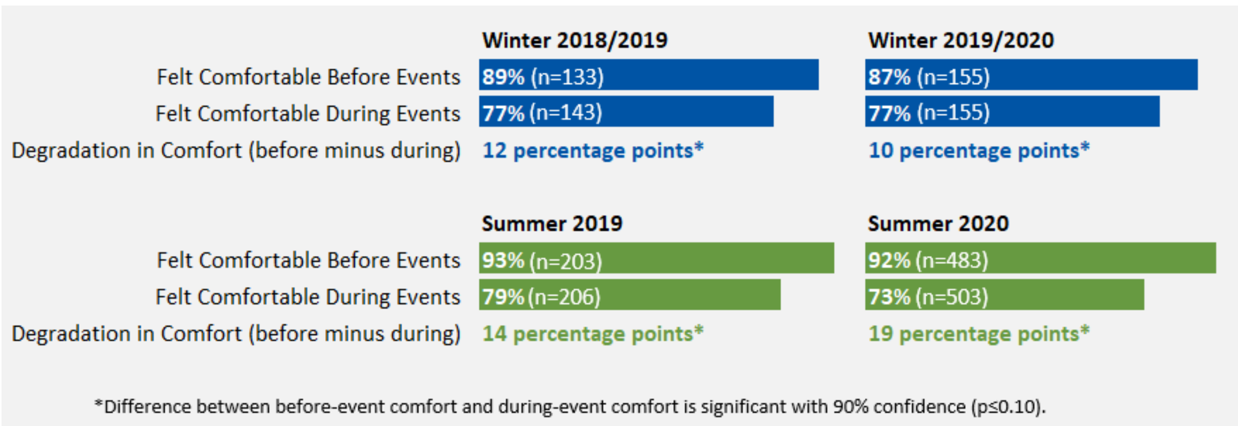
Winter Season Differences	Winter 2018/2019	Winter 2019/2020
Fewer events in winter 2019/2020	6 events called	4 events called
Winter 2019/2020 was colder	Average 36.2 degrees during the 6 events	Average 31.5 degrees during the 4 events
All morning events in winter 2019/2020	5 events called in the evening; 1 event called in the morning	All 4 events called in the morning
Longer events in winter 2018/2019	All 6 events last for 3 hours	Each of 4 events varied from 1-3 hours
Summer Season Differences	**Summer 2019**	**Summer 2020**
Summer 2020 was warmer	Average 89.7 degrees during the 6 events	Average 93.7 degrees during the 6 events
Potentially more customers at home during summer 2020 events	No pandemic	COVID-19 pandemic
Changes in energy efficiency settings from thermostat manufacturers	None	Launch of ecobee's eco+ energy-saving enablement feature; possible changes to Nest's Seasonal Savings feature
Changes in event strategies	No preconditioning on ecobees; IDR implemented	Preconditioning on ecobees; no IDR

Thermal Comfort

The experience surveys asked respondents about their thermal comfort before and during the events. Respondents rated their comfort level on a 0-to-10 scale, where 0 meant *extremely uncomfortable* and 10 meant *extremely comfortable*. Cadmus defined a 6 to 10 rating as *comfortable*.

Respondents' thermal comfort ratings before and during events showed a significant degradation in comfort. As shown in Figure 18, most respondents said they felt comfortable before the events, for both winter and summer seasons. Most respondents also said they felt comfortable during the events, for both winter and summer seasons. However, their comfort rating during the events was significantly lower than their comfort before the events. This degradation in comfort was especially higher in the summer seasons (14 to 19 percentage points) than the winter seasons (10 to 12 percentage points).

Figure 18. Thermal Comfort Before and During Events



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 6 to 10 rating as *comfortable*.
Source: Experience Survey Questions. "Overall this past winter/summer, how comfortable was the interior temperature of your home a few hours *before* the high demand events?" and "Overall this past winter/summer, how comfortable was the interior temperature of your home *during* the high demand events?"

In particular, the highest degradation in comfort was in summer 2020. This could be attributed to the same factors that could have affected customers' awareness of the events (i.e., warmer summer 2020 than previous year, more customers at home due to pandemic, changes in the energy efficiency settings from thermostat manufacturers, and changes in the event strategies).

Self-Reported Event Overrides

The experience survey asked respondents whether they overrode at least one event during the season and, if they did, asked about their reason for overriding.

Figure 19 shows that, in general, one in three respondents reported overriding an event during the season. Respondents who reported overriding most frequently cited thermal discomfort as their reason across all seasons. Self-reported event overrides fluctuated from season to season, especially in summer 2020, which had the highest percentage.

Figure 19. Self-Reported Event Overrides

	Winter 2018/2019	Summer 2019	Winter 2019/2020	Summer 2020
Percentage of Respondents Overriding at Least One Event	36% (n=157)	23%* (n=225)	30% (n=156)	44%* (n=572)
Top Reasons for Overriding	Thermal discomfort 60%; other household members 4%; had guests over 2% (n=55)	Thermal discomfort 90%; baby/pet in the home 4% (n=50)	Thermal discomfort 69%; disagreed with temp. setback 9%; baby/pet in the home 9% (n=45)	Thermal discomfort 81%; disagreed with temp. setback 4% medical/health reasons 4% (n=252)

*Difference between summer 2019 and summer 2020 is significant with 90% confidence ($p \leq 0.10$).
Source: Experience Survey Questions. "Did you or someone else override the thermostat settings during any of the events this past winter/summer?" and "Why did you or someone in your household override the thermostat settings during the peak time events?"

Summer 2020 significantly differed from summer 2019. At first, Cadmus surmised that the difference could be due to the pandemic. For instance, more customers were likely at home during summer 2020 than summer 2019 and could therefore have had easier/direct access to the thermostat to override.

However, Cadmus was, for the first time, able to obtain telemetry data of summarized population-level override statistics provided by the thermostat manufacturers for summer 2020. These summarized data revealed that between 18% and 27% of treatment group customers overrode each event. This meant that the summer 2020 experience survey was overreporting overrides, perhaps due to biases in self-selection and respondent recall. Cadmus did not receive summarized override data for winter 2019/2020 and prior seasons to assess how the other experience surveys compared in respondents' self-reported overrides.

Currently, PGE does not send pre-event notifications directly to customers and does not provide customers a way to review their event participation history. Therefore, customers do not know how many events have taken place nor how many events they participated in or overrode.

As stated earlier, customers who understood the 50% event participation minimum requirement were less likely to override the events.

"I feel like there was some lack of communication around what I was supposed to do. I thought I participated as expected but I got an email that said 'you missed out' and it implied I had not participated... So I don't know what happened."
– Summer 2020 Experience Survey Respondent

Furthermore, in the program satisfaction open-end question in the summer 2020 customer experience survey, 8% of respondents (n=360) expressed negative sentiment about the Smart Thermostat pilot due to a lack of information transparency. These respondents frequently asked for communication and information about events, such as the following:

- Clear information about the 50% event participation minimum requirement
- Direct pre-event notifications
- Communication on the number of overrides

In the open-end comments in previous customer experience surveys, many respondents said they wanted direct pre-event notifications. In the summer 2020 customer experience survey, Cadmus asked respondents if they were interested in receiving notifications before the start of an event. Most respondents (73%, n=572) said they were interested, with 38% saying they were *very interested* and 35% saying they were *somewhat interested*.

All of these findings suggest that customers want more communication and information about the events.

Relationship between Thermal Comfort and Overrides

The evaluation found that customers' perception of thermal comfort contributed to their overriding the demand response event. Using the summer 2020 customer experience survey data, Cadmus ran regressions to assess the relationships between respondents' comfort ratings and their overriding behavior.[19] The regression analysis found the following (additional details provided in *Appendix C*):

- Feeling comfortable before an event increased the likelihood of overriding by 19 percentage points or 31% relative to respondents who reported feeling uncomfortable.
- Feeling comfortable during an event reduced the likelihood of overriding by 32 percentage points or 52% relative to respondents who report feeling uncomfortable.
- No statistically significant differences in the likelihood of overriding an event between thermostat brands or micro-segments.[20]

Impact of Encouragement Email on Overrides

During summer 2020, PGE tested an encouragement email designed to remind customers about the 50% event participation minimum requirement and encourage them to not override the remaining events in the season. One encouragement email was sent to approximately 200 Direct Install customers with an ecobee thermostat who overrode the first two summer 2020 events.

Cadmus surveyed the encouragement email recipients and found that exactly 50% of respondents (n=66) remembered receiving the encouragement email. Of the respondents who remembered the encouragement email (n=33), 42% said they felt more motivated to participate in future events after receiving the email. Without an RCT comparison group, the evaluation could not determine how effective the encouragement email was in reducing overrides. A future test of the encouragement email should consider an RCT design.

[19] The summer 2020 customer experience survey had the largest sample size (i.e., number of respondents) to run regressions. Experience surveys in previous seasons had small sample sizes.

[20] Five PGE customer segments used in characterizing residential customer demand response potential: Big Impactors, Fast Growers, Middle Movers, Borderliners, and Low Engagers.

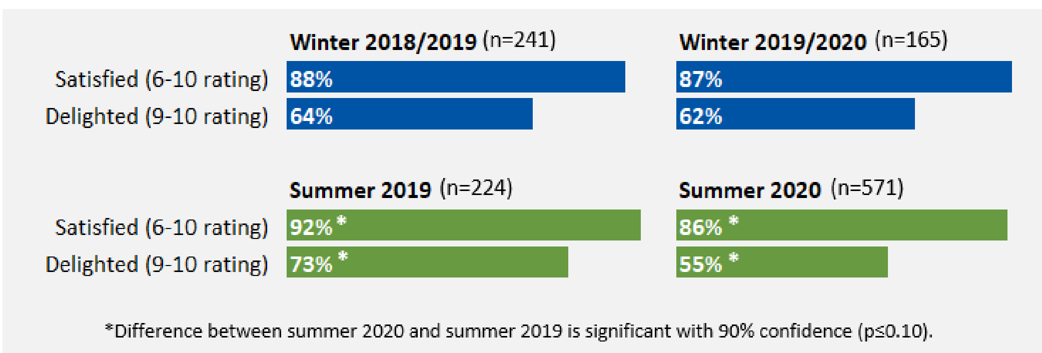
Satisfaction with Program

The customer experience surveys asked respondents to rate their satisfaction with the Smart Thermostat pilot, using 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*.

Winter 2019/2020 and summer 2020 achieved high program satisfaction on par with results from previous seasons with one exception—the percentage of summer 2020 respondents who were *delighted*. Most respondents were satisfied with the program across all seasons (Figure 20). Both winter seasons achieved similar program satisfaction results.

The summer seasons significantly differed in program satisfaction. Summer 2019 had the highest satisfaction results (92%) of any season, while summer 2020 had the lowest (86%). Notably, summer 2020 showed a significant decrease in the percentage of *delighted* respondents (55%) from summer 2019 (73%) and the lowest percentage of *delighted* respondents of any season. The lower satisfaction in summer 2020 may be tied to thermal comfort and the factors that impact comfort. As noted earlier, summer 2020 observed the highest degradation in customers' perception of thermal comfort compared to previous seasons and a combination of factors could have exacerbated customers' discomfort (as identified in Table 15, summer 2020 was warmer, more customers were at home due to pandemic, there were changes in the energy efficiency settings from thermostat manufacturers, and there were changes in the event strategies).

