Portland General Electric
121 SW Salmon Street · Portland, Ore. 97204

August 7, 2019

Public Utility Commission of Oregon
Attn: Filing Center
201 High Street, S.E.
P.O. Box 1088
Salem, OR 97308-1088

RE: UM 1708 Residential Flexible Pricing Pilot (Flex 1.0 and 2.0) and Direct Load Control Thermostat Pilot Combined Reports in Compliance with Order 18-381

Portland General Electric Company (PGE) submits these reports pursuant to Public Utility Commission of Oregon (OPUC or Commission) Order No. 18-381, filed OPUC Docket No. UM 1708, that directs PGE to submit two combined reports on the Residential Flexible Pricing Pilot (FLEX) and Direct Load Control Thermostat pilot (DLCT). These reports and program costs are to be submitted on a timeline that is no less than 90 days prior to filing to adjust tariff rates for PGE's Rate Schedule 135 (Demand Response Cost Recovery Mechanism). PGE intends to file an update to Schedule 135 prices, with the rates effective January 1, 2020, to include Schedules 5 (DLCT) and 6 (FLEX).

While the Commission-approved PGE's application for deferred accounting in UM 1708, the reports are required to enable the OPUC's prudence review. The reports provide are provided as Attachment A and are broken out into the following sections and appendices:

- **FLEX:** Section 1 provides the report for FLEX, which includes both 1.0 and 2.0. Flex 1.0 was the first phase of the pilot where we tested different pricing signals to get customers to respond and shift usage. Flex 2.0 is the second phase where we take the learnings from the first phase and carry forward successful pricing options to test scalability (e.g. Peak Time Rebates). Section 1 includes a summary of the results from the third-party evaluation on Flex 1.0 (there has not yet been an evaluation on Flex 2.0). The third-party evaluation was originally filed in UM 1708 in July 2018. We include it again as Appendix A. The customer satisfaction survey is provided as Appendix B. In addition, Section 1 has a cost summary for both phases of FLEX.

- **DLCT:** Section 2 provides the report for DLCT and includes a summary of the results from third-party evaluations and customer satisfaction surveys. The first third-party evaluation for DLCT covered the 2015-2016 season. It was originally filed in UM 1708 in June 2017. We have included it again as Appendix C. Appendices D-F are the third-party evaluations from 2016-2018, which also include the customer satisfaction surveys for their respective seasons.

Background on the Pilots and Schedule 135

In 2014, PGE proposed two residential pilots that would best inform development of future demand response (DR) programs. FLEX tested combinations of Peak Time Rebate plans with time-of-use pricing. The DLCT pilot has been testing enabling technology and PGE's ability to achieve automated load control among residential customers.

As stated in PGE's 2019 Deferral Reauthorization Application and authorized in Commission Order No. 18-381, filed in this docket, PGE plans to file for amortization of costs associated with FLEX (1.0 and 2.0) and DLCT using Schedule 135. Schedule 135 recovers expenses associated with DR pilots not otherwise included in rates. Schedule 135 is updated annually when PGE adjusts the rates to update forecasted costs and amortize the deferred variance between forecasted and actual costs for the previous 12-month period.

Conclusion

An important source of future DR capacity for PGE will come from residential customers. These customers contribute to PGE's system peak demand through weather-driven increases in demand for air conditioning in summer and space heating in winter. By deploying DR programs, PGE can manage its peak system loads and reduce its costs of electricity supply. Allowing for cost recovery of prudently incurred costs related to these DR offering will allow PGE to scale these offerings from pilots to programs.

Please direct any questions regarding this filing to Kalia Savage at (503) 464-7432. Please direct all formal correspondence and requests to the following email address pge.opuc.filings@pgn.com

Sincerely,

Karla Wenzel
Manager, Pricing and Tariffs

Enclosure(s)

UM 1708

Attachment A

PGE’s Residential Flexible Pricing Pilot and Direct Load Control Thermostat Pilot Report

PGE's Residential Flexible Pricing Pilot and Direct Load Control Thermostat Pilot Report

August 2019

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Table of Contents

Equations, Figures, and Tables

Acronyms

AMI ..... Advanced Metering Infrastructure
API....... Application programming interface
BDR ..... Behavioral Demand Response
BYOT ... Bring-Your-Own Thermostat
CI......... Confidence Interval
CDH..... Cooling Degree Hours
CPP...... Critical Peak Pricing
DLC...... Direct Load Control
DLCT.... Direct Load Control Thermostat
DR .... Demand Response
DRMS .. Demand Response Management System
FLEX .... PGE's Residential Flexible Pricing Pilot
HDH..... Heating Degree Hours
IDR ...... Intelligent Demand Response
IRP....... Integrated Resource Plan
kW....... Kilowatt
kWh..... Kilowatt Hour
MW ..... Megawatt
NOAA .. National Oceanic and Atmospheric Administration
OLS...... Ordinary Least Squares
OO....... Opt-Out
OPUC... Public Utility Commission of Oregon
PGE ..... Portland General Electric Company
PTR...... Peak Time Rebate
QC .... Quality Control
RCT...... Randomized Control Trial
TOU..... Time-of-Use

Key Terms and Concepts

Demand Response (DR) – "Demand response is a non-persistent intentional change in net electricity usage by end-use customers from normal consumptive patterns in response to a request on behalf of, or by, a power and/or distribution/transmission system operator. This change is driven by an agreement, potentially financial, or tariff between two or more participating parties."[1]

Conversion Rate – Measures a given marketing channel's effectiveness in spurring enrollment, calculated by taking the number of customers who enrolled from a given channel and dividing this by the total number of customers that the channel.

Opt-In Rate – The ratio of the number of customers who enrolled in a treatment to the total number of customers invited to participate.

Opt-Out (OO) – Opt-out customers are automatically enrolled in the pilot and given the opportunity to opt out of the pilot; an alternative to opt-in program design format. The ratio of the number of customers who enrolled in a treatment to the total number of customers invited to participate.

Opt-Out Rate – The ratio of the number of enrolled customers who opted out of treatment to the total number enrolled.

[1] Northwest Power Conservation Council, Demand Response Advisory Committee, 8/25/2017, available at https://www.nwcouncil.org/energy/energy-advisory-committees/demand-response-advisory-committee

Section 1: PGE's Residential Flexible Pricing Pilot

The first phase of the Residential Flexible Pricing Pilot (FLEX), known as Flex 1.0, began by testing 12 pricing design options, all aimed at reducing residential peak demand during summer and winter months. The options featured three time-of-use (TOU) rates, three Peak Time Rebate (PTR) incentive levels, behavioral demand response (BDR) options, four hybrid DR treatments (TOU pricing in combination with PTR or BDR) and opt-out (automatically enrolled) and opt-in (choose to enroll) design options. The options offered a range of on-peak/off-peak hours and rates as well as differing PTR incentive levels.

Following an independent evaluation of Flex Pricing 1.0 (described in the section below), PGE proposed, and has since developed, the second phase of the pilot known as Flex 2.0. Flex 2.0 is an opt-in, scalable PTR plan designed to address learnings from the Cadmus evaluation related to customer satisfaction, load shift, and incentive values.

1.1: Third-Party Evaluation for FLEX

As part of Flex 1.0, Cadmus evaluated two winter seasons (2016/2017 and 2017/2018) and two summer seasons (2016 and 2017) which included randomized control trial (RCTs) for twelve DR treatments including combinations of PTR, TOU, and BDR designs as well as opt-in and opt-out enrollments. Cadmus performed the research design, peak demand impact analysis, staff interviews, and customer surveys. Cadmus' evaluation report was submitted in UM 1708 on July 10, 2018 and is provided in Appendix A.

The Cadmus evaluation confirmed that PGE can obtain customer demand savings through pricing and behavior-based DR programs to manage its system peak demand while delivering a positive customer experience. We learned that larger rebates (the pilot offered three incentive tiers ($0.80/kWh, $1.55/kWh, and $2.25/kWh) did not yield larger savings per metered customer.

Informed by the Flex study PGE, when proposing a PTR pilot, sought to balance the need to achieve high levels of customer satisfaction with load shift. Our pilot design addressed the Cadmus recommendation to adjust the PTR incentive value downward. Thus, PGE set the PTR incentive value for Flex 2.0 at $1.00/kWh. The incentive value ultimately balanced customer satisfaction, and program cost effectiveness. PGE has a goal of 55,000 opt-in enrollments by year-end 2019.[2] PGE updated Rate Schedule 7 (Residential Service) to include PTR and received Commission approval on April 12, 2019.[3] In addition, PGE has been engaged with Commission Staff to refine its proposed TOU rate design and plans to file an update to Schedule 7 effective in early summer 2020.

PGE has again retained Cadmus to evaluate Flex 2.0 and report on the Flex 2.0 activities for the next two years. The purpose of the evaluation is to measure the effectiveness of Flex 2.0 in meeting its objectives, areas for continuous improvements, and energy impacts on PGE's system. A summary of planned surveys as well as interim pilot evaluation reports is illustrated in Table 1. Data insights will be used to inform and optimize the pilot design as well as our customer engagement and retention strategies. Additionally, performance, engagement, and satisfaction levels of the opt-in Flex 2.0 PTR population will provide a baseline against which behavioral changes and patterns of the **opt-out** PTR Test Bed participants can be measured and evaluated.

[2] An additional 13,000 customers will participate in the PTR events as part of Schedule 13 Test Bed's opt-out PTR offering.
[3] PGE. *Advice No. 19-03.* 8 Feb 2019.

The following is a list of evaluation objectives that will be addressed throughout the Flex pilot implementation.

1. Track customer enrollment, retention, and satisfaction levels with PTR/hybrid offerings;
2. Track changes in customer awareness and comprehension of DR;
3. Track the values that PGE's DR products and offerings have for customers and how customer values change over time;
4. Measure customer load impacts – for off/mid/on peak periods, by customer segment and season;
5. Measure DR event energy impacts - by customer segment and by season;
6. Assess the impacts of PTR on-bill credit levels;
7. Document customer targeting and marketing effectiveness, and successes/challenges;
8. Assess the impacts of customer educational materials on load shifting;
9. Identify pilot implementation successes and challenges, and improvement opportunities; and
10. Assess differences between Flex 2.0 participants within the PGE Testbed Pilot territories and Flex 2.0 participants outside of these territories (including comparison of load impacts and process findings).

Cadmus' survey and impact evaluation schedule are provided in Table 1.

Table 1 Cadmus Impact Evaluation for Flex Timeline

Activity	2019				2020				2021			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Program Season		Summer		Winter		Summer		Winter		Summer		
Impact Evaluation												
Research Design	■	■										
Customer Matching / Assignment		■										
Impact Eval - Data Request		■	■		■		■		■		■	
Impact Eval - Analysis				■		■		■		■		■
Participation Analytics				■		■		■		■		■
Impact Eval - Seasonal Reporting				1		2		3		4		5
TOU Free Ridership Assessment								■				■
PTR Overpayment Assessment				■		■		■		■		■
Customer Baseline Savings Assessment				■								

1.2: Customer Satisfaction Survey for FLEX

Cadmus has already completed an initial PTR enrollment survey to assess overall satisfaction, ease of engagement, and understanding of pilot goals. This survey is provided as Appendix B – FLEX Customer Satisfaction Surveys. Additionally, the survey asked customers to provide their feedback on general understanding of load shifting (e.g. DR) programs. Those findings are provided in Appendix B and point to opportunities to improve customer communications and provide greater flexibility for outreach channels (enhanced ability for customers to update email and mobile numbers for PTR pre- and post-event notifications).

1.3: Cost Summary for FLEX

The forecast of the FLEX pilot annual costs through 2021 are outlined in the Table 2.