Figure 20. Satisfaction with Program



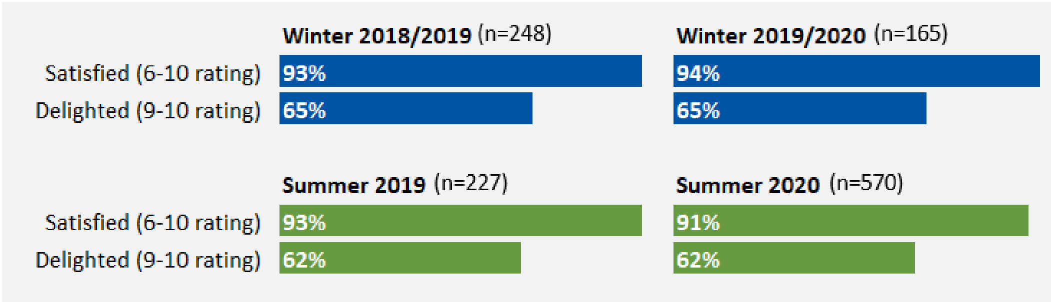
Source: Experience Survey Question. "Please rate your overall satisfaction with PGE's Smart Thermostat Program."

Satisfaction with PGE

The customer experience surveys also asked respondents rate their satisfaction with PGE, using 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*.

Winter 2019/2020 and summer 2020 achieved high customer satisfaction with PGE. High satisfaction with PGE was observed across all seasons (Figure 21). Both the winter and summer seasons achieved similar satisfaction results. This suggests that the metric for satisfaction with PGE is less susceptible to contextual differences and program changes than to the metric for program satisfaction.

Figure 21. Satisfaction with PGE



Source: Experience Survey Question. "Please rate your overall satisfaction with PGE."

Relationship between Thermal Comfort, Overrides, and Satisfaction

The evaluation found that thermal comfort and overrides affected customer satisfaction with the program and with PGE. Cadmus ran regressions to assess the relationships between respondents' comfort ratings, overriding behavior, and satisfaction using the summer 2020 experience survey data.[21] The regression analysis found the following:

- Feeling comfortable during an event increased the likelihood of being satisfied with the program by 22 percentage points or 34%.
- Feeling comfortable during an event increased the likelihood of being satisfied with PGE by 10 percentage points or 13%.
- Overriding behavior was associated with a reduction in the likelihood of being satisfied with the program by 9 percentage points or 14%.
- Overriding behavior was associated with a reduction in the likelihood of being satisfied with PGE by 5 percentage points or 6%.
- There was no statistically significant difference in the likelihood of being satisfied (with the program and PGE) between thermostat brands or micro-segments.

Logic Model Review

Cadmus conducted a high-level review of the logic model by using staff interview findings, customer survey findings, and load impact results to determine whether Direct Install produced the expected outcomes. Due to the limited availability of certain information and data, not all expected outcomes shown in the logic model could be thoroughly assessed.

Given the challenges of operating Direct Install under a pandemic, PGE still managed to deliver on planned activities. Direct Install mostly operated as expected, producing most of its expected outcomes. It did not produce the expected outcomes for enrollment and event participation. Table 16 summarizes the findings from the logic model review in detail.

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[21] The summer 2020 customer experience survey had the largest sample size (i.e., number of respondents) to run regressions. Previous seasons' experience surveys had small sample sizes.

Table 16. Logic Model Review of Direct Install Smart Thermostat Demand Response Program

Logic Model Element		Expected Outcome	Actual Outcome
Program Activities	Capacity planning	PGE outlines the use of demand response to help manage system peak loads	**Met.** PGE outlined its plan in 2019 Integrated Resource Plan. *(Source: previous evaluation report)*
	Program design and implementation	PGE and implementers design and administer the program	**Met.** PGE and implementers administered the winter 2018/2019, summer 2019, winter 2019/2020, and summer 2020 seasons. *(Source: current evaluation report)*
	Evaluation	Cadmus evaluates the program	**Met.** Cadmus evaluated program delivery, load impacts, and customer experience for each season. *(Source: current evaluation report)*
Outputs to Program Activities	Integrated Resource Plan	PGE publishes the plan	**Met.** PGE published the Integrated Resource Plan in July 2019 with smart thermostats as a demand response resource. *(Source: previous evaluation report)*
	Program operations manual	PGE drafts a manual for internal staff	**Met.** A manual was drafted for Direct Install and BYOT. *(Source: current evaluation report)*
	Marketing collateral	PGE and implementers create and disseminate collateral	**Met.** PGE conducted all program marketing activities (email, direct mail, and PGE website) and created educational fact sheets, which CLEAResult installation technicians handed out to customer during the in-home and virtual installation. *(Source: current evaluation report)*
	Program scheduling website and call center	Implementers create, host, and manage the website and call center. Customers can enroll through the website and call center.	**Met.** CLEAResult operated the call center and scheduling web portal. *(Source: current evaluation report)*
	Smart thermostat installation and enrollment	Technicians successfully installs the device and enrolls customers into the program	**Met.** PGE piloted virtual install with CLEAResult and successfully managed to complete installations and enroll customers during the COVID-19 pandemic. *(Source: current evaluation report)*
	Installation technician training and leave-behind materials	PGE provides educational training and educational collateral for technicians to utilize during customer's installation appointment	**Met.** PGE provided technicians with educational fact sheets to leave behind with customers. *(Source: current evaluation report)*
	Demand response platform for PGE to call events	Implementers create, host, and manage the platform. PGE can schedule events.	**Met.** PGE previously used Nest's and Resideo's online management platform to schedule events. In 2020, Resideo became the sole demand response service provider. PGE could now schedule events through one platform. *(Source: current evaluation report)*
	Evaluation report	Cadmus drafts the evaluation report for PGE to submit to the Public Utility Commission of Oregon	**Met.** Cadmus drafted this evaluation report as well as presented results to PGE after the end of each season. *(Source: current evaluation report)*

Logic Model Element		Expected Outcome	Actual Outcome
Short-Term and Intermediate Outcomes (in one to two years)	Program operations	Organized and efficient management of program	**Met.** Operational efficiencies were further gained in 2020 when the pilot program transitioned to Resideo as the sole demand response service provider. PGE could now schedule events and review data through one party and platform. *(Source: current evaluation report)*
	Customer awareness	Customers become aware of demand response and program	**Cannot be determined from this evaluation.** See Cadmus's Interim Evaluation Report of the Test Bed Project (2021) for outcomes on customer awareness of the smart thermostat offering.
	Installation satisfaction	Customers have a positive scheduling and installation experience	**Met.** 98% of survey respondents agreed with the statement, "The contractor was professional and courteous." 93% of respondents agreed with the statement, "I didn't wait long… to the day of installation." 95% of respondents were satisfied and 82% were delighted with their overall installation experience. *(Source: previous evaluation report)*
	Program enrollment	27,768 thermostats enrolled in Direct Install and BYOT by end of 2020	**Did not meet.** Direct Install and BYOT combined together, PGE enrolled 22,408 thermostats by October 2020. Two challenges slowed down enrollments: the Nest-to-Resideo transition lost 15% of the Nest enrollees and the COVID-19 pandemic led to a pause in marketing and installations. *(Source: current evaluation report)*
	Event participation	Customers do not override more than 50% of the event hours	**Cannot be determined.** Hourly event override data were not available. Actual override data for summer 2020 revealed that 18% to 27% of customers overrode events, depending on the event. *(Source: current evaluation report)*
	Customer satisfaction	Customers are satisfied with the program	**Met.** Direct Install achieved high customer satisfaction results. 87% of treatment group survey respondents were satisfied with the program in winter 2018/2019 and 86% were satisfied with the program in summer 2020. *(Source: current evaluation report)*
	Demand impacts	PGE achieves peak demand savings	**Met.** Direct Install achieved average savings of 1.6 kW and 0.9 kW per participant for winter 2019/2020 and summer 2020, respectively. *(Source: current evaluation report)*
	Ongoing participation	Customers renew participation next season	**Cannot be determined.** Current evaluation was not tasked to analyze ongoing customer participation.
Long-Term Impacts and Success (in three to five years)	Program goals	Meet enrollment and demand response capacity goals	**To be assessed in future**
	Customer engagement	Increased customer awareness, consideration, evaluation, action, and loyalty (ACEAL)	**To be assessed in future**
	Company goals	Improvements in reliability of electricity service, cost-effectiveness, and corporate sustainability goals	**To be assessed in future**

Future Changes and Considerations

As demonstrated through the testing of virtual install and the email encouraging customers not to override events, PGE continued to adapt the Direct Install during winter 2019/2020 and summer 2020. More changes and improvements are expected from PGE in the areas of process flow and customer communications and information.

With Resideo now the sole demand response service provider, PGE is considering ways to consolidate and streamline program processes such as customer eligibility, enrollment, and real-time reporting of event results. As there is currently no means for participants to view their event participation history, PGE is working on ways to provide customers with communication and information. Ideas under consideration include sending out direct pre-event notifications, mid-season communications, and an event participation outcomes report.

PGE also plans to transition the Smart Thermostat Demand Response pilot to a full-scale program, so it is important for PGE system operators to understand the demand response properties of smart thermostats to have full confidence in the capabilities of this product as a capacity resource. Additionally, although the program delivered the expected savings, PGE has opportunities to improve performance by addressing the reasons customers override demand response events and possibly discouraging such behavior.

Finally, PGE may be able to finetune marketing and recruitment for the BYOT and Direct Install tracks to maximize the cost-effectiveness of the Smart Thermostat Demand Response pilot. For example, Direct Install may be optimal for specific segments such as less tech-savvy customers who cannot be enrolled through BYOT. The higher Direct Install demand savings in winter may help to compensate for the additional costs of directly installing the thermostat.

Appendix A. Evaluation Methodology

This section describes Cadmus's methodology for evaluating the Direct Install track of the Smart Thermostat pilot.

Evaluation Design

To estimate the demand response impacts of the Direct Install track, Cadmus worked with PGE to implement a randomized controlled trial (RCT). RCTs are the gold standard in program evaluation and expected to produce unbiased estimates of the program savings. This evaluation design involved randomly assigning program participants (residential customers who enrolled in the program) to a treatment group or control group. Treatment group customers received the load control signals during demand response events, while control group customers did not. Savings were estimated by comparing the average demand of treatment and control group customers during event hours.

Cadmus randomized customers prior to each event season by program and brand. Customers were assigned to one group for the whole season and not informed about the group to which they had been assigned. If a customer had multiple smart thermostats at the time of the randomization, all thermostats were assigned to the treatment group or control group. For participants who enrolled after the Cadmus randomization, PGE randomly assigned them to the treatment group using a pre-randomized assignment list based on the order of enrollment. Customers were rerandomized at the beginning of the next season.

Table A-1 shows random assignments of participating customers overall, by number of thermostats, and by HVAC system for the winter 2019/2020 and summer 2020 event seasons.

Table A-1. Direct Install and Virtual Install Program Enrollments by Event Season

Category	Direct Install			Virtual Install			Total
	Control	Treatment	Total	Control	Treatment	Total	
Winter 2019/2020 Enrollments							
Total Thermostats	541	2,739	3,280	-	-	-	3,280
Total HVAC Systems	541	2,734	3,275	-	-	-	3,275
Total Customers	532	2,680	3,212	-	-	-	3,212
Summer 2020 Enrollments							
Total Thermostats	1,413	3,852	5,265	3	12	15	5,280
Total HVAC Systems	1,414	3,852	5,266	3	12	15	5,281
Total Customers	1,412	3,846	5,258	3	12	15	5,273

Note: Total Thermostats and HVAC Systems represent the number of individual thermostats and HVAC equipment associated with all enrolled participants. Total Customers is the number of unique Service Premise IDs. Virtual Install customers were grouped with Direct Install customers in the analysis.

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 for homes 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 the commands, and homes that do not receive or execute the commands due to some operational issue. In its evaluations of PGE's thermostat programs, Cadmus has estimated and reported the intent-to-treat effect because the ITT is 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 treatment effect on the treated (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 obtain telemetry data from the demand response service providers to determine the percentage of homes that did not execute the demand response setback. 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 we learn that 80% of homes successfully executed the setback, the estimate of the TOT effect equals 1 kW/0.8 = 1.2 kW. 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.

Data Collection and Preparation

Cadmus collected and prepared several types of data for analysis:

- ***Participant enrollment data***, provided by PGE, tracked enrollment for treatment group and control group customers. These data included participant name, contact information (such as address), a unique premise identifier (the point of delivery ID), and an enrollment date.
- ***Interval consumption data*** was provided by PGE for all enrolled participants. For post-enrollment periods, these included watt-hour electricity consumption at 15- or 60-minute intervals, measured using advanced metering infrastructure (AMI) meters. For usage periods prior to enrollment, only hourly data were available.
- ***Local weather data,*** including hourly average temperatures from December 2019 through September 2020 for five National Oceanic and Atmospheric Administration (NOAA) 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,*** including dates and times of all load control events, were provided by PGE.

- ***Summarized telemetry data,*** including 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, were provided by Resideo. These data were not provided at the individual customer level.

The AMI meter data recorded a customer's electricity consumption at 15- or 60-minute intervals and covered every hour of winter and summer. Cadmus aggregated all 15-minute interval consumption data to the customer-hour level and performed standard data-cleaning steps (detailed below) to address duplicate observations, outliers, and missing values.

The weather data were high-frequency, asynchronous temperature and humidity readings from five NOAA weather stations across PGE's service area. Cadmus aggregated the weather data to the hourly level and merged these data with the hourly interval consumption data.

Cadmus used the enrollment and participation data to identify customers in the treatment and control groups and develop survey sample frames. These data provided several key fields for each customer, including the following:

- Assignment to treatment or control group
- Dates for participant enrollment and un-enrollment date, if applicable
- Customer ID and address
- Eligibility for winter and summer demand response programs determined by HVAC equipment

Robustness checks of the Direct Install treatment group savings estimates indicate that the estimates were not sensitive to the specific solutions Cadmus developed.

Analysis Samples

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

- Adjust timestamps to account for daylight savings time
- Remove a small number of duplicate interval readings from the data
- Adjust timestamps from end of read period to start of read period
- Sum 15-minute interval consumption data to obtain hourly interval consumption
- Drop a small number of outliers and hourly observations missing one or more 15-minute interval readings
- Combine the consumption of meters connected to the same thermostat
- Since all events occurred on weekdays, remove holidays, weekends, and days outside of event seasons

Cadmus excluded a small number of customers from the analysis sample. A customer was excluded from the analysis sample if the customer had any of the following:

- Lacked AMI meter data
- Had multiple thermostats enrolled in the program and these thermostats had been assigned to different groups (treatment or control)
- Appeared in a list of treatment and control group customers who were rejected from the program for a variety of reasons, including Nest customers who did not sign the new terms and conditions agreement prior to the beginning of the summer 2020 season
- Average daily consumption greater than or equal to 300 kWh, suggesting they were not residential customers
- Enrolled in multiple PGE programs
- Had multiple HVAC systems

Table A-2 and Table A-3 show attrition of customers from the analysis sample for winter 2019/2020 and summer 2020, respectively. Each row represents a level of filtering, with the corresponding number of participants assigned to each group after the filter step. Total program participation is the number of unique Service Premise IDs in the raw Smart Thermostat pilot participation data obtained from PGE.

Table A-2. Direct Install Final Analysis Sample Attrition – Winter 2019/2020

Filter	Treatment Group		Control Group	
	Customers	Percent	Customers	Percent
Customers in Tracking Data	2,680	100%	532	100%
Customers with one program enrollment	2,680	100%	532	100%
Customers with one HVAC System	2,680	100%	530	99.6%
Customers in AMI Data	2,679	100%	530	99.6%
Customers with ADC < 300 kWh	2,678	99.9%	530	99.6%
Customers included in analysis	**2,678**	**99.9%**	**530**	**99.6%**

Table A-3. Direct Install Final Analysis Sample Attrition – Summer 2020

Filter	Treatment Group		Control Group	
	Customers	Percent	Customers	Percent
Customers in Tracking data	3,858	100%	1,415	100%
Customers in AMI data	3,770	97.7%	1,382	97.7%
Customers with ADC < 300 kWh	3,770	97.7%	1,382	97.7%
Customers included in analysis	**3,770**	**97.7%**	**1,382**	**97.7%**

The final analysis sample includes participants used in the impact estimation and excludes a small number of customers who had multiple HVAC systems, were missing AMI data, or had average daily consumption (ADC) greater than 300 kWh.

Equivalency Checks of Randomized Treatment and Control Groups

Cadmus checked for statistically significant differences in demand between treatment and control group customers in the final analysis sample on non-event days.

Figure A-1 and Figure A-2 show average demand by hour on winter 2019/2020 and summer 2020 weekdays, 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. In winter 2019/2020, there were small (0.2 kW), statistically significant differences between treatment and control group demand in hours 7 and 8. However, the difference-in-difference panel regression approach used to estimate demand savings controls for differences in customer demand.

Figure A-1. Equivalency of Treatment and Control Groups – Winter 2019/2020

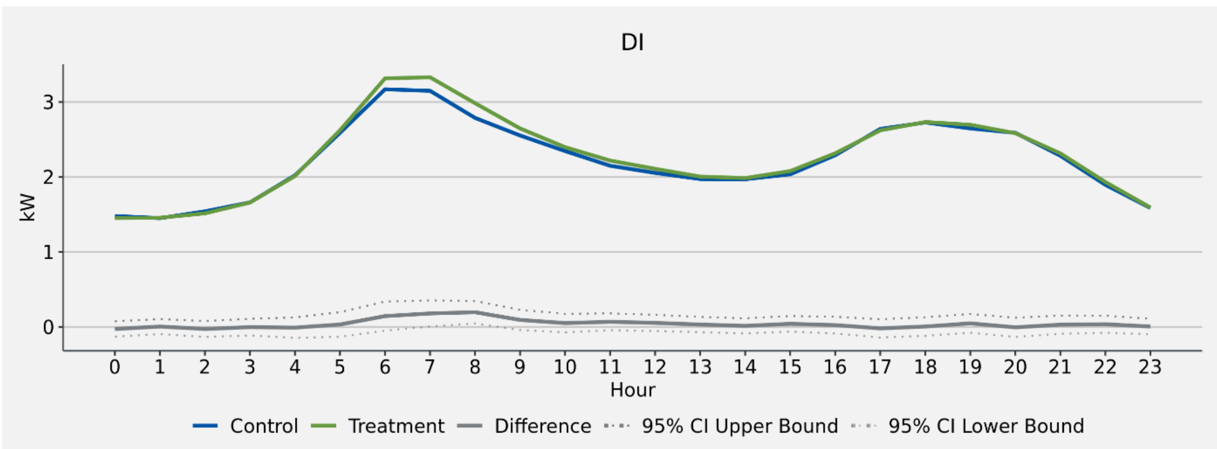
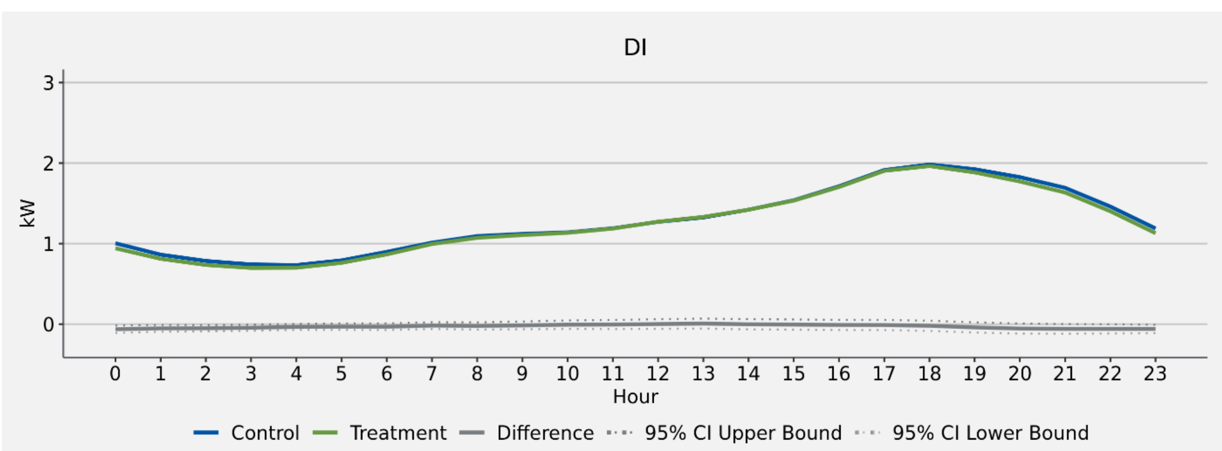


Figure A-2. Equivalency of Treatment and Control Groups – Summer 2019



Load Impact Analysis

Savings Estimation Approach

Cadmus estimated savings by collecting individual customer AMI interval consumption data and by comparing the demand of customers in the randomized treatment and control groups during each event hour. We employed panel regression analysis to estimate demand impacts for the two hours before, two or three hours during, and four hours after each event. In addition to assignment to treatment or control group, the panel regression controlled for the impacts of hour-of-the-day, day-of-the-week, 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'
$Hour_{kt}$	=	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
β_k	=	Average load impact (kWh/hour) per customer of hour 'k' on customer consumption
ϑ_k	=	Average incremental load impact (kWh/hour) per customer for treatment group customers in hour 'k'
DH_{it}	=	Heating or cooling degree hour for customer 'i' in hour 't' for a given base temperature
γ_k	=	Average effect per customer of a cooling degree hour on customer consumption in hour 'k'
τ_k	=	Average incremental effect per cooling degree hour per customer on consumption of treatment group customers in hour 'k'
$I(Event=1)_{mjt}$	=	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
π_{mj}	=	Average load impact (kWh/hour) per customer during hour 'j' of event 'm,' which affects treatment and control group customers

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

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

φ_{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 treatment group customer 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 treatment group customer during pre-event hour 'l' of event 'm'

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

Cadmus estimated the models by ordinary least squares (OLS) and clustered the standard errors on customers to account for correlations over time in customer demand. The model included all non-holiday weekdays days in June, July, August, or September 2020 for summer and January and February 2020 for winter. We estimated alternative model specifications to treatment the estimates' robustness to specification changes and found that the results were very robust.