Table 2 FLEX Cost Summary ($)

Activity	2015-2017 Actuals	2018 Actuals	2019 (Jan-Jun) Actuals	2019 (Jul-Dec) Forecast	2020 Forecast	2021 Forecast
Incremental Contract Labor	197,620	97,152	255,183	62,789	-	-
Incremental PGE Labor	2,721	23,287	61,940	106,985	375,000	375,000
DRMS Provider	1,044,775	33,301	988,651	579,613	75,000	1,285,085
Evaluation	341,759	182,904	44,947	200,000	180,000	184,000
Rectruitment & Customer Outreach	94,861	119,200	39,626	751,782	866,550	658,578
Third-Party Services	-	512	-	47,931	-	-
Total Administrative Cost	**1,681,737**	**456,356**	**1,390,347**	**1,749,100**	**1,496,550**	**2,502,663**
PTR	75,549	38,002	-	573,630	1,850,000	3,060,000
Vendor	-	-	-	651,177	-	-
Total Incentive Cost	**75,549**	**38,002**	**-**	**1,224,807**	**1,850,000**	**3,060,000**
Total Cost	**1,757,286**	**494,358**	**1,390,347**	**2,973,907**	**3,346,550**	**5,562,663**
Average MW Achieved per Event	**1**	**1**	**-**	**16**	**38**	**50**

Section 2: PGE's Direct Load Control Thermostat Pilot

The Direct Load Control Thermostat pilot (DLCT or Smart Thermostat Demand Response) began as a "bring-your-own-thermostat" and was limited to the thermostats from a single manufacturer. The pilot then expanded to allow thermostats from additional manufacturers. More recently, PGE expanded the DLCT pilot to allow the direct installation of residential thermostats. This aspect is focused on residential customers with ducted heat pumps and electric forced air furnaces due to their high DR capacity value.

For the "bring-your-own-thermostat" option, customers with qualifying thermostat and central air conditioners receive a $25 sign-up incentive and $25 on-going incentive for each summer season in which they participate. Customers with ducted heat pumps also receive a $25 sign-up incentive and are eligible for $25 for each summer and winter season. Customers must meet guidelines requiring them to participate in 50% of the event hours per season to be eligible to receive the incentive.

For the direct installation option, PGE will install thermostats for our residential customers. This incentive is in lieu of the seasonal incentives those customers would receive under the "bring-your-own-thermostat" option. Customers who select the direct installation option agree to participate in the DLCT pilot for five years or will have to repay a prorated portion of the thermostat's installed cost.

Current participation levels for the DLCT pilot are 3,500 customers and we project this to increase to 8,000 customers in the coming year. For the summer 2018 event season, the DLCT pilot provided an average demand savings of 7.6 MW per event-hour.

2.1: Third-Party Evaluations for DLCT Pilot

PGE retained Cadmus to evaluate the load impacts and customer satisfaction associated with the DLCT Pilot. In total, Cadmus evaluated three winter seasons (2015/2016, 2016/2017, 2017/2018) and three summer seasons (2016, 2017, 2018) which included randomized treatment and control enrollments. Cadmus performed the research design, peak demand impact analysis, staff interviews, and customer surveys.

The following are evaluation objectives that have been addressed throughout the DLCT pilot implementation:

- Implement the pilot over five seasons (i.e. winter 2016, summer 2016, winter 2017, summer 2017, winter 2018), with six to 10 events per season;
- Measure the impact of events on customers' comfort and satisfaction;
- Measure the demand reduction capacity, any preconditioning or rebound effects, and cost-effectiveness;
- Determine the best strategies for scaling the pilot into a mass market program; and
- Achieve positive customer experiences.

The Cadmus evaluations confirmed that PGE can obtain customer demand savings through DLCT/Smart thermostat DR pilots to manage its system peak demand while delivering a positive customer experience. In fact, the DLCT pilot moved PGE closer to reaching its goal of 25 MW of DR capacity from residential smart thermostats by 2021. In recent evaluations Cadmus has expanded its evaluation to cover the Connected Savings thermostat part of the pilot (reviews Ecobee and Honeywell thermostats) as well as Rush Hour Rewards (Nest).

Cadmus evaluations also Recommended we do the following:

- PGE should expand the program to include customers with other brands of connected thermostats. Expanding eligibility for the program would provide PGE with additional demand response capacity. **Update:** PGE integrated with Whisker labs in 2017 to include Ecobee and Honeywell Thermostats in the DLC Program.
- PGE should expand the program to include customers with electric furnaces. Expanding eligibility for the program would provide PGE with additional demand response capacity. **Update:** PGE has started including Electric Forced Air Furnaces starting in September of 2018 to increase Winter DR capacity.
- PGE should consider taking on a greater lead role on mass marketing Connected Savings to customers via email and direct mail, rather than relying on the manufacturers. The manufacturers can then focus on pushing out program promotions to eligible customers via the smartphone app, a channel PGE does not have access to or control over. **Update:** PGE has increased its own marketing and marketing in concert with the thermostat manufacturers to increase enrollments in both BYOT and Direct install channels

Recent Load Impacts: Rush Hour Rewards (Nest) reduced peak electricity demand from residential air conditioning and space heating.

The pilot achieved average demand savings of 0.93 kW and 0.62 kW per participant for summer and winter, respectively. These savings represented 32% of summer event hour demand and 23% of winter event hour demand. Evaluated savings surpassed the PGE planning value for Bring-Your-Own-Thermostat (BYOT) smart thermostat DR of 0.8 kW per participant, though winter savings were less than the 1.0 kW planning estimate.

Recent Load Impacts: Connected Savings (Ecobee & Honeywell) achieved the expected summer capacity savings of 0.8 kW per participant.

Participants achieved average savings of 0.84 kW (or 27% of baseline demand) for the summer 2018 season, which was approximately equal to PGE's planning value for smart thermostat demand response (DR) savings per participant of 0.8 kW.

Cadmus' evaluation reports are provided as Appendices C-F.

2.2: Customer Satisfaction Surveys for DLCT Pilot

PGE's DLCT pilot has consistently achieved high levels of customer satisfaction in which overall average ratings of 8 or greater on a 10-point scale were seen from both treatment and control group customers. Customer Satisfaction surveys are sent to participants by our evaluator Cadmus after the completion of a DR season. Objectives for customer satisfaction surveys were to measure Satisfaction in the following:

- Event Awareness
- Event Comfort
- Satisfaction with the Smart Thermostat
- Satisfaction with the Incentive check

- Satisfaction with the Pilot
- Satisfaction with PGE

You can find the Customer Satisfaction survey findings in the Cadmus evaluations in in the following Appendices and page ranges:

- Appendix C – Cadmus Evaluation of PGE's Rush Hour Rewards 2015-2016,[4] pg. 152;
- Appendix D - Cadmus Evaluation of PGE's Rush Hour Rewards 2016-2017, pg. 195;
- Appendix E - Cadmus Evaluation of PGE's Rush Hour Rewards 2017-2018, pg. 269; and
- Appendix F - Cadmus Evaluation of PGE's Connected Savings 2017-2018, pg. 321.

2.3: Cost Summary for DLCT Pilot

The forecast for the DLCT pilot annual costs through 2021 are outlined in the Table 3.

Table 3 DLCT Pilot Costs Summary ($)

Activity	2015-2017 Actuals	2018 Actuals	2019 (Jan-Jun) Actuals	2019 (Jul-Dec) Forecast	2020 Forecast	2021 Forecast
Incremental Contract Labor	114,528	94,420	95,036	(95,036)	-	-
Incremental PGE Labor	-	-		60,000	120,000	120,000
DERMS Provider	130,696	244,250	53,952	580,594	1,093,819	1,657,877
Evaluation	130,239	95,095	63,716	(37,049)	40,000	40,000
Recruitment & Customer Outreach	12,942	84,064	84,572	25,428	75,000	55,000
Third party services	50,535	112,250	29,811	105,412	57,279	-
Total Administrative Costs	**438,940**	**630,079**	**327,087**	**639,349**	**1,386,097**	**1,872,877**
Direct Install OEM #1	-	63,730	273,337	397,317	663,585	453,432
Direct Install OEM #2	-	126,020	465,413	658,825	1,110,206	758,498
Total Direct Install Costs	**-**	**189,750**	**738,750**	**1,056,142**	**1,773,791**	**1,211,930**
Enrollment	322,425	344,950	45,050	50,946	206,000	329,600
Winter	-	-	48,450	9,150	93,600	151,200
Summer	-	-		318,720	517,920	836,640
Total Incentives	**322,425**	**344,950**	**93,500**	**378,816**	**817,520**	**1,317,440**
Totals	**761,365**	**1,164,779**	**1,159,337**	**2,074,307**	**3,977,409**	**4,402,248**
Annual MW Achieved	**4**	**8.2**	**13.0**	**17.4**	**29.3**	**48.0**

[4] Originally filed in UM 1708 and attached to PGE's reauthorization of the deferral on June 2, 2017.

Appendix A - Cadmus Evaluation of Flex 1.0

Flex Pricing and Behavioral Demand Response Pilot Program

EVALUATION REPORT

June 25, 2018

Prepared for:

Portland General Electric
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CADMUS

Prepared by:

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Abstract

Through its residential Pricing and BDR Pilot program (Flex), PGE sought to assess the load impacts from and customer satisfaction with different pricing and behavior-based DR treatments. Findings from the pilot would be used to inform offerings for a future, large-scale rollout of a PGE DR program.

In 2015, PGE contracted with Cadmus to evaluate Flex. The evaluation covered two winter seasons (2016/2017 and 2017/2018) and two summer seasons (2016 and 2017) and involved analysis of RCTs for 12 DR treatments including PTRs, TOU pricing, BDR, and combinations of these treatments. Cadmus performed the research design, peak demand impact analysis, program staff interviews, and customer surveys.

Opt-in PTR produced demand savings during Flex events ranging from 17%–21% in summer and 7%–12% in winter. Opt-out PTR and BDR yielded event demand savings of 7% and 2% in summer, and 5% and 1% in winter, respectively. Two of three TOU rates delivered demand savings during peak periods of 5%–8% in summer. In winter, none of the TOU rates produced statistically significant savings. Hybrid treatments combining TOU and either PTR or BDR achieved peak period demand savings of 8%–23% in summer and 1%–5% in winter. During summer and winter Flex events, TOUxPTR treatments tended to produce less demand savings than opt-in PTR-only customers. For many treatments, the estimated load impacts equaled or surpassed PGE planning estimates.

In general, Flex customers were satisfied with the pilot. Opt-in PTR customers consistently had the highest satisfaction (79%–92%). TOU and opt-out customer automatically enrolled in the pilot tended to have lower satisfaction (51%–82%). TOU and TOU-hybrid customers had lower satisfaction in winter, as demand saving or shifting proved challenging for them in this season.

These findings demonstrate that PGE can deploy pricing and behavior-based DR to manage its system peak demand while delivering a positive customer experience. This report makes recommendations for increasing Flex demand savings and improving the customer experience.

Executive Summary

In 2016, Portland General Electric (PGE) launched Flex, a pricing and BDR pilot program. PGE launched the program to test the load impacts and customer acceptance of various demand response strategies. The program enrolled 14,000 customers and tested 12 pricing and behavior-based program design options (referred to as “treatments” in this report) aimed at reducing residential peak demand during summer and winter months. The treatments featured three TOU rates, three peak-time rebates (PTR), BDR, four hybrid demand response treatments (TOU pricing in combination with PTR or BDR), and OO BDR and PTR demand response that automatically enrolled customers.

PGE called upon customers enrolled in PTR or BDR treatments to reduce loads during a limited number of Flex events in summer and winter. PGE paid rebates of $0.80/kWh, $1.55/kWh, or $2.25/kWh to PTR customers for reducing consumption during Flex events below individual-customer baselines, and PGE provided encouragement to BDR customers to save during Flex events but did not compensate them for saving or shifting their demand. In contrast to event-based PTR and BDR, TOU pricing always was in effect. PGE moved participating customers on a standard flat rate to rate schedules that varied the cost of electricity as a function of the day of the week and hour of the day. Table 1 shows the three rates schedules (TOU1, TOU2, and TOU3) that PGE tested for the Flex pilot.

Table 4 Flex Pilot Summer and Winter TOU Rate Schedules[5]

Summer	TOU1	TOU2	TOU3
Off Peak	7.5¢/kWh	8.3¢/kWh	6.9¢/kWh
	10:00 pm–6:00 am	8:00 pm–3:00 pm	10:00 pm–11:00 am
Mid Peak			11.9¢/kWh
			11:00 am–3:00 pm 8:00 pm–10:00 pm
On Peak	13.6¢/kWh	17.6¢/kWh	18.0¢/kWh
	6:00 am–10:00 pm	3:00 pm–8:00 pm	3:00 pm–8:00 pm
Winter	**TOU1**	**TOU2**	**TOU3**
Off Peak	8.0¢/kWh	8.8¢/kWh	7.4¢/kWh
	10:00 pm–6:00 am	8:00 pm–7:00 am; 11:00 am–3:00 pm	10:00 pm–7:00 am
Mid Peak			12.4¢/kWh
			11:00 am–3:00 pm; 8:00 pm–10:00 pm
On Peak	14.1¢/kWh	18.1¢/kWh	18.5¢/kWh
	6:00 am–10:00 pm	7:00 am–11:00 am; 3:00 pm–8:00 pm	7:00 am–11:00 am; 3:00 pm–8:00 pm

TOU customers paid a higher unit price to consume electricity during peak periods (e.g., weekday afternoon hours) when electricity was most costly to supply and a lower unit price during off-peak periods (weekday morning, weekend, and evening hours). The TOU3 rate also included a mid-peak period, when the retail electricity price was about midway between the off-peak and on-peak prices.

Evaluation Context

As presented in its 2016 Integrated Resource Plan (IRP), in the next several years, PGE expects to face a shortfall in generating capacity from the planned closure of its Boardman facility in 2020 and the expiration of wholesale power contracts.[6] At the same time, PGE plans to increase its production of electricity from intermittent renewable energy resources to comply with the requirements of Oregon Senate Bill 1547. In consideration of these developments, PGE's IRP (2016) calls for the use DR to help manage system peak loads and to assist with integration of renewable energy resources. The IRP sets a goal of adding DR capacity of 77 MW in winter and 69 MW in summer.

[5] TOU rates effect as of August 1, 2016.
[6] PGE's IRP for 2016 is available at https://www.portlandgeneral.com/ourcompany/energy-strategy/resource-planning/integrated-resource-planning/2016-irp

An important source of future DR capacity for PGE will come from residential customers. These customers contribute to PGE's system peak demand through weather-driven increases in demand for air conditioning in summer and demand for space heating in winter. By deploying DR programs to residential customers, PGE can manage its peak system loads and reduce its costs of electricity supply. Between 2010 and 2013, PGE ran a critical peak pricing (CPP) pilot and obtained demand savings between 10%–12%. To lay the groundwork for a full-scale launch of residential pricing and behavior-based DR offerings, PGE implemented the Flex pilot and hired Cadmus to conduct an evaluation. The evaluation sought to assess a range of program design options, including different peak rebates, TOU rate schedules, BDR, and customer opt-in and opt-out designs.

This evaluation report presents findings addressing the Flex pilot's design and delivery, load impacts, and customer experience, and provides recommendations to help PGE optimize its future DR program offerings. Cadmus evaluated four seasons of the Flex pilot (Summer 2016, Winter 2016/2017, Summer 2017, and Winter 2017/2018), but this report focuses on Summer 2017 and Winter 2017/2018 as PGE did not reach its customer recruitment targets until summer 2017, and PGE changed some aspects of the program's delivery during the first two seasons.

Key Findings

Table 5 presents findings from the Flex pilot evaluation regarding peak demand savings, customer satisfaction, and customer opt-out rates across treatments for Summer 2017 and Winter 2017/2018. The table shows demand savings during Flex events for all treatments and on-peak period demand savings for all TOU and Hybrid treatments. Although PGE did not notify TOU-only customers of Flex events, Cadmus estimated Flex event savings for these customers to assess the peak capacity impacts of TOU pricing.

The most significant findings follow:

- Opt-in PTR treatments produced demand savings during Flex events ranging from 17%–21% in summer and 7%–12% in winter.
- Opt-out PTR and BDR treatments reduced loads during Flex events by 7% and 2% in summer and 5% and 1% in winter, respectively.
- The TOU1 rate, which defined on-peak periods as weekday hours between 6:00 a.m. and 10:00 p.m., did not result in shifting of loads from on-peak periods to off-peak periods or demand savings during Flex events. The TOU1 load impacts were not statistically different from zero.
- In summer, the TOU2 and TOU3 rates, which defined a shorter on-peak period on weekdays from 3:00 p.m. to 8:00 p.m., resulted in demand savings from 5%–8% during on-peak periods and Flex event hours. In winter, neither TOU2 nor TOU3 resulted in statistically significant Flex event demand savings or shifting of loads from peak to off-peak hours.
- During on-peak TOU periods, Hybrid treatments, which combined PTR or BDR with TOU pricing, resulted in demand savings from 8%–23% in summer and 1%–5% in winter. During summer Flex events, Hybrid treatments saved 10%–20% of peak demand. During winter Flex events, TOU2 and TOU3 hybrid treatments saved about 13%.

- None of the TOU-only or Hybrid treatments led to changes in total energy consumption. Estimates of changes in total energy consumption were close to zero and not statistically significant.
- Opt-in PTR customers were those most satisfied with the pilot. In summer and winter, 80% or more of PTR customers reported a satisfaction rating of 6 or higher on a 10-point scale.
- TOU-only customers and opt-out customers were the least satisfied with Flex. Among TOU-only customers, 76% were satisfied with Flex in summer and 61% were satisfied in winter. For optout customers, 56% were satisfied in summer and 61% were satisfied in winter. Some TOU customers reported less-than-expected bill savings, and some opt-out customers were not interested in participating.
- TOU customer satisfaction with the pilot depended on perceived bill savings. Satisfied customers (those giving 6–10 ratings on a 10-point scale) most often noted that the program delivered bill savings. Unsatisfied customers (those giving 0–5 ratings a 10-point scale) most often noted seeing little to no difference in their bills.
- Customers opting into the pilot exhibited high engagement with Flex events. Depending on the season, 93% to 96% of opt-in PTR-only respondents and 94% to 97% of opt-in Hybrid respondents remembered receiving event notifications. Also, 76% to 86% of opt-in respondents reported conserving electricity during events in both seasons.
- Opt-out customers automatically enrolled in the pilot exhibited lower awareness of Flex events compared to opt-in customers. Depending on the season, 77% to 89% of opt-out respondents remembered receiving event notifications, and 48% to 63% reported conserving electricity during events in both seasons.
- TOU customers did not have strong awareness of their rate schedules. Only about one-half of TOU and Hybrid respondents (52%) correctly identified their rate schedules from a list of three rate schedule images, a result only slightly better than customers guessing at random.
- During the first season, PGE experienced challenges in providing accurate and timely feedback to participants about savings during Flex events. However, with improvements in the baseline calculation methodology and data QC procedures, PGE increased the feedback's accuracy and shortened the time required to send customers feedback to less than 24 to 48 hours after the event.
- Around one-half of customers (48%) did not know they could change their event notification channel preferences on the Flex website. PGE received complaints from BDR-opt-out (OO) customers that they received too many event notifications.
- TOU and Hybrid customers, who faced financial risks from participating in the pilot, opted out of the pilot at higher rates (8%–11%) than opt-in PTR, opt-out PTR, and BDR customers (2%–6%), who did not face such risks.
- PGE experimented with three marketing channels (email, postcard, and business letter) and three messaging themes (economics, control, and community) to determine which marketing strategies converted to higher customer enrollment. The two paper-based channels (business letter 4.5% and postcard 2.5%) had a higher conversion rate than email (1.5%).

- PGE found that financial-focused messaging resonated more with customers as PGE enrolled a higher percentage of customers when it emphasized the opportunity to earn bill credits or savings. In surveys, customers reported that saving money on electric bills was the top reason for enrollment (78%).

Table 5 Flex Evaluation Findings by Treatment and Season[7]

Category	Treatment		Summer				Winter					Program Opt-Out Rate[8]
			Savings[9]		Satisfaction[10]		Savings[11]			Satisfaction[12]		
			Planning	Evaluation	Satisfied (6-10)	Delighted (9-10)	Planning	Evaluation		Satisfied (6-10)	Delighted (9-10)	
								AM	PM			
PTR-Only	PTR1		13%	18%	79%	46%	14%	13%	7%	80%	44%	4%
	PTR2			22%	92%	42%		0%	8%	89%	55%	6%
	PTR3			17%	84%	52%		3%	12%	89%	58%	5%
Opt-Out	PTR2-OO		6%	7%	73%	40%	7%	0%	6%	79%	35%	2%
	BDR-OO		3%	2.3%	51%	23%	3%	-0.7%	1%	57%	25%	3%
TOU-Only	TOU1	On-Peak	5%	2%	57%	23%	6%	-1%		54%	23%	8%
		Flex Event		-1%				2%	0%			
	TOU2	On-Peak		8%	82%	45%		3%		62%	23%	9%
		Flex Event		5%				2%	2%			
	TOU3	On-Peak		5%	82%	42%		0%		68%	23%	9%
		Flex Event		6%				3%	1%			
Hybrids	TOU1xPTR2	On-Peak	5.2% TOU; 12.9% PTR	3%	72%	34%	5.8% TOU; 14.2% PTR	1%		69%	38%	11%
		Flex Event		10%				10%	5%			
	TOU2xPTR2	On-Peak	5.2% TOU; 12.9% PTR	24%	70%	27%	5.8% TOU; 14.2% PTR	5%		73%	18%	10%
		Flex Event		20%				12%	13%			
	TOU2xBDR	On-Peak	5.2% TOU; 3.0% BDR	8%	81%	37%	5.8% TOU; 3.3% BDR	1%		71%	36%	8%
		Flex Event		11%				-1%	1%			
	TOU3xPTR2	On-Peak	5.2% TOU; 12.9% PTR	9%	88%	50%	5.8% TOU; 14.2% PTR	4%		72%	46%	10%
		Flex Event		8%				4%	13%			

[7] Seasonal results presented only for Summer 2017 and Winter 2017/2018.
[8] Opt-out rates show the percentage of customers enrolled in a specific treatment who have unenrolled through February 2018.
[9] Impact values reflect percentage demand reduction during Flex peak-time events (and on-peak periods for TOU rates); green font indicates significance at 90%.
[10] Satisfaction values represent participant survey respondents' satisfaction with Flex on a 0-10 rating scale.
[11] Impact values reflect percentage demand reduction during Flex peak-time events (and on-peak periods for TOU rates); green font indicates significance at 90%.
[12] Satisfaction values represent participant survey respondents' satisfaction with Flex on a 0-10 rating scale.

Conclusions and Recommendations

Key takeaways from the Flex pilot evaluation include the following:

Peak-Time Rebates

Larger rebates did not yield more Flex event savings.

Opt-In PTR customers saved about 20% of consumption during summer Flex events and between 7% and 12% of consumption during winter Flex events. No statistically significant differences in savings appeared by rebate amount. In summer, customers receiving a $0.80/kWh rebate achieved the same savings as customers receiving a $2.25/kWh rebate.

Of 12 treatments, Opt-In PTR-only customers were most satisfied with the Flex pilot.