Staff Interviews

In fall 2020, Cadmus conducted a total of four interviews with utility and implementation staff involved with the Direct Install track of the Smart Thermostat pilot:

- Two interviews with PGE staff
- One interview with Resideo staff
- One interview with CLEAResult staff

These interviews aimed to document Direct Install's winter 2019/2020 and summer 2020 operations, including changes in delivery and impacts from the COVID-19 pandemic. Copies of the interview guides are provided in Appendix D. Cadmus used information obtained from the interviews to design the customer surveys and review the logic model.

Customer Surveys

Cadmus designed and administered two online customer surveys:

- Direct Install winter 2019/2020 customer experience survey (fielded in March 2020)
- Direct Install summer 2020 customer experience survey (fielded in November 2020)

Survey Design

For the winter 2019/2020 customer experience survey, Cadmus administered the survey to treatment and control group customers. The survey asked treatment group customers about their event awareness, thermal comfort, event participation, reasons for overriding the load control, and satisfaction. Because control group customers did not experience any load control events, they were asked questions only about satisfaction with the program and with PGE. The survey took respondents less than seven minutes to complete. Respondents did not receive an incentive for completing the survey.

The summer 2020 customer experience was administered to treatment and control group customers and the survey covered the following topics:

- Event awareness and participation
- Thermal comfort before and during events
- Satisfaction with the program and with PGE
- Understanding of program participation requirements
- Impact of the encouragement email
- COVID-19 impacts
- Virtual install experience

The survey largely targeted the treatment group customers. Control group customers were only included if they had participated in the virtual install service and these customers answered questions only about their virtual install experience. The survey took two to eight minutes to complete and respondents did not receive an incentive for completing the survey.

A copy of the two surveys are provided in Appendix E.

Survey Sampling and Response Rates

Cadmus contacted a random sample of participants stratified by assignment group for the winter 2019/2020 experience survey. For the summer 2020 experience survey, Cadmus contacted the census of recipients who received encouragement email and participants in the virtual install service. With the remaining population, Cadmus contacted a random sample of customers in the treatment group. Table A-4 and Table A-5 show the number of participants contacted and the response rate for the two surveys. On average, the two experience surveys achieved a response rate of 24%.

Table A-4. Direct Install: Winter 2019/2020 Experience Survey Samples and Response Rates

	Population	Sample Frame*	Number of Completes (Achieved Sample)	Response Rate
By Assignment				
Treatment	2,678	814	165	20%
Control	530	222	74	33%
By Brand				
Brand A	1,713	404	86	22%
Brand B	1,495	632	153	24%
By HVAC System				
Heat Pump	2,430	764	191	25%
Electric Forced-Air Furnace	773	272	48	18%
Both	5	0	N/A	N/A
Overall	**3,208**	**1,036**	**239**	**23%**

* Cadmus selected a random sample of 1,036 records stratified by assignment for the survey.

Table A-5. Direct Install: Summer 2020 Experience Survey Samples and Response Rates

	Population	Sample Frame*	Number of Completes (Achieved Sample)	Response Rate
By Assignment				
Treatment	3,318	2,289	572	25%
Control	1,207	11	3	27%
By HVAC System				
Central Air Conditioner	2,684	1,398	342	24%
Heat Pump	1,841	902	233	26%
By Virtual Install				
Yes (Participant)	68	41	11	27%
No (Nonparticipant)	4,457	2,259	564	25%
By Encouragement Email				
Yes (Recipient)	206	205	66	32%
No (Nonrecipient)	4,319	2,095	509	24%
Overall	**4,525**	**2,300**	**575**	**25%**

* A mix of stratified random sampling and census of records were selected for the survey.

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, when the number of responses permitted statistical testing, Cadmus compared survey results by assignment, brand, and event override status at the 90% confidence level (or $p \leq 0.10$ significance level). The winter 2019/2020 experience survey data were not weighted as the sample proportions closely aligned with the population proportions. The summer 2020 experience survey data were weighted by the encouragement email status.

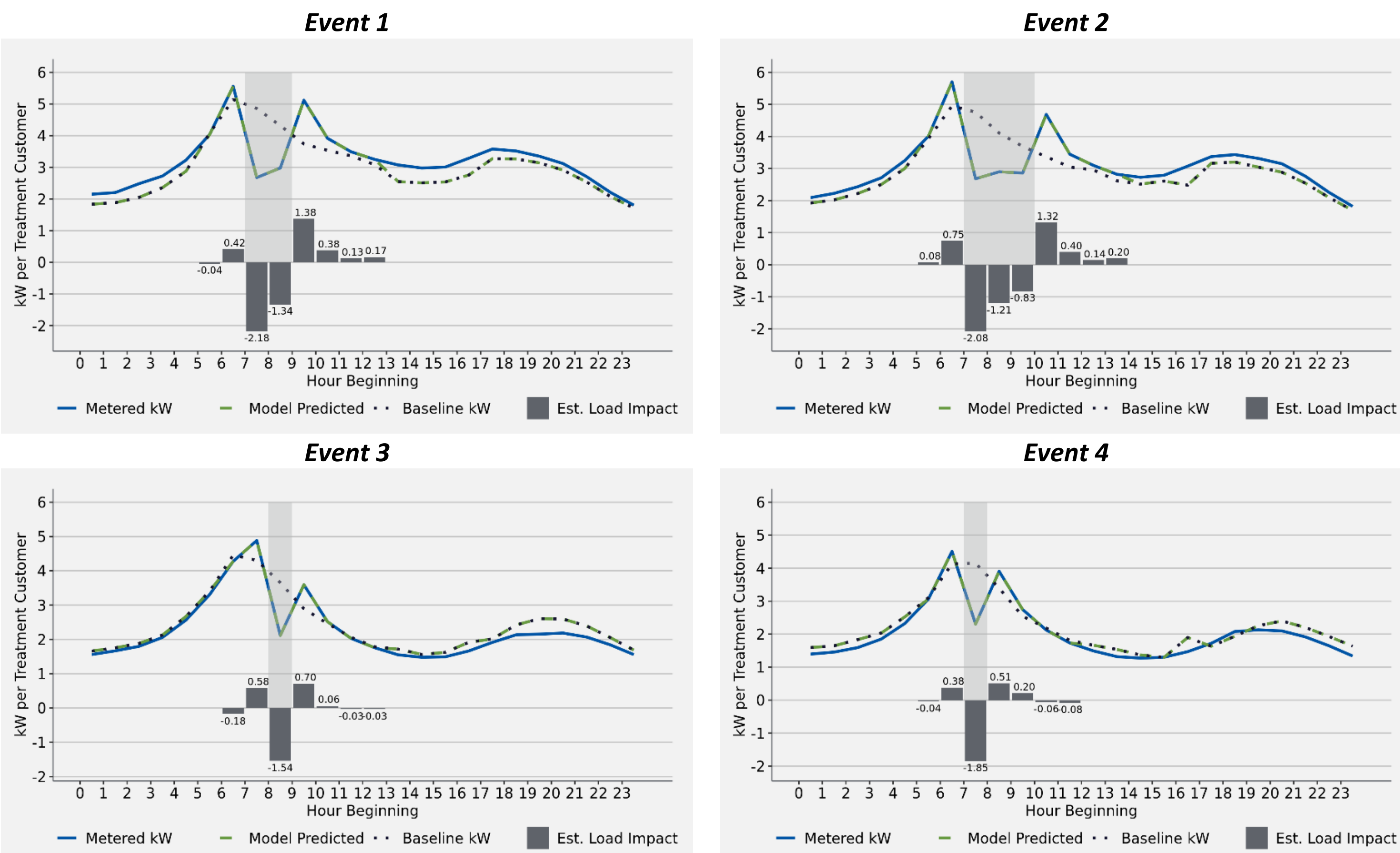
Appendix B. Additional Impact Findings

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 2019/2020

Figure B-1 displays estimates of the average load impacts per treatment group customer for demand response events in winter 2019/2020. 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 demanded if the event had not been called.

Figure B-1. Average Daily Load Impacts per Treatment Group Customer by Event – Winter 2019/2020

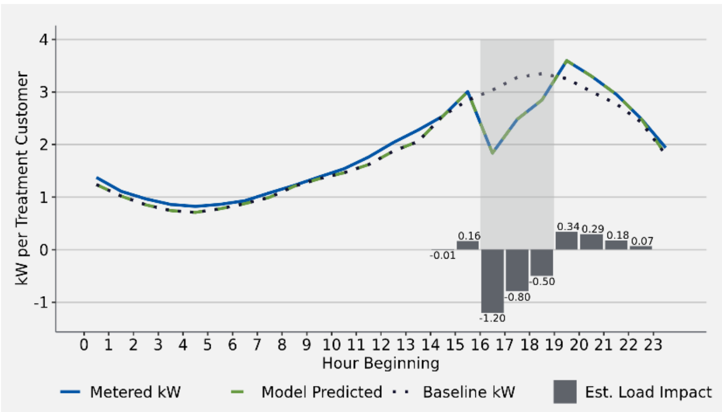


Load Impacts by Event Days – Summer 2020

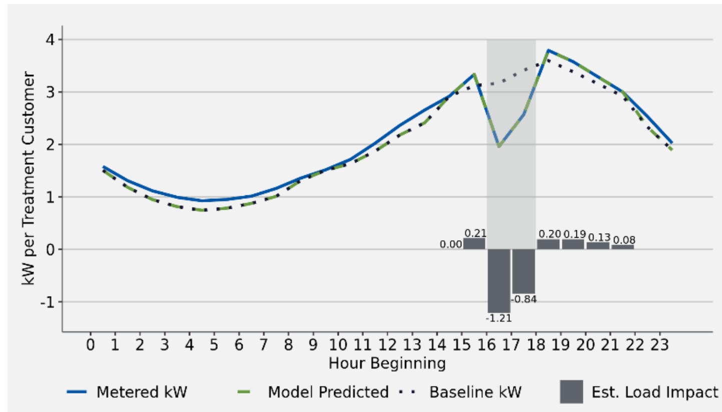
Figure B-2 displays estimates of the average load impacts per treatment group customer for demand response events in summer 2020.