In both seasons, Opt-In PTR-only respondents had the highest satisfaction rates with Flex (83% reported a program satisfaction score of 6 or higher on a 10-point scale in winter; 86% in summer) compared to Hybrids (71% in winter; 79% in summer) and TOU-only (61% in winter; 76% in summer).[13] Opt-In PTR2 treatment achieved the highest satisfaction rate of 92% in the summer survey. Opt-In PTR2 (89%) and PTR3 (89%) treatments also achieved high satisfaction rates in the winter survey. PTR customers may have been most satisfied as they faced no financial risk from participation. Customers could earn rebates for saving energy during Flex events but were not penalized if their consumption increased.

Larger rebates (greater than $1.55/kWh) increased customer satisfaction with the Flex pilot. PTR1 customers, who received the smallest rebate ($0.80/kWh), had lower satisfaction with Flex for both winter and summer seasons than PTR2 ($1.55/kWh) or PTR3 ($2.25/kWh) customers. In summer, 79% of PTR1 customers expressed satisfaction with the program, while 92% of PTR2 customers and 84% of PTR3 customers expressed satisfaction. In winter, PTR1 had a satisfaction rate of 80%, about 10 percentage points lower than that of PTR2 (89%) and PTR3 (89%).

Flex event savings from peak-time rebates did not depend on outside temperatures.

A statistical relationship was not found between PTR savings and outside temperatures during Flex events in winter or summer. Outside temperatures during Flex events ranged between 82°F and 96°F in summer and 28°F and 45°F in winter.

PTR Recommendation

- When setting rebates for future PTR programs, PGE should consider the tradeoff arising from offering a higher rebate: over the lower range of rebates tested ($0.80/kWh to $1.55/kWh), there were positive effects on customer satisfaction but no impacts on Flex event savings

[13] Respondents rated their overall satisfaction with the program on a 0–10 scale, where 0 meant *extremely dissatisfied* and 10 meant *extremely satisfied*. PGE defined a 6–10 rating as *satisfied*.

from increasing the rebate. This suggests that larger rebates may raise customer satisfaction, but lower program cost-effectiveness.

TOU Rates

Customers under the TOU1 rate schedule encountered difficulties in shifting consumption from peak to off-peak hours.

The TOU1 rate used "day/night" off-peak and on-peak period definitions. As the on-peak period was set from 6:00 a.m. to 10:00 p.m., many customers were awake only during peak hours and asleep during off-peak hours, making load shifting inconvenient or difficult. Shifting loads would require many customers to adjust their sleep schedules or to have appliances programmed to run at night. Among TOU customers, those on the TOU1 rate had the lowest program satisfaction rates (57% in summer and

54% in winter) and did not achieve peak savings in either season. TOU1 respondents dissatisfied with Flex most often mentioned the rate schedule being difficult for their households; these respondents said it was not convenient or worth changing one's sleep time to do chores during off-peak periods.

TOU rate schedules with short peak-period definitions yielded peak savings and high satisfaction in summer.

In summer, TOU2 and TOU3 customers achieved significant savings during peak periods (8% and5%, respectively). They also saved 5%–6% during Flex event hours, which Cadmus used as a proxy for the peak capacity impact of TOU, even though TOU customers did not receive Flex event notifications or incentives. In summer, the TOU2 and TOU3 schedules had relatively short peak periods, from 3:00 p.m. to 8:00 p.m., which coincided with PGE's summer system peak and enabled customers to shift loads to off-peak periods. In summer, TOU2 and TOU3 customers had relatively high customer satisfaction ratings of 82%.

The simpler TOU rate schedule achieved the same peak period savings and satisfaction as the more complex one.

In summer, the TOU3 rate, with peak (3:00 p.m.–8:00 p.m.), mid-peak (11:00 a.m.–3:00 p.m.), and off-peak periods, reduced loads by 5% during the mid-peak period. However, no differences emerged in peak period savings between the simpler TOU2 rate, which only had peak (3:00 p.m.–8:00 p.m.) and off-peak periods, and the more complex TOU3 rate. TOU2 and TOU3 showed statistically similar program satisfaction rates in summer (TOU2 82%; TOU3 82%) and winter (TOU2 62%; TOU3 68%).

In winter, TOU customers experienced difficulties in shifting loads from peak to off-peak periods and achieving bill savings.

During winter, none of the TOU-only treatments produced statistically significant reductions in or shifts in peak-period loads. Either TOU did not affect customer loads, or the load impacts were too small to detect with the existing sample sizes. TOU customers also reported relatively low satisfaction with Flex (54%–68%) because of adverse bill impacts and the rate schedule being difficult for their households.

TOU schedules had morning *and* evening peak periods. Notably in the survey's open-ended comments, TOU-only and Hybrid customers mentioned the program was more difficult to participate in during winter than summer. Moreover, TOU-only and Hybrid treatments showed significantly lower program satisfaction rates in winter (61%–71%) than in summer (76%–79%).[14] This seasonal pattern in program satisfaction for TOU-only and Hybrid treatments suggests that the TOU aspect may be more challenging for customers in winter than in summer.

TOU Recommendations

- Unless an economic case justifies shifting customer loads from mid-peak to off-peak hours, PGE should implement the TOU2 rate schedule, which is simpler for customers to understand.
- PGE should consider redesigning the winter TOU rate schedules by removing the morning peak period. This would minimize the potential for adverse customer bill impacts and simplify the customer experience.
- PGE should redesign the TOU1 rate schedule or offer TOU1 customers enabling technology to facilitate load shifting from peak to off-peak periods.
- PGE did not test the impacts of pairing enabling technology with TOU pricing, but studies of other TOU pricing programs suggest that enabling technology such as price-responsive smart thermostats can increase load shifting. PGE should consider testing the load impacts of enabling technology in the future.
- PGE should consider enhancing customer screening during the enrollment process to determine whether a customer is a good fit for a TOU rate.
- Given TOU customers' challenges in achieving winter bill savings, PGE should offer them more education about how to save energy or shift loads from peak to off-peak periods.

Opt-Out Behavioral Demand Response

Behavior-based treatments caused PGE customers to save energy during Flex events.

BDR-OO customers saved an average of 2.3% of consumption in summer and 1.2% of consumption in winter. PGE sent opt-out BDR customers Flex event alerts, encouragement to reduce consumption, and individualized post-event feedback but did not charge them higher electricity prices or provide them with

[14] Significant difference with 90% confidence (p≤.10).

rebates during Flex events, demonstrating that residential customers responded to non-price interventions.

Opt-out BDR program design yielded capacity benefits but resulted in relatively low customer satisfaction.

PGE automatically enrolled over 12,000 residential customers in the BDR-OO treatment. While average savings per treated customer were small (only 1%–2% of consumption), total program demand savings were large due to the size of the treated population. In the future, PGE can deploy the BDR program to help manage system peaks, but at the potential cost of lower customer satisfaction: only 51% of BDROO customers in winter and 57% in summer rated the program a 6 or higher on a 10-point scale.

Satisfaction ratings were likely low due to the opt-out program design and the unfamiliarity of many customers with BDR and the costs of supplying energy during utility system peaks. The program sent event notifications to many customers who had little interest in receiving them or participating in a BDR program. PGE also mentioned in the interviews that it received feedback from some BDR customers that it dispatched too many events and that these customers had not been aware that they could change their event notification settings.

BDR Recommendations

- PGE should consider using opt-out BDR for achieving capacity savings targets, given its success with BDR in reducing loads during this pilot; but it should consider possible changes to program design to increase customer satisfaction, such as:
  - Limiting the frequency of future BDR events, which would also limit the number of event notifications customers received.
  - Shortening the duration of future BDR events to lessen the burden on customers.
  - Spacing out future BDR events to avoid calling back-to-back events or multiple events in the same week.
  - Sending BDR customers a handy reminder magnet or sticker about BDR events and how to save, akin to the clock sticker PGE sent to TOU customers.
- PGE should clearly inform opt-out BDR customers that they can opt out of treatment and should make it relatively easy for customers to opt out if they do not want to participate.

Opt-Out Peak-Time Rebates

The opt-out participation program design significantly increased program participation. PGE attained a much higher participation by presenting customers with a choice to opt out of the program rather than opt in. PGE automatically enrolled approximately 1,600 customers in the PTR2-OO program. By the end of the Winter 2017/2018 season, only 2.3% of customers had opted out. In comparison, at the end of the recruitment period for opt-in PTR treatments, less than 7% of PGE customers accepted offers to participate in a PTR1 (4.3%), PTR2 (2.8%), or PTR3 (6.2%) treatment.[15] Of customers opting in to PTR treatment, between 4.5% and 6.3% subsequently opted out. The opt-out design took advantage of customers who were expected to be "complacent": they would neither opt in nor opt out of a DR program, if given the choice. Cadmus estimated that 92% of opt-out customers were complacent customers. By making participation the default choice, PGE obtained program participation and peak capacity that it would not have achieved otherwise.

The design of the pilot participation choice (opt-in vs. opt-out) presents a tradeoff between savings per customer and number of participants.

Depending on the rebate amount, opt-in PTR customers saved 17% to 21% of consumption during summer Flex events and from 7% to 12% of consumption during winter Flex events. Customers automatically enrolled in PTR2 saved an average of 7% during summer Flex events and 5% during winter Flex events.[16] Cadmus estimated that in Summer 2017, "complacent customers"—who would neither opt in nor opt out of a PTR program if given the choice—saved 6% during Flex events. While opt-in PTR customers saved more, the opt-out design enrolled many more customers. As noted above, fewer than 6% of PGE customers took up offers to participate in the PTR program. In contrast, more than 97% of customers defaulted onto PTR2-OO remained in treatment through the end of the Winter 2017/2018 season.

Adding a peak-time rebate to behavior-based DR increased Flex event demand savings and customer satisfaction.

The opt-out BDR treatment and the opt-out PTR treatment only differed in the rebate paid to customers for saving energy during Flex events. PTR customers received the same notifications, tips for saving energy, and individualized feedback about savings as BDR-OO customers. Opt-out PTR customers, however, saved significantly more during Flex events than BDR-OO customers (5% in winter and 7% in summer vs. 1% and 2%, respectively), demonstrating that the rebate lifted savings and complemented the behavior-based treatment. The rebate also increased customer satisfaction. PTR2-OO customers reported 73% program satisfaction in summer and 79% in winter—high customer satisfaction rates for

[15] PGE experimented with different marketing strategies during the first two waves and obtained higher rates of acceptance during the third wave after improving its approach. Also, PGE stopped recruiting for the opt-in PTR2 treatment after the second wave.

[16] The surveys also found that a higher percentage of opt-in (75% in summer, 89% in winter) than opt-out (37% in summer, 75% in winter) PTR2 customers reported participating in Flex events.

customers automatically enrolled in a program. In contrast, BDR-OO customers only reported program satisfaction rates of 51% in summer and 57% in winter.

Opt-Out PTR Recommendation

- Given the tradeoff between savings per customer and numbers of participants, PGE should analyze whether the opt-in or opt-out PTR design proved more cost-effective, and whether each design will generate the desired aggregate DR capacity.

Hybrid Treatments

TOU pricing did not enhance (and possibly diminished) savings from PTR during Flex events and customer satisfaction (TOUxPTR vs. PTR).

During Summer Flex events, opt-in PTR customers saved 17% to 21% of consumption, but TOUxPTR customers only saved 9% to 19%[17]. During Winter Flex events, opt-in PTR customers saved 7% to 12%, but TOUxPTR customers only saved 4% to 12%. TOU pricing may cause PTR customers to become inattentive to Flex event alerts, or TOUxPTR customers may have less incentive to save energy during Flex events because their consumption baseline used for calculating rebates is lower. In summer and winter, satisfaction with Flex was 10 to 20 percentage points lower for TOUxPTR customers than for PTR-only customers.

Adding peak-time rebates to TOU pricing increased customer satisfaction and Flex event savings (TOUxPTR and TOUxBDR vs. TOU-Only).

Peak-time rebates had positive impacts on customer satisfaction for TOU customers. Depending on the TOU rate, TOU-only customers reported program satisfaction ranging from 57% to 82% in summer and 54% to 68% in winter. In contrast, TOUxPTR customers reported satisfaction levels ranging from 70% to 88% in summer and from 69% to 73% in winter, suggesting that the PTR enhanced customer satisfaction with the program.

During Flex events (i.e., hours used in this report to approximate system capacity conditions), TOUxPTR customers also saved more than TOU-only customers. In summer, TOUxPTR or TOUxBDR customers saved from 8% to 19% of Flex event demand, while TOU-only customers saved from 2% to 8%. During Winter events, TOU2xPTR2 and TOU3xPTR2 customers saved 12% of consumption, while TOU-only customers did not save any demand.

[17] The Flex event savings estimate for Hybrid customers indicates the combined effects of TOU and PTR during Flex events. The savings are estimated relative to customers who are treated with neither PTR nor TOU pricing.

Hybrid Treatment Recommendations

- If PGE's primary objective is to save demand during system peaks, it should consider enrolling more customers in PTR-only treatments than hybrid TOUxPTR treatments to maximize the impact on system peak.
- If PGE deploys TOU rates on a wide scale, it should consider pairing TOU rates with a peak-time rebate to raise customer satisfaction and Flex event savings.

Customer Experience

TOU and Hybrid customers reported higher satisfaction with the Flex pilot in summer than winter, primarily due to greater summer bill savings.

Overall, participant respondents were more satisfied with the Flex pilot in Summer 2017 (74% *satisfied*) than Winter 2017/2018 (69% *satisfied*).[18] The seasonal satisfaction differences, however, were greatest for treatments involving TOU pricing, which typically produced annual bill savings, with most or all savings occurring in summer. For TOU-only and Hybrid treatments, respondents reported significantly higher program satisfaction in summer (76%–79% *satisfied*) than in the winter (61%–71% *satisfied*).[19] Summer and winter respondents giving the program satisfied ratings most often noted that the program delivered bill savings. Respondents giving a less-than-satisfied rating most often noted seeing little to no difference in their bill savings. In summer, 16% of TOU survey respondents said they saved on their electric bills, compared to 9% of TOU survey respondents in winter. These program satisfaction results align with demand savings estimates showing participants achieved higher peak-period load reductions in summer than winter.

Although PGE automatically enrolled them, opt-out PTR and BDR customers showed high event awareness and engagement with the pilot.

As expected, customers opting into the pilot exhibited high awareness of and engagement with Flex events. Depending on the season, 93% to 96% of opt-in PTR-only respondents and 94% to 97% of opt-in Hybrid respondents remembered receiving event notifications. Also, 76% to 86% of opt-in respondents reported conserving electricity during events in both seasons. These awareness and engagement levels were higher than for BDR-OO and PTR2-OO customers automatically enrolled in the pilots. and 89% of opt-out respondents remembered receiving event notifications. Also, 48% of opt-out respondents in summer and 63% of respondents in winter reported conserving energy during these events. This suggests that PGE can engage customers in achieving demand savings who are automatically enrolled in DR programs.

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[18] Respondents rated their overall satisfaction with the program on a 0–10 scale, where a zero meant *extremely dissatisfied* and a 10 meant *extremely satisfied*. PGE defined a 6–10 rating as *satisfied*.

[19] Significant differences at the 90% level (p≤.10).

PGE has an opportunity to increase peak period and Flex event demand savings from TOU rates through additional education with existing TOU customers.

TOU2 and TOU3-only and Hybrid treatments saved 5% to 8% of demand during peak periods and 8% to 20% of demand during Flex events, indicating that TOU treatments proved effective. TOU customers, however, did not have strong awareness of their rate schedules. Only about one-half of TOU and Hybrid respondents (52%) correctly identified their rate schedules from a list of three rate schedule images. That was only slightly better than results one would expect (33%) if all customers guessed at random. This suggests TOU customers could save more if they knew of their rate schedules. PGE might be able to increase TOU customer demand savings through doing additional education and outreach.

PGE identified several pilot implementation issues that negatively affected customer experiences and either corrected the issues or will correct them in future Flex deployments.

In interviews with Cadmus, PGE managers and implementation contractors described several program implementation issues:

- PTR and BDR customers received inaccurate and delayed feedback regarding their demand savings during Flex events. The inaccurate feedback may have discouraged some customers from saving, and the delay in providing feedback prevented PGE from calling additional events until these issues resolved. By the start of Winter 2016/2017, PGE had resolved the savings calculation issues and managed to deliver feedback to participants within 24 to 48 hours of events.
- Another issue concerned communication about event notification settings. Some customers complained that they received too many notifications or that the notifications did not arrive through their preferred delivery channels. Many customers reported being unaware that they could change their notification settings. In the future, PGE plans to communicate more proactively with participants about options for program communications and will simplify the process for changing the settings.

Pairing technology with Flex treatments may improve customer's ability to achieve load reduction. While the Flex pilot did not test the impacts of pairing enabling technologies, such as smart thermostats, advanced water heaters, or in-home displays, with the pricing or behavior-based treatments, other studies have found the pairing of these technologies enhances peak demand savings. The experience of TOU1 customers illustrates the potential benefits of enabling technology. TOU1 customers reported challenges in shifting loads from daytime on-peak periods to nighttime off-peak periods; programmable or price-responsive enabling technologies may facilitate shifting of loads and increase TOU1 on-peak demand savings.

Customer Experience Recommendations

- PGE should consider modifying the TOU design and delivery for the winter season to help customers save or shift more electricity consumption. This would improve customer satisfaction and increase load impacts. Modifications could include eliminating the morning on-peak period, shortening the length of the on-peak periods, or automatically enrolling TOU customers in the PTR program. A conjoint analysis of the TOU program offering could examine tradeoffs between different rate schedule designs, customer satisfaction, and load impacts.

- PGE should provide TOU customers with additional education about their rate schedules. This information should be simple and easy to understand. One idea is delivering educational information through alternative media, such as online video.

- PGE should consider opt-out DR programs as a component of its DR portfolio. The Flex pilot demonstrated that opt-out programs can reach large numbers of customers and that 50% or more of customers automatically enrolled in PTR or BDR remained engaged, as measured by self-reported rates of Flex event awareness and conservation.

- PGE should conduct test events before the start of each season to assess readiness of its customer communications and data analytics platforms. Testing will allow PGE to correct issues before the season starts, refamiliarize customers with the program, and give customers a chance to change their communications preferences.

- PGE should consider conducting pilots to test the impacts of pairing enabling technologies such as smart thermostats or advanced water heaters with time-based rates or behavior-based treatments if PGE expects the technologies would be cost effective.

Marketing

Paper-based marketing and bill-savings messaging resonated most with customers.

PGE experimented with email, postcard, and business letter marketing, and found business letters achieved the highest customer marketing conversion rate (4.5%), followed by postcards (2.5%), and then email (1.5%).[20]

Business letters emphasized financial messaging (i.e., rate comparison information and a bill savings pitch). PGE initially used economic, control, and community messaging in the emails and post cards, but those approaches proved unsuccessful in enrolling customers. The recruitment survey also found a large

[20] A conversion rate measures a given marketing channel's effectiveness in spurring enrollment, calculated by taking the number of customers who enrolled from a channel and dividing this by the total number of customers that the channel reached.

majority of participants enrolled to save money on their electric bills (78%); far fewer respondents indicated enrolling to save energy (46%) or help the environment (28%).

Marketing Recommendation

- PGE should consider employing business letter marketing approach for future DR programs to increase the cost-effectiveness of its marketing. This approach would include leading with bill savings and rate comparisons rather than energy savings or community as primary messages in postcards, emails, or other marketing channels.

Introduction

In the next several years, PGE will face a shortfall in generating capacity from the planned closure of its

Boardman facility in 2020 and the expected expiration of wholesale power contracts. At the same time, PGE plans to increase its production of electricity from intermittent renewable energy resources to comply with the requirements of Oregon Senate Bill 1547. In consideration of these developments, PGE's IRP (2016) calls for the use of dispatchable resources including DR to help manage system peak loads and to assist with the integration of renewable energy resources. The IRP sets a goal of adding DR capacity of 77 MW in winter and 69 MW in summer.

Residential customers participating in DR programs will provide an important source of PGE's future DR capacity. These programs use price signals, direct load control (DLC), behavior-based treatments, or combinations of these to encourage customers to reduce demand during periods when it is costly for the utility to supply or distribute electricity.

DR represents a fundamental shift in the utility's relationship with its customers. Customers participating in DR programs do not simply just consume utility-supplied electricity; they also provide peak capacity to utilities. To take full advantage of this evolving "prosumer" role, PGE will need to offer its customers new retail electricity rates or other incentives as well as compelling education, marketing, and program experience to encourage customers to participate.

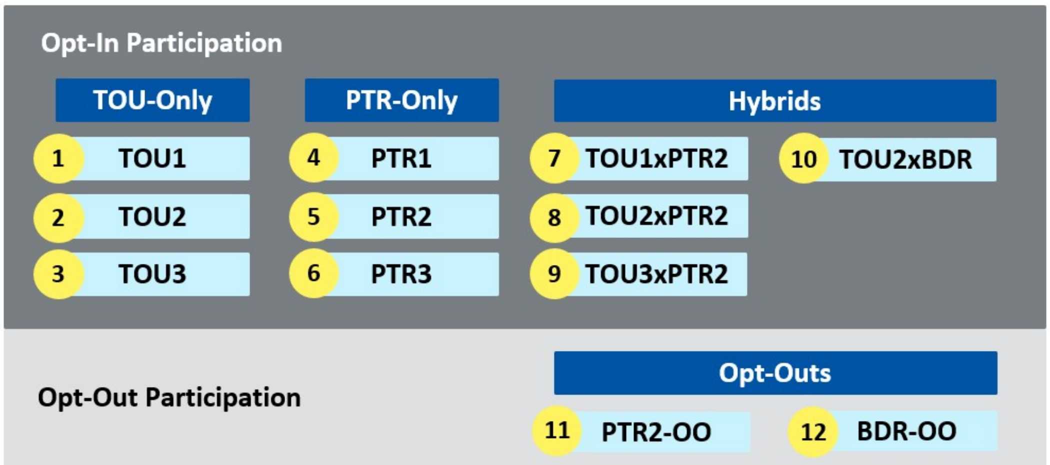
In 2015, PGE launched the Flex pilot program to test the effectiveness and customer acceptance of different DR program offerings, including TOU pricing, peak-time rebates (PTR), and BDR. By assessing a range of program treatment designs involving different incentive levels, rate structures, and recruitment approaches, PGE sought to understand its options and to lay the groundwork for a future where most of its residential customers participate in DR programs.

This evaluation report assesses the design and delivery, load impacts, and customer experiences of 12 DR treatments. PGE tested the DR treatments as RCTs, providing highly credible evidence about the treatment effects. The evaluation provides PGE with feedback about the pilot's performance in these areas and presents insights that can be used to optimize PGE's future DR program offerings.

Pilot Program Description

In 2016, PGE launched the Pricing and BDR Pilot Program. The pilot enrolled approximately 14,000 residential customers and tested 12 pricing and behavior-based program design options (treatments), aimed at reducing residential peak demand during summer and winter months. The treatments featured TOU pricing, peak-time rebates (PTR), BDR, hybrid DR (TOU in combination with PTR or BDR), and DR OO that automatically enrolled customers. PGE offered the 12 treatments as the Flex Pilot Program. Figure 1 shows a diagram of the Flex Pilot Program's multi-treatment program design.

Figure 1 Twelve Treatments Tested in the Flex Pilot Program



PGE outlined the following Flex Pilot Program objectives:

- Implement the program over four seasons (e.g., Summer 2016, Winter 2016/2017, Summer 2017, and Winter 2017/2018), with six to 10 peak demand events per season
- Identify treatment(s) that could be cost-effective at scale, with 10% of customers participating
- Help customers achieve lower or cost-neutral rates
- Achieve positive customer experiences

To facilitate evaluation and planning for a future, full-scale rollout of Flex, PGE established planning estimates for expected demand reduction during Flex events (shown in Table 6). PGE developed the planning estimates based on load impacts reported by utilities operating similar DR programs.