Figure B-2. Average Daily Load Impacts per Treatment Group Customer by Event – Summer 2020

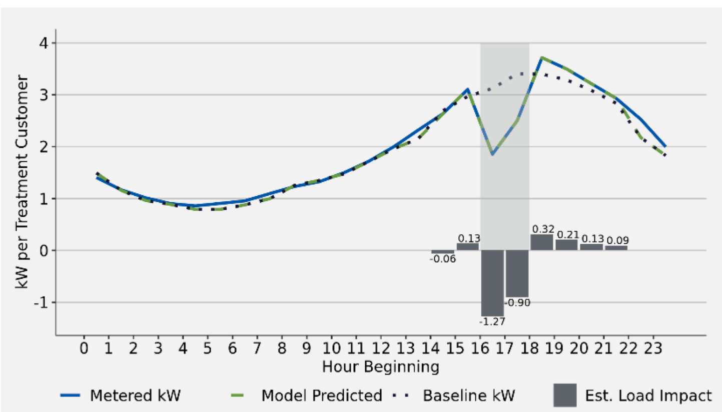
Event 1



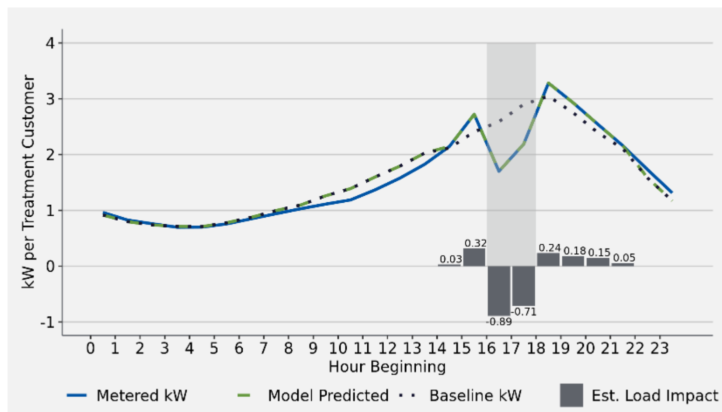
Event 2



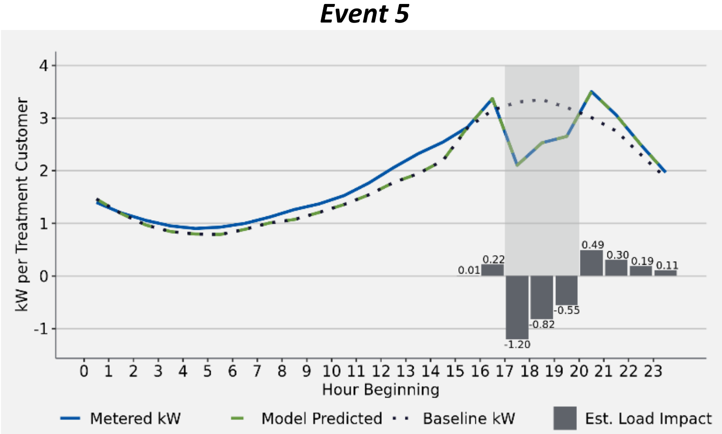
Event 3



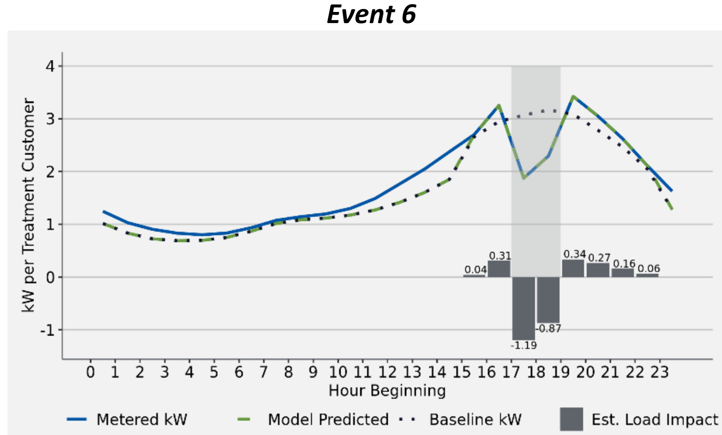
Event 4



Event 5



Event 6



Event Impact Estimates Tables

Table B-1 and Table B-2 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. Direct Install Demand Reduction by Event – Winter 2019/2020

Event Hour	Event			
	1	2	3	4
Event Start Time	7:00 a.m.	7:00 a.m.	8:00 a.m.	7:00 a.m.
Pre-Event Hour 1	0.42***	0.75***	0.58***	0.38***
Event Hour 1	**-2.18*****	**-2.08*****	**-1.54*****	**-1.85*****
Event Hour 2	**-1.34*****	**-1.21*****	**N/A**	**N/A**
Event Hour 3	**N/A**	**-0.83*****	**N/A**	**N/A**
Post-Event Hour 1	1.38***	1.32***	0.7***	0.51***
Post-Event Hour 2	0.38	0.40	0.06	0.2***
Post-Event Hour 3	0.13	0.14	-0.03	-0.06**
Post-Event Hour 4	0.17	0.20	-0.03	-0.08
Event Avg. Demand Impact (kW)	**-1.76**	**-1.37**	**-1.54**	**-1.85**
Avg. Energy Impact (kWh)	**-1.72**	**-2.05**	**-0.26**	**-0.82**

Notes: Estimates obtained from Cadmus panel regression analysis of customer hourly electricity demand. ***, **, * denotes the estimate is statistically significant at the 1%, 5%, and 10% levels. Energy impacts were estimated 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 – Summer 2020

Event Hour	Event					
	1	2	3	4	5	6
Event Start Time	4:00 p.m.	4:00 p.m.	4:00 p.m.	4:00 p.m.	5:00 p.m.	5:00 p.m.
Pre-Event Hour 1	0.16***	0.21***	0.13***	0.32***	0.22***	0.31***
Event Hour 1	**-1.20*****	**-1.21*****	**-1.27*****	**-0.89*****	**-1.20*****	**-1.19*****
Event Hour 2	**-0.80*****	**-0.84*****	**-0.90*****	**-0.71*****	**-0.82*****	**-0.87*****
Event Hour 3	**-0.50*****	**N/A**	**N/A**	**N/A**	**-0.55*****	**N/A**
Post-Event Hour 1	0.34***	0.20***	0.32***	0.24***	0.49***	0.34***
Post-Event Hour 2	0.29***	0.19***	0.21***	0.18***	0.30***	0.27***
Post-Event Hour 3	0.18***	0.13***	0.13***	0.15***	0.19***	0.16***
Post-Event Hour 4	0.07*	0.08*	0.09**	0.05	0.11***	0.06*
Event Avg. Demand Impact (kW)	**-0.83**	**-1.03**	**-1.09**	**-0.80**	**-0.86**	**-1.03**
Avg. Energy Impact (kWh)	**-0.50**	**-0.84**	**-0.90**	**-0.71**	**-0.55**	**-0.87**

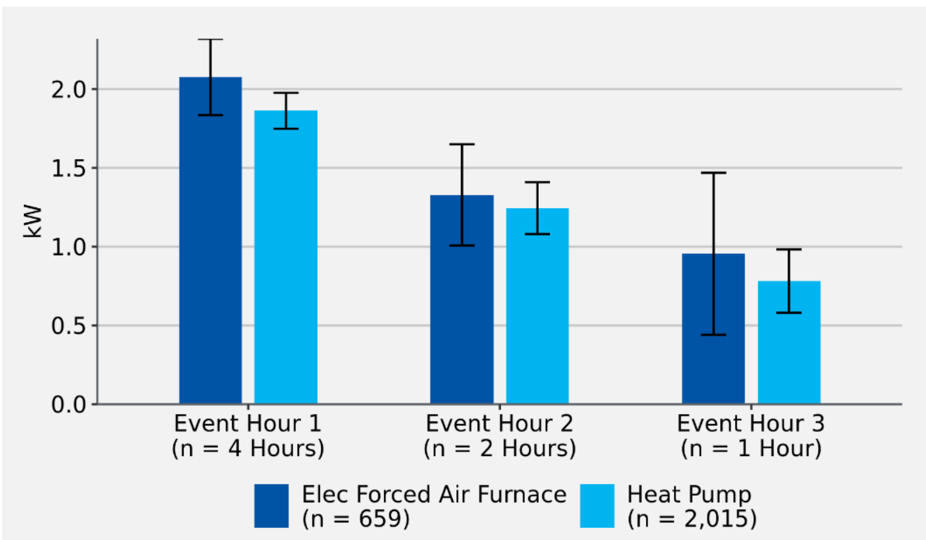
Notes: Estimates obtained from Cadmus panel regression analysis of customer hourly electricity demand. ***, **, * denotes the estimate is statistically significant at the 1%, 5%, and 10% levels. Energy impacts were estimated by summing the load impacts across the pre-event hour 1, event hours, and post-event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

Demand Savings by HVAC Equipment Type – Winter 2019/2020

Cadmus also estimated the demand savings by heating system type. Electric forced air furnaces (EFAFs) are less efficient at heating homes than are heat pumps, so it is expected that savings will be higher in homes with EFAFs due to their higher savings potential.[22] However, at very cold temperatures, heat pumps may operate less efficiently, which can diminish the savings from demand response.

Figure B-3 shows the average kW savings per treatment group customer by heating system type and event hour. In winter 2019/2020, homes with heat pumps saved 1.9 kW per treatment group customer in the first event hour, while customers with EFAFs saved 2.1 kW in hour 1. Savings for EFAFs was also higher in the second and third hours. However, none of the differences are statistically significant, as the confidence intervals for the estimates include the estimate of the other heating system type across all event hours.

Figure B-3. Direct Install Savings by HVAC System for Event Hours – Winter 2019/2020



Note: Demand impacts by HVAC system type were estimated in separate OLS panel regression models for customers with EFAFs and customers with heat pumps. n indicates the number of treatment group customers in the analysis sample with each heating system type.

These results should be interpreted with caution because any difference in savings between home heating equipment types may reflect the impacts of not just home heating equipment but also other home features or customer behaviors correlated with having a particular heating equipment type. For example, homes with heat pumps may have higher savings because they were newer and therefore better insulated than homes with EFAFs.

[22] It is also important to keep in mind that heat pump homes may have different features and energy use behaviors that affect their thermal efficiency, heating energy demand, and the savings from demand response. For example, home heating equipment type could be correlated with home size and thermal efficiency of the home envelope.

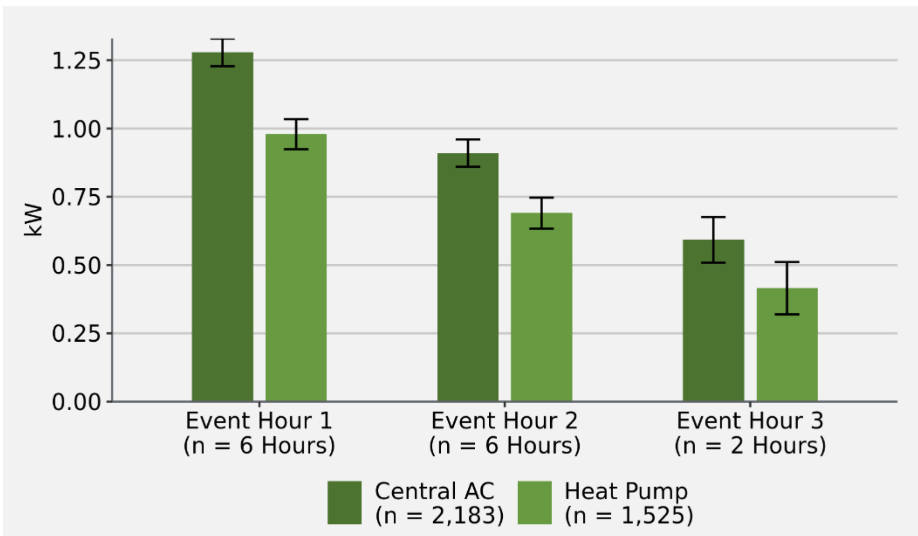
Demand Savings by HVAC Equipment Type – Summer 2020

Cadmus also estimated summer 2020 savings by cooling system type. Since heat pumps in cooling mode operate similar to central air conditioners (CACs), it was expected there would not be large differences in savings between customers by HVAC system type.

Figure B-4 shows the average kW savings per treatment group customer for each event hour by cooling system. Customers with CACs achieved slightly higher savings than customers with heat pumps.