Table 6 Flex Pilot Program Demand Reduction Planning Estimates[21]

Treatment	Summer	Winter
TOU-Only: TOU1, TOU2, TOU3	5.2%	5.8%
PTR-Only: PTR1, PTR2, PTR3	12.9%	14.2%
Hybrids (PTR): TOU1xPTR2, TOU2xPTR2, TOU3xPTR2	5.2%–12.9%	5.8%–14.2%
Hybrids (BDR): TOU2xBDR	3.0%–5.2%	3.3%–5.8%
PTR2-OO	6.4%	7.1%
BDR-OO	3.0%	3.3%

PGE also set total enrollment goals of approximately 3,850 customers for the 10 opt-in treatments and 13,610 customers for the two opt-out treatments. These enrollment goals ensured sufficient statistical power for testing the various treatments.

PGE designed and implemented the pilot program with assistance from CLEAResult and AutoGrid as the implementation contractors. CLEAResult co-managed day-to-day program implementation and executed program marketing, while subcontracting with AutoGrid to provide the program's technology platform software and data services. PGE selected Cadmus as the program evaluator, assisting PGE with research design, savings analyses, and customer surveys.

Treatments Tested

The Flex Pilot Program tested 12 treatments, consisting of TOU, PTR, BDR, Hybrids, and Opt-Out program designs. This section summarizes these five program designs and the 12 different treatments.

Time-of-Use Rates

Customers enrolled in a TOU treatment paid a different unit price for electricity depending on when the electricity was consumed. TOU rates encourage customers to shift electricity consumption from periods when the utility's cost of supplying electricity is high to periods when the cost is low.

[21] Table shows PGE planning estimate of percentage demand savings during Flex events.

PGE tested three TOU rate schedules: TOU1, TOU2, and TOU3. Table 7 shows TOU rate schedules for summer and winter seasons under Flex.[22] TOU1 and TOU2 only had off-peak and on-peak periods, with TOU1 charging lower on- and off-peak rates, but having a longer on-peak period than TOU2. TOU3 had off-peak, mid-peak, and on-peak periods, with the off-peak rate below and the on-peak rate above those of TOU1 and TOU2. The TOU rate schedules also varied by season. During winter, each TOU rate included morning and afternoon peak periods, while, during summer, the TOU rates only included an afternoon peak period.

In summer, the peak-to-off-peak price ratio equaled 1.8 for TOU1, 2.1 for TOU2, and 2.6 for TOU3. In winter, the peak-to-off-peak price ratios were essentially unchanged, equaling 1.8 for TOU1, 2.1 for TOU2, and 2.5 for TOU3. A higher peak-to-off-peak price ratio should encourage greater load shifting, all else equal.

During the first year of participation, TOU customers could request refund if their annual electricity bills exceeded what they would have paid under the standard PGE residential rate. After the first year of participation, the bill protection lapsed, and customers could not request a refund.

Table 7 Flex Schedule: TOU Summer and Winter Rates[23]

Summer	TOU1	TOU2	TOU3
Off Peak	7.5¢/kWh	8.3¢/kWh	6.9¢/kWh
	10:00 pm–6:00 am	8:00 pm–3:00 pm	10:00 pm–11:00 am
Mid Peak			11.9¢/kWh
			11:00 am–3:00 pm 8:00 pm–10:00 pm
On Peak	13.6¢/kWh	17.6¢/kWh	18.0¢/kWh
	6:00 am–10:00 pm	3:00 pm–8:00 pm	3:00 pm–8:00 pm
Winter	**TOU1**	**TOU2**	**TOU3**
Off Peak	8.0¢/kWh	8.8¢/kWh	7.4¢/kWh
	10:00 pm–6:00 am	8:00 pm–7:00 am; 11:00 am–3:00 pm	10:00 pm–7:00 am
Mid Peak			12.4¢/kWh
			11:00 am–3:00 pm; 8:00 pm–10:00 pm
On Peak	14.1¢/kWh	18.1¢/kWh	18.5¢/kWh
	6:00 am–10:00 pm	7:00 am–11:00 am; 3:00 pm–8:00 pm	7:00 am–11:00 am; 3:00 pm–8:00 pm

[22] Summer TOU rates are in effect from May 1 to October 31. Winter TOU rates are in effect from November 1 to April 30. This evaluation estimated TOU pricing impacts in summer between June 1 and September 30 and in winter between December 1 and February 28.
[23] TOU rates effect as of August 1, 2016.

TOU customers received a rate schedule (the Flex schedule), depicting these various costs and times. Each month during summer and winter seasons, PGE sent TOU customers a report on how much money they saved under the TOU rate, with comparisons to the previous month, and tips on how to conserve or shift energy. For the first year, PGE provided bill protection to customers on TOU rates. This insured that TOU customers would not pay more than they would have if they remained on the standard flat rate. Bill protection was applied to a customer's annual—not monthly—consumption.

Peak-Time Rebate

Customers enrolled in a PTR treatment received cash rebates for reducing electricity consumption during Flex time events. PGE tested three rebate amounts[24]:

- PTR1 customers received $0.80 per kWh of savings
- PTR2 customers received $1.55 per kWh
- PTR3 customers received $2.25 per kWh

A customer's PTR savings were calculated relative to his or her baseline consumption, which was an estimate of what normal consumption would have been during the event hours.

One day in advance, PGE dispatched event notifications via email, text, and voice mail to customers, with another notification on the day of the event. These event notifications came with tips on conserving or shifting energy.

Within two days after an event, PGE provided PTR customers with feedback regarding their performance, showed them how much electricity they saved, and incentives earned. Within two weeks after the season's end, PGE mailed a report (along with a rebate check) to customers, addressing the total amount of electricity they saved during the season's events. The end-of-season report also showed energy savings for the customer and all Flex Program participants.

Behavioral Demand Response

The BDR treatment used behavior-based strategies to encourage customers to reduce electricity consumption during Flex events. PGE sent BDR customers event notifications, like those for PTR treatment, asking them to reduce electricity during specific hours of high demand. BDR customers, however, did not receive rebates or other financial incentives for reducing consumption during events. Rather, PGE provided BDR customers with social-normative peer comparisons and appeals to participate in collective actions to reduce electricity demand during peak periods. BDR customers received an end-of-season report like that provided for the PTR treatment, but they did not receive a rebate check.

[24] PTR incentives reflect pricing as of August 1, 2016.

Hybrids

Customers in Hybrid treatment received a combination of TOU and PTR treatments or a combination of TOU and BDR treatments:

- **TOUxPTR**: PGE tested three TOU rate treatments paired with the PTR2 treatment: TOU1xPTR2, TOU2xPTR2, and TOU3xPTR2. Customers in this Hybrid treatment paid different unit prices for electricity, depending on the day of week and time of day, *and* became eligible to receive a rebate for reducing consumption below baseline levels during Flex events.

- **TOU2xBDR**: PGE tested TOU2 paired with BDR. Customers in this Hybrid treatment paid the TOU2 rate *and* were asked to reduce consumption during Flex events, without financial incentive.

Opt-Out Participation

PGE tested BDR as an opt-out treatment, automatically enrolling customers but allowing them to opt out at any time. PGE also tested PTR2 as an opt-out and opt-in treatment to determine how the framing of the participation choice affected enrollments, demand savings, and customer satisfaction. PGE administered the PTR2 treatments identically to opt-out and opt-in customers.

Research Design and Program Set-Up

PGE implemented a large, randomized field experiment to test the Flex Pilot Program, using recruit-and deny randomized controlled trials (RCT) to test the 10 opt-in treatments and a standard RCT to test the two opt-out treatments. Randomized field experiments serve as the gold standard for demand-side management program evaluation and are expected to produce unbiased estimates of treatment effects.

Customer Eligibility Requirements

PGE identified 246,000 residential customers eligible to participate in the pilot. To receive an invitation to participate or to be automatically enrolled in the pilot, customers had to meet the following criteria:

- Receive electricity service from PGE and the current service address for at least the previous 12 months
- Not be a solar energy customer (i.e., did not have solar panels installed on the premises and on a net metering rate)
- Not be a participant in the Rush Hour Rewards thermostat control DR program
- Provide PGE with a valid email address
- Have a functioning interval consumption meter that records and communicates energy consumption to PGE

PGE did not impose eligibility requirements regarding minimum or maximum energy consumption or peak demand levels, allowing customers with low or high consumption levels to participate. However, PGE screened all eligible customers for expected bill savings from TOU treatments. Only customers expected to reduce their annual electricity bill payments with TOU pricing were given the opportunity to participate.[25]

Random Assignment to Treatment

PGE randomly assigned eligible customers to a pricing treatment (e.g., TOU2 or PTR1) and to a test or control group, and then invited them to participate in the pilot. Customers who opted into the pilot and had been randomly assigned to a test group were placed into treatment, while customers who opted in and had been assigned to the control group were not enrolled. Customers assigned to an opt-out treatment test group were automatically enrolled and received the assigned treatment unless they opted out. Customers assigned to the control group of an opt-out pricing treatment did not receive that treatment or any program-related communications. None of the customers assigned to a control group could participate in the Flex pilot.

Marketing and Recruitment

Customer recruitment for 10 opt-in treatments began in mid-February 2016 and continued through Spring 2017. PGE recruited customers to the pilot in three waves: Spring 2016; Summer/Fall 2016; and Spring 2017.

PGE and CLEAResult developed marketing materials and messaging for the pilot. This messaging focused on economics (personal gains, including bill savings), control (taking charge of your consumption), and community (the greater good). For customers invited to participate in a TOU treatment, the marketing presented expected bill savings under the assumptions of 7% and 15% shifts in consumption from the peak to off-peak period. For TOUxPTR hybrid customers, the marketing also presented bill savings with expected PTR-earnings.

In marketing the program to customers, PGE employed the following communication channels:

- **Email.** PGE sent multiple emails to customers with valid email addresses.
- **Direct mail.** PGE first sent postcards and then later sent business letters.
- **Flex website:** PGE established a customer engagement web portal, where customers could enroll in the program, review their current pricing plan, view information on ways to save, and obtain information about their household's electricity consumption.

Opt-In Treatment Recruitment and Enrollment Process

As discussed, PGE and Cadmus randomly preassigned eligible customers to one of 10 opt-in treatments and to either a test group or a control group. All eligible customers received an email and postcard

[25] Only customers with positive bill savings under the assumption that they shifted 7% of load from peak period to off-peak period were invited to participate in a TOU or Hybrid treatment.

invitation to enroll in Flex. The email and postcard included rate comparison information pertaining to the customer's assigned pricing option. The email and postcard provided customers with an activation code to sign up through the Flex website. Customers received a reminder email to enroll a week after the initial email and were given up to 45 days to enroll.

After logging into the Flex website, a customer completed enrollment by accepting the assigned pricing treatment. Test group customers who accepted their assigned pricing treatment became program participants. Control customers who accepted their pricing treatment were not placed into treatment, but rather received a message saying they did not qualify to enroll currently but may be able to do so in the future.

PGE initially offered test and control customers a reward for enrolling during the early 2016 recruitment period. Enrolled customers could choose between an Amazon gift card and a pair of zoo tickets. After seeing very little enrollment impact, however, PGE eliminated the enrollment reward.

Test group customers participating in the 10 opt-in pricing treatments could opt out at any time by contacting the pilot's call center.

Opt-Out Treatment Enrollment Process

PGE automatically enrolled randomly-chosen customers into one of two opt-out treatments: a PTR (PTR2-OO); or a BDR-OO. Customers randomly assigned to an opt-out treatment test group received a welcome email and postcard in mid-June 2016. The email and postcard included a link to access the Flex website.

Test-group customers participating in an opt-out treatment could opt out of the program in two ways: unsubscribing to the emails; or contacting the program's call center.

Recruitment Targets and Actual Enrollments

Table 8 shows PGE's enrollment targets, the number of customers enrolled in each Flex test group at the beginning of each season, and historical maximum enrollment as a percentage of the target. The enrollment targets were determined through statistical power analysis, with the objective of enrolling enough customers to detect the expected load impacts through statistical analysis. At first, recruitment proceeded slower than expected. In Summer 2016, only 50% of the targeted customers had enrolled, but, by Summer 2017, the program exceeded its targets, with many treatments reaching 150% or more of the sample size targets.[26] All treatments except for BDR-OO met their enrollment targets.

[26] Because PTR2 had recruitment priority to achieve a sample size large enough to support analysis for the Summer 2016 season, PGE stopped recruiting for PTR2 after Spring 2016.

Table 8 Flex Customer Recruitment Targets and Enrollments

Treatment	Number of Customers (N)				Target (N)	Percent of Target Achieved (Maximum)
	Summer 2016	Winter 2016/2017	Summer 2017	Winter 2017/2018		
PTR1	112	144	368	344	220	167%
PTR2	243	227	225	206	220	110%
PTR3	165	219	456	414	220	207%
TOU1	136	152	413	386	390	106%
TOU1xPTR2	132	146	346	329	220	157%
TOU2	480	564	1013	946	875	116%
TOU2xBDR	184	217	898	833	875	103%
TOU2xPTR2	251	234	220	202	220	114%
TOU3	130	158	432	401	390	111%
TOU3xPTR2	126	147	321	292	220	146%
PTR2_OO	375	703	631	564	430	163%
BDR_OO	6,233	11,215	10,089	9,095	13,180	85%
Total Opt-In	**1,959**	**2,208**	**4,692**	**4,353**	**3,850**	**122%**
Total Opt-Out	**6,608**	**11,918**	**10,720**	**9,659**	**13,610**	**88%**

Table 9 shows target and enrolled numbers of control group customers by treatment and season for the Flex pilot study. The control group sizes for individual treatments largely mirror those for the test groups. All treatments except BDR-OO achieved their targets by Summer 2017.

Table 9 Flex Control Group Sizes

Treatment	Number of Customers (N)				Target (N)	Percent of Target Achieved (Maximum)
	Summer 2016	Winter 2016/2017	Summer 2017	Winter 2017/2018		
PTR1	121	155	363	343	220	165%
PTR2	212	199	191	181	220	96%
PTR3	160	218	453	422	220	206%
TOU1	114	128	454	417	390	116%
TOU1xPTR2	118	123	326	302	220	148%
TOU2	388	453	554	513	390	142%
TOU2xPTR2	230	208	189	171	220	105%
TOU3	108	136	460	422	390	118%
TOU3xPTR2	126	159	309	287	220	140%
PTR2_OO	405	730	662	605	430	170%
BDR_OO	6,186	11,178	10,087	9,081	13,180	85%
Total Opt-In	**1,577**	**1,779**	**3,299**	**3,058**	**2,490**	**132%**
Total Opt-Out	**6,591**	**11,908**	**10,749**	**9,686**	**13,610**	**87%**

Event and Data Management

CLEAResult subcontracted with AutoGrid to operate the Flex Pilot Program's technology platform and to provide PGE with program management software and data management services. AutoGrid built and configured an online system to handle data from three different program designs (TOU, PTR, and BDR), employing a two-part system to manage the program's DR events and data:

- The engagement portal (Flex website), which houses and tracks customer-facing program data and information
- The DR management system (DRMS), designed to schedule events and measure consumption at short time intervals

AutoGrid's system communicated with PGE's customer information system to gather up-to-date customer account information and, through PGE's AMI, to gather customer interval consumption data at the meter level. PGE scheduled and dispatched events via the AutoGrid system, which sent event notifications to customers on the day before the scheduled event. On the day after the event, the AutoGrid system received and analyzed interval consumption data and estimated the load impacts. After reviewing the event performance results, PGE released them to customers, usually within 24-48 hours.

Table 10 shows Flex events that PGE called over the two summer and winter seasons.

Table 10 Flex Time Events by Season

Season	Date	Event Period	Notes
Summer 2016	7/27/2016	4:00 p.m.–7:00 p.m.	
	7/29/2016	4:00 p.m.–7:00 p.m.	
	8/11/2016	4:00 p.m.–7:00 p.m.	
	8/12/2016	4:00 p.m.–7:00 p.m.	
	8/18/2016	4:00 p.m.–7:00 p.m.	
	8/25/2016	4:00 p.m.–7:00 p.m.	
Winter 2016/2017	12/6/2016	4:00 p.m.–7:00 p.m.	
	12/8/2016 (snow day)	4:00 p.m.–7:00 p.m.	
	12/15/2016 (snow day)	4:00 p.m.–7:00 p.m.	BDR-OO not dispatched.
	1/3/2017	4:00 p.m.–7:00 p.m.	
	1/4/2017	4:00 p.m.–7:00 p.m.	
	1/11/2017	5:00 a.m.–8:00 a.m.	
	2/1/2017	7:00 a.m.–10:00 a.m.	
	2/3/2017 (snow day)	7:00 a.m.–10:00 a.m.	TOU2xBDR and BDR-OO not dispatched.
Summer 2017	7/25/2017	4:00 p.m.–7:00 p.m.	
	8/1/2017	5:00 p.m.–8:00 p.m.	
	8/3/2017	4:00 p.m.–8:00 p.m.	
	8/7/2017	4:00 p.m.–7:00 p.m.	TOU2xBDR and BDR-OO not dispatched.
	8/9/2017	3:00 p.m.–6:00 p.m.	
	8/28/2017	4:00 p.m.–8:00 p.m.	
	9/5/2017 (fire day)	4:30 p.m.–7:30 p.m.	Air quality issue from Eagle Creek fire.
Winter 2017/2018	1/3/2018	5:00 p.m.–8:00 p.m.	
	1/9/2018	5:00 p.m.–7:00 p.m.	TOU2xBDR and BDR-OO not dispatched.
	1/18/2018	5:00 p.m.–8:00 p.m.	
	1/25/2018	5:00 p.m.–8:00 p.m.	TOU2xBDR and BDR-OO not dispatched.
	1/31/2018	5:00 p.m.–8:00 p.m.	TOU2xBDR and BDR-OO not dispatched.
	2/20/2018	5:00 p.m.–8:00 p.m.	
	2/23/2018	7:00 a.m.–10:00 a.m.	

Evaluation Objectives

PGE specified the following evaluation objectives for the Flex pilot:

- Estimate the load impacts for each treatment and compare the estimated treatment effects.
- Assess customer enrollments in and satisfaction with the different treatments, including opt-in and opt-out treatments.
- Assess whether customer opt-in rates, satisfaction, and estimated load reductions depend on the PTR incentive amount or TOU pricing schedule.
- Determine whether behavior-based treatments result in significant and sustained reductions in customer demand.
- Assess whether Hybrid treatments result in larger peak demand reductions than single treatments.
- Identify implementation challenges, improvement opportunities, and potential for expanding the pilot.
- Assess program successes, challenges, and areas for improvement and scalability.

PGE's research objectives did not include cost-effectiveness analysis, as PGE planned to conduct the cost-effectiveness analysis using the study's results as inputs.

Evaluation Activities

Evaluation Background

In October 2015, PGE hired Cadmus to evaluate the Flex pilot. At the beginning, Cadmus assisted with the research design for the evaluation, which involved selecting DR treatments, designing the randomized field experiments, and determining minimum sample sizes. After selecting the 12 treatments for testing, PGE began implementing the pilot. Cadmus assisted by randomly assigning eligible customers to one of the 12 treatments and to a test or control group. In March 2016, PGE began recruiting customers for enrollment; this was the first of three recruitment waves, with subsequent waves launching in summer/fall 2016 and spring 2017.

This Flex evaluation covers two summers and two winters, beginning in June 2016 and ending in

February 2018. While Cadmus evaluated the pilot during all four seasons, this report focuses on Summer 2017 and Winter 2017/2018 seasons because the pilot did not reach its customer recruitment targets until summer 2017 and PGE changed some aspects of the program's delivery during the first two seasons.

To assess program delivery, design, and the customer experience, Cadmus performed a series of participant surveys (for treatment and control groups), including just after recruitment, during seasons after a peak-saving events, and at the end of a season, after all events had been completed. Cadmus also conducted multiple interviews with program and implementation staff at various points across the evaluation cycle.

Cadmus estimated pilot load impacts by analyzing hourly AMI customer consumption data. This involved performing separate regressions by season and treatment to assess differences in loads between test and control customers.

Table 11 summarizes the Flex pilot evaluation activities and how each relates to PGE's evaluation objectives. Below, we discuss each of these evaluation activities in greater detail, except for the research design, which was discussed already.

Table 11 Flex Pilot Evaluation Activities

Activity	Description	Outcomes	Relevance to Study Research Objectives
Research design	Designed recruit-and-deny RCT for opt-in treatments and RCT for opt-out treatments. Determined sample sizes for each treatment required to detect expected savings.	Randomized field experiment design and required sample sizes to obtain accurate and precise estimates of treatment effects.	1, 2, 3, 4, 5
Data collection and preparation	Collecting and preparing analysis of individual-customer AMI meter interval consumption data.	Final analysis sample for estimation of load impacts.	1
Load impact analysis	Regression analysis of individual-customer AMI meter interval consumption data.	Estimates of Flex event savings for 12 treatments and for peak and off-peak load impacts for TOU pricing.	1, 3, 4, 5, 6
PGE manager and implementation contractor interviews	Interviewed managers and contractors regarding program design, implementation, successes, and challenges.	Documentation of pilot implementation and lessons learned.	1, 6, 7
Customer surveys	Recruitment, event, and customer experience surveys.	Findings about customer satisfaction with the program and PGE, customer engagement, and event awareness.	2, 3, 6, 7

Data Collection and Preparation

Cadmus collected and prepared the following data for analysis:

- Individual-customer AMI meter electricity consumption data for all test and control group customers
- Weather data for each customer from the NOAA weather station closest to each customer's residence.
- Pilot enrollment, program participation, and account closure data for customers who received an invitation to participate in Flex, were automatically enrolled in the pilot (opt-out BDR or PTR), or assigned to the opt-out BDR control group or PTR control group.
- Dates and times of all Flex events and rate schedules for all Flex TOU pricing treatments

The AMI meter data recorded a customer's electricity consumption at 15 or 60-minute intervals and covered 12 months before the customer first received treatment (i.e., the customer's TOU rate became active) and all post-treatment months while the customer's account remained active. Cadmus aggregated all 15-minute interval consumption data to the customer-hour level. We performed standard data-cleaning steps to address duplicate observations, extreme outliers, and missing values. These data cleaning steps are discussed in Appendix A.

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

The pilot enrollment and program participation data included the following fields for each customer:

- Assignment to treatment (e.g., BDR, TOU1, etc.), assignment to test or control group, and indicator for recruiting wave (Wave 1, Wave 2, or Wave 3)
- For opt-in customers an indicator for whether the customer opted into the pilot and the date when the customer opted in.
- The official enrollment date if the customer opted into the pilot and had been assigned to the test group
- For customers assigned to receive an opt-out treatment, the date when the customer was automatically enrolled in the pilot.
- The account closure date if the customer's account closed during the pilot.
- The date the customer unenrolled from the pilot if the customer opted out of treatment.

Cadmus used the pilot enrollment and program participation data to identify customers in the test and control groups for each treatment, to define different variables for the load impact analysis, such as treatment and test-group indicator variables, to develop survey sample frames, and to calculate treatment opt-out rates.