During the first hour of events, CAC homes saved 1.3 kW, while heat pump homes saved 1.0 kW. These differences persisted in event hour 2 and event hour 3. Though CAC customers saved more than heat pump customers, the differences may be due not to the cooling equipment type but rather to other home features or energy consumption behaviors correlated with having a particular system type.

Figure B-4. Direct Install Savings by HVAC System for Event Hours – Summer 2020



Note: Demand impacts by HVAC system type were estimated in separate OLS panel regression models for customers with EFAFs and customers with heat pumps. n indicates the number of treatment group customers in the analysis sample with each heating system type.

Appendix C. Summer 2020 Customer Experience Survey Regression Analysis

Approach

Cadmus used linear probability models to assess the relationships between customers' thermal comfort before and during demand response events, overriding, and satisfaction with the program and PGE as reported by respondents in the summer 2020 customer experience survey.

Results

Table C-1 reports results from the analysis. The six models (each corresponding to an outcome) were linear probability models estimated by OLS, and the standard errors were White (1980) heteroskedasticity-robust standard errors.[23] All regressions included control variables for the customer thermostat brand and the customer demand response micro-segment (see Table C-2 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 model 3, the coefficient on thermal comfort during events indicates that survey respondents who reported being comfortable during events were 32.5 percentage points or 52% (-0.325/0.629) less likely to override events than respondents who said they were uncomfortable.

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

Table C-1. Summer 2020 Experience Survey Regression Analysis Output

	(1) Thermal Comfort Before	(2) Thermal Comfort During	(3) Overrode Events	(4) Program Satisfaction	(5) PGE Satisfaction
Intercept	0.882***	0.782***	0.629***	0.646***	0.786***
	(0.035)	(0.054)	(0.103)	(0.086)	(0.079)
T-stat Brand B	-0.038	-0.142***	0.016	0.019	0.002
	(0.024)	(0.040)	(0.045)	(0.028)	(0.025)
Thermal Comfort Before			0.199*	0.065	0.079
			(0.102)	(0.091)	(0.081)
Thermal Comfort During			-0.325***	0.222***	0.102**
			(0.054)	(0.048)	(0.043)
Overrode Events				-0.092***	-0.049*
				(0.030)	(0.027)
Participation Requirements			-0.153***		
			(0.049)		
Big Impactor	0.060*	0.043	0.053	0.037	-0.023
	(0.034)	(0.058)	(0.063)	(0.038)	(0.034)
Fast Grower	0.028	0.076	-0.022	0.009	-0.011
	(0.035)	(0.055)	(0.060)	(0.038)	(0.032)
Borderliner	0.026	0.074	-0.118	-0.051	-0.056
	(0.043)	(0.068)	(0.073)	(0.055)	(0.046)
Low Engager	-0.027	0.181*	-0.176	0.023	-0.021
	(0.100)	(0.094)	(0.132)	(0.084)	(0.083)
N	481	501	467	467	467

Notes: All regressions were linear probability models estimated with data from the summer 2020 experience survey and by ordinary least squares, with robust standard errors in parentheses. The column headings show the model dependent variable and the row names represent the independent variables. Where no coefficient is reported means the independent variable was not included in the regression. All independent and dependent variables are 0-1 indicator variables and defined as follows. T-stat Brand B = 1 if the respondent had a Brand B thermostat and =0, otherwise. Thermal Comfort Before =1 if the respondent reported their thermal comfort before the event between 6 and 10 on a 0-10 scale and = 0 if the respondent reported comfort below 6. Thermal Comfort During pertains to comfort during the event and is defined analogously. Overrode Events=1 if the respondent reported having overrode one or more events in summer 2020 and =0, otherwise. Participation Requirement=1 if the respondent demonstrated that they understand the requirements for participation in the Direct Install pilot and = 0, otherwise. Big Impactor, Fast Grower, Borderliner, and Low Engager are 0-1 indicator variables for the demand response micro-segments. Program satisfaction =1 if the respondent reported satisfaction between 6 and 10 on a 0-10 scale. PGE Satisfaction is defined analogously. The omitted category is customers who had brand A thermostats and were Middle Movers. ***, **, * denotes estimated coefficient is statistically significant at the 1%, 5%, and 10% levels.

Table C-2. 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 shows the most engaged with technology behaviors. Most likely to make online purchases.
Middle Movers	Will track with Fast Growers, proportionally lower values on housing sizes, income, notably close with respect to technology
Borderliners	Individuals in this group are split, some may tend by value to lean into Low Engagers, while some are aligned more with Middle Movers, a key may be viewing this group as potential Middle Movers, tend to rent
Low Engagers (lowest potential)	Most likely to interact with newspapers, flyers and traditional media, least technologically engaged, tendencies to live in smaller square foot housing, lower household income and comparatively older demographic with fewer children living at home

Source: PGE

Findings

The following are findings from the above regression analysis. All marginal effects discussed below were statistically significant at the 10% level or better.

Thermal Comfort Before Event

- Big Impactors were more likely to have been comfortable by 6 percentage points or 7% relative to Middle Movers.

Thermal Comfort During Event

- Brand B respondents were more likely to report having been less comfortable during events by 14 percentage points or 18% than Brand A respondents (omitted category).
- Low Engagers were more likely to say they were comfortable during events by 18 percentage points or 23% than the omitted category (Middle Movers).

Overriding

- Comfort before events increases the likelihood of overriding by 19 percentage points or 31% relative to those who reported they were uncomfortable before events.
- Comfort during events reduces the likelihood of overriding by 32 percentage points or 52% relative to those who reported having been uncomfortable.
- Understanding of program participation requirements reduced the likelihood of overriding by 15 percentage points or 24% relative to those who do not understand the requirements.
- There were no statistically significant differences in probability of overriding between micro-segments or brands.

PGE Satisfaction

- Comfort during events increased probability of being satisfied with PGE by 10 percentage points or 13%.
- Overriding was associated with a reduction in probability of satisfaction with PGE by 5 percentage points or 6%.
- No statistically significant differences in probability of PGE satisfaction between micro-segments or brands.

Program Satisfaction

- Comfort during events increased probability of being satisfied by 22 percentage points or 34%.
- Overriding was associated with a reduction in probability of program satisfaction by 9 percentage points or 14%.
- Awareness of events was associated with an increase in probability of PGE satisfaction by 6 percentage points or 10%.
- No statistically significant differences existed in the probability of program satisfaction between micro-segments or brands.

Appendix D. Staff Interview Guides

CADMUS

PGE Residential Direct Install Smart Thermostat Program

Process Interview Guide for PGE Staff

Respondent name: ______________________________

Interview date: ______________________________________ Interviewer initials: _________________

Topics	Corresponding Items
Program Organization and Staffing	Section A
Outreach & Enrollment	Section B
Risks, Challenges, Solutions and Program Updates	Section C
Evaluation Uses & Updates	Section D

Introduction: Thank you for making time for this interview. This interview is critical to informing the evaluation as well as for tracking the evolution of Direct Install. I've structured the interview to cover these topics: program organization, outreach, enrollment, risks, challenges, solutions, program updates, and evaluation. Do you prefer discussing the topics in the order I just mentioned or are there topics you want to discuss first? If you don't have the answer to the question, let me know who would and I can follow-up with them. Also, if you're not familiar with the topic, just let me know and we can move on to something else.

A. Program Organization

Let's discuss the program's organization and how you work with internal and external staff.

A1. Please tell me about your role and responsibilities regarding the smart thermostat programs and how you work with other PGE program staff.

A2. Is Nay still the marketing lead for smart thermostats?

A3. A while back, there was mention of PGE drafting a program operations manual for smart thermostats. Has that manual been drafted?

A4. [Ask Beth only] How do you coordinate with CLEAResult?

A5. [Ask Beth only] How do you coordinate with Resideo?

A6. How do you coordinate with ETO?

B. Outreach and Enrollment

Let's discuss Direct Install's outreach and enrollment.

B1. [Ask Beth only] Back in April, PGE transferred its DR service provider from Nest to Resideo. I understand that this transition is taking some time as Nest customers have to accept the terms & conditions of having their thermostat device controlled by Resideo. How is the transition going and what percentage of the Nest customers in Direct Install have accepted the terms & conditions?

B2. Do you have any enrollment and capacity goals for 2020?

B3. How many thermostats are enrolled in Direct Install overall to date and so far in 2020?
   A. [If meeting enrollment goals] What do you think is driving the strong enrollment?

B4. [Ask Beth only] In general, how is PGE doing on the marketing of Direct Install?

B5. [Ask Beth only] In general, how is CLEAResult doing in terms of managing the enrollment process?

B6. [Ask Beth only] Does Ecobee's Eco Plus app play a role in customer recruitment and enrollment for Direct Install?

B7. [Ask Beth only] We will discuss program challenges from COVID shortly, but besides COVID, were there any other challenges to Direct Install enrollments in 2020?

B8. [Ask Beth only] Educating customers about how to use the smart thermostat device and about the events are important aspects of the program. How is PGE and CLEAResult doing on the customer education front?

B9. What are your thoughts regarding next steps / vision for the thermostat DR offerings in the context of a capacity resource, moving from pilot to program status? Are there any knowledge gaps regarding this transition, research questions – anything specific for moving to operationalizing these as a DR capacity resource?

C. Risks, Challenges, Solutions, and Program Updates

I'd like to hear about the risks, challenges, solutions, and program updates on Direct Install. We'll start with some questions I have regarding challenges from and program responses to COVID, CLEAResults' management of installations, and a few other topics. Then we'll open the discussion for additional challenges you are aware of, and recent and planned program updates.

C1. [Ask Brenda only] How has COVID impacted Direct Install?

C2. [Ask Beth only] How has COVID impacted Direct Install's marketing?

C3. [Ask Beth only] How has COVID impacted the installation jobs?
   A. How does virtual installation work and have you started it?
   B. What goals do you have for virtual installations? (number of installs, customer satisfaction, etc.)

C. [If virtual has started] How is it going so far? How many have you done so far?
D. What are some concerns you have with virtual installation?
E. Anything you'd like customer feedback on regarding virtual installation?

C4. How has COVID impacted customer experience with Direct Install? (Probes: number of events, customer service, setback temperature, incentives, etc.]

C5. [Ask Beth only] In general, how is CLEAResult doing in terms of managing the installation process?

C6. In general, how is Resideo doing in managing the DR service and events?

C7. [Ask Beth only] How is the summer event season going so far for Direct Install?

C8. [Ask Beth only] In terms of event overrides, how is customer event participation going so far this summer?
A. Encouragement emails: Why send these emails – what is the intended outcome? Is PGE sending the emails? Have you sent any emails yet? When do you send them and how many Direct Install customers have you sent the emails to? Are these being sent to Direct Install and not BYOT, if so, why?

C9. I understand that PGE is partnering with ETO on Direct Ship.
A. Is Direct Ship its own program or is this related to or an evolution of Direct Install?
B. What is the direct ship program design? (Is it similar to an online marketplace?)
C. Why is PGE partnering under ETO's Direct Ship?
D. What is the goal or expected outcome of Direct Ship?
E. When will Direct Ship offer start?
F. Will the ETO smart thermostat coupon still be available or is Direct Ship replacing the coupon offer?

C2. Other than what we've discussed, are there any new challenges facing Direct Install since last summer?

C3. What changes, if any, has the program made since last summer? Is the program considering any other updates?

D. Evaluation Uses & Updates

Let's discuss how you're utilizing Cadmus' evaluation and ideas on upcoming research.

D1. How is PGE using the Cadmus evaluation?
A. Has PGE followed through on any recommendations from the recent Direct Install evaluation report? If so, which ones?
B. Rita is a big proponent of logic models and there was a push to develop logic models for PGE's internal use. Cadmus developed the Direct Install's logic model two years ago. How has PGE used the logic model, if at all?

C. How can logic models be of better use to PGE? What improvements can be made?
D. In general, how can Cadmus improve its evaluation?

D2. Based on reviewing the Direct Install evaluation report, were there any research activities or topics that you felt were missing or needed?

D3. Cadmus will be conducting a summer season experience survey with Direct Install customers in early fall. What are some research questions you have or burning topics you'd like us to investigate?

D4. We will be interviewing Resideo and CLEAResult towards the end of the season to obtain event implementation details and get their perspective on program challenges and successes. Is there anything you'd like us to ask Resideo and CLEAResult?

A. Are the contacts still Sofie Morris for Resideo and Stefanie Reiter for CLEAResult?

CADMUS

PGE Direct Install Smart Thermostat Program

Process Evaluation Interview Guide for Resideo

Interviewee:____

Interview Date: ______________________________ Interviewer:____________________________

Topics	Corresponding Items
Roles and Responsibilities	Section A
Nest-to-Resideo Transition	Section B
Enrollment	Section C
Event Implementation	Section D
Wrap Up	Section E

Introduction: Thank you for making time for this interview. This interview 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. We'll cover these topics during the interview: the Nest-to-Resideo transition, enrollment, event implementation during the most recent winter and summer seasons, and the future.

A. Roles and Responsibilities

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

B. Nest-to-Resideo Transition

B1. Earlier this year, I know that Google transferred its Nest DR service over to Resideo. How has that transition been for Resideo?

A. What went well with the transition and what challenges did you encounter with the transition?
B. Is the transition complete? (If no, probe for completion date and what's left to do)
C. What percentage of PGE Nest customers accepted the terms & conditions?
D. Did you have any goals or expectations regarding the number of customers who accept the terms & conditions?
E. What will happen to those customers who didn't accept? Will there be another attempt to get those customers in the future?

B2. Please clarify the roles Resideo and Google served regarding delivery of the program over the summer 2020 season.

B3. What, if any, operational efficiencies does PGE gain by having a single aggregator instead of two?

C. Enrollment

C1. During this past year, did you work with the thermostat manufacturers (ecobee, Honeywell, and Nest) on customer recruitment? If so, please describe the work you did.

C2. How are customer enrollments coming along this year?

C3. What changes have you made to the customer enrollment process and experience this year?
   A. I noticed that now when customers want to enroll in PGE's Smart Thermostat program, there are different enrollment websites based on the brand of the thermostat. In the past, customers with an ecobee or Honeywell thermostat were all directed to the same Connected Savings website. Why the change?
   B. How are you handling enrollments coming from customers with a Nest thermostat?

C4. How has the new ecobee Plus app impacted customer enrollments this year?

C5. Have you made any changes to the Connected Savings enrollment website?
   A. Have you implemented any changes to improve the accuracy of customer identification of their HVAC system?

C6. Now that people are spending more time at home and working from home, we're curious to hear about any WiFi connectivity challenges. About what percentage of the enrolled thermostats this year were connected to the Internet?
   A. Are these disconnections mostly temporary or permanent disconnections?
   B. Were disconnected thermostats a problem for PGE's program this year?
   C. Does disconnection lead to unenrollment after a certain period of time?
   D. How do you handle disconnected thermostats?
   E. Are there any efforts to encourage customers to reconnect their thermostat?

D. Event Implementation

D1. Next, I want to confirm with you the event orchestration details for this past winter and summer seasons.

Brand	Pre-Event Notification	Event In-Progress Notification	Pre-Conditioning before Event	Temperature Setback during Event

D2. Does the ecobee Plus app or Nest's Seasonal Savings impact any of these items (in the above table) or other ways thermostats settings are managed and/or how they function during event dispatch?

D3. During this past winter and summer seasons, did you run events any differently from previous seasons? For example, did you run any Intelligent DR or try out any new strategies?

A. [If yes] What were they and how effective were they?

D4. During this past winter and summer seasons, were there any event issues that came up that we should be aware of? If yes, please describe.

A. [If yes] Were the issues resolved and if so, how were they resolved?

D5. How was managing events on Nest thermostats for the first time this past summer season?

A. What issues did you run into with Nest, if any?
B. [If had issues] Were the issues resolved and if so, how were they resolved?

D6. Are you doing anything to help encourage customers not to override events? For example, any user experience or interface design on the app and thermostat screen?

A. Is there any place in the app or thermostat screen where customers can see their event participation history? (Probe about Nest having a new event participation history feature)
B. What about an event participation or results outcome report to customers?
C. Are any of these things being considered with PGE for the future?

D7. Please describe if any Intelligent Demand Response (IDR) strategies were employed during the summer season related to event dispatch, if these differed by brand or across events.

A. What are the specific goals of these strategies?
B. How are the strategies implemented?
C. Are these consistent with previous seasons? (confirm if these relates to variation in temperature setbacks across customer types or strategies to smooth out peak reduction by staggering customer groups).

E. Wrap Up

E1. Speaking of the future, do you have any changes or improvements in store for the program in this upcoming winter and summer seasons? If yes, please describe.

E2. 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 Direct Install Smart Thermostat Program

Process Evaluation Interview Guide for CLEAResult

Interviewee:____

Interview Date: ______________________________ Interviewer: ________________________

Topics	Corresponding Items
Management	Section A
Scheduling and Installation Operations	Section B
Customer Education	Section C
Returning to the Field	Section D
Wrap Up	Section E

Introduction: Thank you for making time for this interview. This interview is critical to informing the evaluation. This is also a chance for you to provide your perspectives on how PGE's Direct Install Program is working and where implementation can improve. We'll cover these topics during the interview: management changes, impacts of COVID on the scheduling and installation operations, customer education, plans to return to the field, and future implementation plans.

A. Management

A1. It's been well over a year since we last spoke to the CLEAResult team. I've heard that a lot has happened to your team and the installation technicians due to COVID. What does the CLEAResult team for PGE's Direct Install look like at the moment?

A2. How many installation technicians had been originally staffed for PGE's DI effort?

- A. How many were let go due to COVID and how many are you currently operating with?
- B. Any plans to hire more or bring back installation technicians later this year?

A3. How else has COVID impacted CLEAResult's services for PGE's Direct Install Program? (Probe about scheduling and call center)

B. Scheduling and Installation Operations

B1. Earlier this year before COVID, how was the scheduling and installation coming along?

- A. Were there any challenges to scheduling and installation pre-COVID?
- B. [If yes] Did you resolve those challenges and if so, how did you resolve them?

B2. What happened to the scheduling and installation when COVID and the shutdown occurred?

B3. I understand that you've worked with PGE to pilot Virtual Install. How did the Virtual Install idea come about?

A. Did you already have Virtual Install in development before COVID?
B. Is PGE the first utility client you're testing Virtual Install on?

B4. Please walk me through the Virtual Install process. How does it work? (Probe about their online product called STREAM)

B5. What successes and challenges have you experienced with Virtual Install?

A. Is this something you plan to continue in the future?

B6. From what you've seen so far with Virtual Install, what type of customer goes for Virtual Install and what type of customer is Virtual Install best suited for?

B7. Is CLEAResult contracted to obtain a certain number of enrollments/installations by end of this year?

A. [If no] Where do you currently stand on the number of enrollments/installations this year?
B. [If yes] What is your contracted goal and where do you currently stand?
C. [If yes] Do you think you will meet your goal by end of this year? Why or why not?

B8. Do you have any other contracted goals or KPIs for PGE's Direct Install Program?

A. [If yes] What are they?
B. [If yes] How are you currently doing?

C. Customer Education

C1. In the Direct Install Program, there is a customer education component. Earlier this year before COVID, how was CLEAResult educating PGE customers on the device and the program? (Probe about education during scheduling/call center interaction and the installation)

A. What educational materials do you supply customers with?
B. Were these materials developed by you or PGE?

C2. Since COVID, has PGE/CLEAResult changed the way it approaches customer education?

A. [If yes] How are you now educating customers about the device and the program?

C3. Has there been any emphasis on overrides or event participation in the educational materials this year?

A. [If yes] What were those materials and what was the messaging?
B. Have you considered different messaging or approaches for customers already engaged in efficiency settings (e.g., Nest seasonal savings)?

C4. From your perspective, what do most customers seem to grasp easily about the program?

C5. What are some areas where customers could use more education on or that PGE should develop more educational materials on?

D. Returning to the Field

D1. PGE mentioned that you will be going back into the field do onsite installations, beginning in October. What does that rollout look like?

D2. For the fall rollout, has PGE began marketing and are you scheduling customers now?

  A. [If yes] When did marketing and scheduling start?
  B. [If now] When will marketing and scheduling start?

D3. Besides incorporating health and safety protocols, how will/do the installation jobs in the field differ?

D4. [If field work already started] What have you been hearing from your installation technicians about the field work?

  A. Are customers feeling safe and satisfied with their installation?
  B. Any concerns raised with customers or the installation technicians? (Probe)

D5. Does it look like you have a busy fall and early winter with the number of installation jobs?

  A. Do you feel you have enough installation technicians to keep up with the demand?

E. Wrap Up

E1. What does the rest of the year look like for the program?

  A. Any changes or improvements in store?
  B. [If yes] Please describe.

E2. 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

PGE Direct Install

Winter 2019-20 Experience Survey

Research Topics	Corresponding Question Numbers
Event awareness	A1-A3
Event participation	B1-B3
Thermal comfort	C1-C5
Satisfaction with program and thermostat	D1-D4
Satisfaction with PGE	E1

Target Audience: Test (treatment) and control group customers with a Nest or Ecobee smart thermostat who are enrolled in the Direct Install Smart Thermostat Program for winter season

Expected number of completions: 350-400 completes stratified by test and control group

Estimated timeline for fielding: Early March 2020. One survey reminder email may be sent 5-7 days after initial email, depending on the number of completes.

Variables to be Pulled into Survey

- CadmusID
- Email
- FirstName
- LastName
- EnrollDate
- Assignment = Test or Control
- Brand = Nest or Ecobee
- System = AC, HP or EF
- Micropersona
- TestBedStatus = In TB or Out TB
- Substation
- Program = DI
- SurveyName = Winter 2019-20 Experience

Email Invitation

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

Dear [FirstName],

Thank you for participating in PGE's Smart Thermostat Program during this recent winter. Your smart thermostat worked with PGE to shift your electricity consumption from when demand for electricity was highest. Would you take a moment to answer a few questions about your experience with the program? Your input will be used to improve PGE programs, and 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
Research Manager, Portland General Electric

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

Survey Start Screen

PGE

Welcome! This survey will take less than 5 minutes to complete. Your responses will remain confidential and will only be used for research purposes.

[Ask section A if Assignment=Test]

A. Event Awareness

A1. Your smart thermostat works with PGE to shift electricity consumption from times when demand for electricity is highest. How many high demand events did you notice this past winter?

1. Enter a number [Numeric entry 1-99]
2. None [Skip to B1]
3. Don't know

A2. Do you recall receiving notifications of high demand events before they occurred?

1. Yes
2. No

[Ask if 0=1]

A3. How did you receive notification about the high demand events? Please select all that apply. [Randomize order 1-2]

1. Notification from smart thermostat app
2. Display on smart thermostat
3. Other (please describe) [Open-end text entry]
4. Don't know [Exclusive answer]

[Ask section B if Assignment=Test]

B. Event Participation

B1. About how many high demand events did you participate in this past winter where you or someone else did not override the thermostat settings during the events?

1. Enter a number [Numeric entry 1-99]
2. None [Skip to C1]
3. Don't know

B2. How easy or difficult was it to participate in the events?

1. Very easy
2. Somewhat easy
3. Somewhat difficult
4. Very difficult
5. Don't know

[Aski if B2=3 or 4]

B3. What made it difficult to participate in the events? Please select all that apply. [Randomize 1-6]

1. Other household members overriding the event
2. The timing of the events
3. Notifications were not early enough
4. Health/medical reasons
5. Having guests or visitors around
6. Not understanding how the program works
7. Other (please describe) [Open-end text entry]
8. Don't know [Exclusive answer]

[Ask section C if Assignment=Test]

C. Thermal Comfort

C1. Overall this past winter, how comfortable was the interior temperature of your home a few hours **before** the high demand events?

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. I was not at home

C2. How often did you notice a change in your home's interior temperature **during** the high demand events?

1. Always noticed
2. Sometimes noticed
3. Never noticed
4. I was not at home for any events [Skip to D-1]

C3. Overall this past winter, how comfortable was the interior temperature of your home **during** the high demand events?

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

C4. Did you or someone in your household make changes to the thermostat settings during any of the winter events?
1. Yes
2. No
3. Don't know

[Ask if C4=1]

C5. Why did you or someone in your household change the thermostat settings during the events? [Open-end text entry]

[Ask section D to everyone]

D. Satisfaction with Program and Thermostat

D1. 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

D2. Please tell us why you gave that rating for overall satisfaction. [Open-end text entry]

D3. 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

D4. Please rate your overall satisfaction with your smart thermostat.
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

[Ask section E to everyone]

E. Satisfaction with PGE

E1. 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

End of Survey Message

Your responses have been submitted. Thank you!

PGE Direct Install

Summer 2020 Experience Survey

Research Topics	Corresponding Question Numbers
Event awareness – Did customers notice the events? How did they notice the events?	A1-A3
Thermal comfort – How comfortable were customers before and during the events?	B1-B2
Event participation and overrides – Did customers override the thermostat settings during the events? If yes, why? How long do customers participate in an event before overriding? How effective was the encouragement email on motivating customers to participate in subsequent events?	C1-C8
COVID and changes in electricity consumption – How has COVID changed customers' electricity consumption and space cooling usage? What other external factors have impacted how customers manage their electricity usage?	0-D3
Virtual install – How was the customers' experience with the virtual installation? How satisfied are customers with the virtual installation?	E1-E4
Program Barriers – Has PGE reduced or addressed customers' participation barriers since 2018?	F1
Understanding of Program Participation – How familiar are customers with the 50% event participation minimum requirement and the 5-year commitment? Do customers understand what it means to "participate" in events?	G1-G3
Satisfaction with program – How satisfied are customers with the thermostat and program? Why are customers satisfied/dissatisfied and what do they value about the program? How likely are they to recommend the program to others?	H1-H6
Satisfaction with PGE – How satisfied are customers with PGE?	I1

Target Audience: Customers who were enrolled in the Direct Install Smart Thermostat Program for summer 2020 season.

Expected number of completions: 350-400 completes

Estimated timeline for fielding: Mid October 2020. One survey reminder email may be sent 5-7 days after initial email, depending on the number of completes.

Variables to be Pulled into Survey

- Email
- FirstName
- LastName
- Assignment = Treatment or Control
- System = AC or HP
- VirtualInstall = Yes or No
- EncourageEmail = Yes or No (only customers with an Ecobee who did participate in the first two events received the encouragement email)
- Micropersona

- TestBedStatus = In TB or Out TB
- Substation

Email Invitation

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

Dear [FirstName],

Thank you for participating in PGE's Smart Thermostat program. Would you take a moment to answer a few questions about your experience with the program? Your input will be used to improve this program, and 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 Athena Dodd at Cadmus, the research firm conducting this survey on PGE's behalf. You can reach her at (303) 389-2539 or athena.dodd@cadmusgroup.com.

Sincerely,
Adam Gardels
Smart Thermostat Evaluation Project 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.

[Ask section A if Assignment = Treatment]

A. Event Awareness

A1. During peak time events, your smart thermostat works with PGE to shift electricity consumption from times when demand for electricity is highest. Each event lasts 2 to 3 hours. How many peak time events did you notice this past summer?

1. Enter a number [Numeric entry 1-99]
2. None [Skip to A3]
3. Don't know

[Ask if A1=1]

A2. How did you notice the events were happening? Please select all that apply. [Randomize 1-4]

1. Display on smart thermostat
2. Notification from smart thermostat app
3. Noticed cool air was cycling on and off
4. Noticed a temperature change
5. Other (please describe) [Open-end text entry]
6. Don't know [Exclusive answer]

A3. Did you notice your smart thermostat undergo extra cooling in the hours right before the peak time events?

1. Yes
2. No

A4. At this time, PGE does not notify customers in advance when a peak time event will be activated on their smart thermostat. How interested are you in receiving notifications before the start of a peak time event?

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

[Ask section B if Assignment = Treatment]

B. Thermal Comfort

B1. Overall this past summer, how comfortable was the interior temperature of your home a few hours **before** the peak time events?

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. I was not at home
13. Don’t know

B2. Overall this past summer, how comfortable was the interior temperature of your home **during** peak time events?
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. I was not at home
13. Don’t know

[Ask section C if Assignment = Treatment]

C. Event Participation and Overrides

C1. Did you or someone else override the thermostat settings during any of the peak time events this past summer?
1. Yes
2. No

[Ask if C1=1]

C2. How many peak time events this past summer did you or someone else override the thermostat settings?
1. Enter a number [Numeric entry 1-99]
2. Don’t know

[Ask if C1=1]

C3. Why did you or someone in your household override the thermostat settings during the peak time events? [Open-end Text Entry]

C4. During the peak time events, did you usually leave the thermostat alone for the full duration of the event or did you usually make adjustments part way through the event?

1. Left thermostat alone for full duration of event
2. Made adjustments to thermostat part way through event
3. Don’t know

[Ask if C1=1]

C5. How significant was COVID in your decision to override the events this past summer?

1. Very significant
2. Somewhat significant
3. Not too significant
4. Not at all significant
5. Don’t know

[Ask if C1=2]

C6. How significant was COVID in your decision to not override the events this past summer?

1. Very significant
2. Somewhat significant
3. Not too significant
4. Not at all significant
5. Don’t know

[Ask if EncourageEmail = Yes]

C7. PGE sent you an email this past summer after the second peak time event of the season. This email let you know that you missed a peak time event and to not miss out again. Do you remember receiving this email?

1. Yes
2. No

[Ask if C7=1]

C8. After receiving this email, how motivated were you to participate in the next peak time events?

1. More motivated than before
2. About the same motivation as before
3. Less motivated than before

4. Don't know

[Ask section D if Assignment = Treatment]

D. COVID and Changes in Electricity Consumption

These next questions are about how this summer compared to last summer regarding your electricity use.

D1. Would you say your household used more electricity this summer 2020 or last summer 2019?

1. Our household used more electricity this summer
2. Our household used more electricity last summer
3. Our household used the same amount both summers
4. Don't know

D2. Would you say your household used more cooling this summer 2020 or last summer 2019?

* Cooling refers to equipment such as central air conditioning and heat pump.

1. Our household used more cooling this summer
2. Our household used more cooling last summer
3. Our household used the same amount both summers
4. Don't know

D3. Do you think you were more or less focused on managing your electricity use at home this summer versus last summer due to: [Response options: more focused on electricity use this summer; less focused on electricity use this summer; about the same both summers] [Randomize order]

A. The health threat of COVID-19
B. Financial hardship as a result of the pandemic
C. More time at home as a result of the pandemic
D. Loss of work/life balance as a result of the pandemic
E. Loss of social connections due to the pandemic
F. Social unrest in your community
G. The weather

[Ask section E if VirtualInstall = Yes]

E. Virtual Install

E1. Our records show that your household completed the smart thermostat installation online with guidance from a technician. Do you remember completing the virtual installation?

1. Yes
2. No [Skip to F1]

E2. Please tell us if you agree or disagree with the following statements about your experience with the virtual installation. [Response choices: 1=Strongly agree, 2=Somewhat agree, 3= Somewhat disagree, 4=Strongly disagree, 5=Don't know] [Randomize order]

A. The installation was easy to follow
B. The technician communicated instructions to me clearly
C. The technician was professional and courteous
D. I would be comfortable with doing another similar, virtual installation in the future

E3. Please rate your overall satisfaction with the virtual installation.

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. How can PGE improve the virtual installation? [Open-end Text Entry]

[Ask section F if Assignment = Treatment]

F. Program Barriers

F1. When deciding whether to enroll in PGE's Smart Thermostat Program, did you experience the following? Please select Yes or No for each statement.[Response choices: 1=Yes, 2=No] [Randomize order]

A. I had concerns about letting someone into my home to install the smart thermostat
B. I needed more information about the program
C. I wasn't sure I could operate a smart thermostat
D. I wasn't sure I wanted a smart thermostat
E. I felt the program might inconvenience my household
F. I felt the program might make my home feel uncomfortable
G. I had concerns about how my thermostat data would be used
H. I had concerns about giving PGE control of my smart thermostat

[Ask section G if Assignment = Treatment]

G. Understanding of Program Participation

When you signed up for PGE's Smart Thermostat program, you received a free or discounted smart thermostat along with a complimentary installation. In exchange, you were asked to (1) participate in at least 50% of peak time events each season, and (2) stay enrolled in the program for 5 years.

G1. Were you aware of the 50% event participation minimum requirement?

1. Yes
2. No

G2. Were you aware of the 5-year commitment to the program?

1. Yes
2. No

G3. Which statement best describes the 50% event participation minimum requirement?

[Randomize order 1-4]

1. To keep the thermostat turned on for at least 50% of the season
2. To not override more than 50% of the events during the season
3. To let PGE take control of my thermostat for 50% of the season
4. To not change the thermostat settings for 50% of the time
5. Don't know

[Ask section H if Assignment = Treatment]

H. Satisfaction with Program

These last questions are about your satisfaction.

H1. Please rate your overall satisfaction with your smart thermostat.

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

H2. 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

H3. Please tell us why you gave that rating for overall satisfaction. [Open-end text entry]

H4. 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

H5. PGE sent you an email recently describing your event participation in the Smart Thermostat Program this past summer. Do you remember receiving this end-of-season email?
1. Yes
2. No

[Ask if H5=1]

H6. How motivated are you to participate in next year's summer season events?
1. Very motivated
2. Somewhat motivated
3. Not too motivated
4. Not at all motivated
5. Don't know

I. Satisfaction with PGE

I1. 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

End of Survey Message

Your responses have been submitted. Thank you!