In cleaning and preparing the AMI meter data, Cadmus encountered several issues that had to be addressed before the data could be analyzed. These issues included:

- Some AMI datasets were recorded on Coordinated Universal Time (UTC) instead of Pacific Time (UTC -8 or UTC -7).
- During the pre-treatment period, some customers' AMI meter data were recorded as integer kWh instead of as watt-hours.
- PGE did not provide pretreatment data for the same 12 months for all pilot customers

Appendix A discusses Cadmus' solutions to these issues. Robustness checks of the Flex treatment savings estimates indicate that the estimates were not sensitive to the specific solutions Cadmus developed.

Analysis Samples

Table 12 shows the initial and final analysis samples for each treatment in Summer 2017 and Winter 2017/2018 seasons. The initial analysis sample includes all customers who were randomly assigned to a test or control group and whose billing account remained active at the beginning of the Flex season.

Customers who opted out of treatment were included in both total enrollment and final analysis customer counts. Customers who moved or discontinued electricity service before the season began were excluded from samples.

Table 12 Flex Pilot Final Analysis Sample Sizes

Treatment	Summer 2017			Winter 2017/2018		
	Initial Analysis Sample (N)	Final Analysis Sample (N)	Analysis Sample Percentage	Initial Analysis Sample (N)	Final Analysis Sample (N)	Analysis Sample Percentage
PTR1	731	722	99%	687	678	99%
PTR2	416	408	98%	387	380	98%
PTR3	909	889	98%	836	823	98%
PTR2-OO	1,293	1,256	97%	1,169	1,149	98%
BDR-OO	20,176	19,587	97%	18,176	17,889	98%
TOU1	867	827	95%	803	787	98%
TOU2	1,567	1,510	96%	1,459	1,406	96%
TOU3	892	849	95%	823	805	98%
TOU1xPTR2	672	638	95%	631	612	97%
TOU2xPTR2	409	385	94%	373	354	95%
TOU2xBDR	1,452	1,398	96%	1,346	1,317	98%
TOU3xPTR2	630	598	95%	579	559	97%

The final analysis sample includes customers used in the impact estimation. The analysis sample excluded only a small number of test and control group customers in each treatment. For most treatments, the analysis included more than 97% of enrolled customers in the analysis. The main drivers of customer attrition from the analysis sample included lack of pre- or post-period AMI data.

Cadmus verified that there were not statistically significant differences in pre-treatment consumption between test and control group customers in the final analysis sample. For almost all treatments, the test and control groups were well balanced. Appendix C provides detailed balance test results.

Savings Estimation Approach

Cadmus estimated savings for each Flex treatment by collecting individual-customer AMI interval consumption data from before and after the customer enrolled in the Flex pilot and by comparing the peak demand of customers in the randomized test and control groups. This evaluation reports the following impacts:

- Flex event demand savings for all treatments, including TOU rates

- Peak period and off-peak period load impacts for TOU-based treatments, including TOU-only and hybrid treatments

We provide an overview of the estimation approach, but a more detailed description is found in Appendix B.

Event-Based Treatments

Cadmus estimated the demand savings from event-based treatments (e.g., PTR1, opt-out BDR) by comparing demand during Flex events of customers in the randomized test and control groups. Using data for event hours during each winter or summer season, Cadmus estimated a multivariate panel regression of customer hourly energy demand on control variables for pretreatment hourly average demand, hour-of-sample fixed effects, and assignment to treatment. We estimated a separate model for each treatment.

The pretreatment demand variables controlled for average differences in electricity demand between customers during Flex event hours. Cadmus calculated separate mean pretreatment demand for morning and evening hours for each season, using AMI interval data for days before the beginning of the Flex season. Cadmus did not calculate mean pre-treatment demand using non-event days during the DR season in consideration of evidence from other studies showing that event-based treatment can produce savings on non-event days. The hour-of-sample fixed effects controlled for weather and other unobserved factors specific to each event hour.

Cadmus estimated the models by ordinary least squares (OLS) and clustered the standard errors on customers to account for correlation over time in customer demand. Given the random assignment of customers to test and control groups, the regression was expected to produce an unbiased estimate of the treatment effect. Cadmus estimated alternative model specifications to test the estimates' robustness to specification changes, and found the results were very robust. Cadmus tested specifications that included indicator variables for a customer's recruitment wave (i.e., Wave 1, Wave 2, or Wave 3) as standalone variables and interacted with other explanatory variables and that dropped the pre-treatment consumption variables from the regression.

Time-of-Use Rate and Hybrid Treatments

Cadmus estimated treatment effects for TOU rate and hybrid-TOU rate treatments by comparing demand of customers in each treatment's randomized test and control groups. Using interval data on customer demand for each winter or summer season, Cadmus estimated a multivariate panel regression of customer hourly energy demand on control variables for pretreatment demand, peak and off-peak hours, day-of-the-week, weather, and assignment to treatment. We estimated treatment effects for Summer 2017 using data from June 1, 2017 to September 30, 2017 and for Winter 2017/2018 using data from December 1, 2017 to February 28, 2018. We estimated a separate model for each treatment.

Cadmus estimated the TOU and Hybrid models by OLS and clustered the standard errors on customers. Again, because of random assignment of customers to test and control groups, the regression was expected to produce unbiased savings estimates. Cadmus also estimated alternative model specifications to test the robustness of estimates to specification changes. For example, Cadmus tested specifications that included indicator variables for a customer's recruitment wave (i.e., Wave 1, Wave 2, or Wave 3) as standalone variables and interacted with other explanatory variables. The results proved robust to this and other specification changes. To estimate the treatment effect for the TOU3 rate, which included a mid-peak period, Cadmus added an indicator variable for the mid-peak period to the specification.

To estimate treatment effects for the Hybrid treatments such as TOU1xPTR2 or TOU2xBDR, Cadmus specified a model that allowed the effect of peak period hours to depend on whether the hour was a Flex event hour.

Adjusting the Treatment Effects for Customer Opt-Outs

Estimation of the average treatment effect using data for all customers who were randomly assigned to the test or control groups and whose account remained active provides an estimate of the intent-to treat (ITT) effect. However, not all customers assigned to treatment received treatment or treatment for the duration of the study. Over the randomized field experiment's course, some customers opted out of the pilot, ending their participation. Including these opt-outs in the analysis yields a savings estimate across customers who remained in treatment and those who opted out.

To estimate the average treatment effects for customers randomly assigned to and remaining in treatment, Cadmus scaled the intent-to-treat (ITT) savings estimates by dividing them by one minus the percentage of customers assigned to treatment who opted out before or during the season.[27] This produces an estimate of savings for treated customers. Since, in general, the opt-out rates for individual treatments were small, scaling of the ITT savings estimates had little effect.

Staff Interviews

Over the course of two summer and winter Flex seasons, Cadmus conducted five interviews with PGE and CLEAResult managers of the Flex pilot. The first interview occurred prior to Summer 2016 and focused on documenting and understanding the program design, recruitment, marketing, and delivery plan for the individual treatments. After each subsequent summer and winter season, Cadmus conducted additional interviews, focused on implementation changes and new perspectives on program successes, challenges, and learnings. Cadmus also used information from the interviews to design and refine the customer surveys for each season.

[27] This scaling produces an unbiased estimate of the treatment's effect for treated customers (i.e., those not opting out) if customers who opt out do not continue to save demand. If opt-out customers continue to save, the treatment effect estimate will be biased upward. Although customers did not receive event notifications after opting out, they could continue to save demand if they had programmed thermostats or other household appliances to run during off-peak periods and do not adjust the settings after opting out.

Customer Surveys

Cadmus designed and administered the following six customer surveys online:

- Recruitment survey (fielded in May 2016)
- Summer 2016 event survey (fielded in August 2016)
- Summer 2016 experience survey (fielded in November/December 2016)
- Winter 2016/2017 experience survey (fielded in April 2017)
- Summer 2017 experience survey (fielded in January 2018)[28]
- Winter 2017/2018 experience survey (fielded in April 2018)

The recruitment survey asked test group customers in the 10 opt-in treatments about how they heard about Flex, their awareness of TOU pricing and Flex events, about their satisfaction with PGE, and questions designed to establish demographics.

The event surveys asked test group customers in PTR and BDR treatments about event notifications and participation, load-shifting and conservation behaviors, and satisfaction with Flex and PGE. Control group customers were surveyed at the same time to collect comparative data on satisfaction with PGE.

The experience surveys asked test group customers in all 12 treatments about program awareness and participation, load-shifting and conservation behaviors, satisfaction with Flex and PGE, and demographics. Control group customers were surveyed at the same time to collect comparative data on satisfaction with PGE and demographics.

Each survey took respondents, on average, five minutes to complete and were fielded for a two-week period. Respondents did not receive an incentive or reward for completing a survey. For more details on the customer survey design, see Appendix E.

Survey Sampling and Response Rates

The number of test and control customers available at the time of survey fielding in each of the 12 treatments determined the sampling method for customer surveys. For all treatments except BDR-OO, Cadmus surveyed the census of active customers. For BDR-OO, however, Cadmus surveyed a random sample of 3,333 customers due to the very large number of customers in this treatment. Table 13 shows the number of test group customers contacted for each survey and the response rates by opt-in and opt-out treatment type. Table 14 shows the number of control group customers contacted and the response rate by opt-in and opt-out treatment types. For sampling and response rate details on each of the 12 treatments, see Appendix E.

[28] Cadmus fielded the Summer 2017 experience survey late compared to the previous summer experience survey due to survey instrument revisions and coordination with PGE on customer contact approval.

Table 13 Customer Survey Samples and Response Rates: Test Group

	Recruitment Survey 2016	Summer 2016 Event Survey	Summer 2016 Experience Survey	Winter 2016/2017 Experience Survey	Summer 2017 Experience Survey	Winter 2017/2018 Experience Survey
Opt-In Treatments						
Number of Contacted	865	969	1,467	1,659	3,828	3,635
Number of Completes	458	348	319	328	817	833
Response Rate	53%	36%	22%	20%	21%	23%
Opt-Out Treatments						
Number of Contacted	–	3,610	3,551	3,679	3,895	3,840
Number of Completes	–	329	119	160	202	277
Response Rate	–	9%	3%	4%	5%	7%
Total (Opt-In and Opt-Out Treatments Combined)						
Number of Contacted	865	4,579	5,018	5,338	7,723	7,475
Number of Completes	458	677	438	488	1,019	1,110
Response Rate	53%	15%	9%	9%	13%	15%

Table 14 Customer Survey Samples and Response Rates: Control Group

	Summer 2016 Event Survey	Winter 2016/2017 Experience Survey	Winter 2017/2018 Experience Survey
Opt-In Treatments			
Number of Contacted	–	–	2,647
Number of Completes	–	–	599
Response Rate	–	–	23%
Opt-Out Treatments			
Number of Contacted	3,602	3,729	3,926
Number of Completes	389	345	362
Response Rate	11%	9%	9%
Total (Opt-In and Opt-Out Treatments Combined)			
Number of Contacted	3,602	3,729	6,573
Number of Completes	389	345	961
Response Rate	11%	9%	15%

Survey Data Analysis

Cadmus compiled frequency outputs, coded open-end survey responses, and ran statistical tests to determine whether survey responses differed significantly between treatments and groups. Cadmus also compared survey responses between seasons.

Detailed Findings

Customer Enrollment and Retention

Opt-In Rates

Table 15 provides the cumulative opt-in rates for each opt-in treatment through the Summer 2017 season when PGE stopped recruiting customers for Flex. These rates indicate the number of customer who opted into the pilot compared to the total number of customers invited to participate. Cadmus calculated opt-in rates across all three waves of recruitment that received enrollment offers via mail or email and included opt-in rates for customers who were assigned to the control group. Note that in Table 15 the TOU2 and TOU2xBDR treatments are combined, since PGE randomly assigned some customers who opted into the TOU2 treatment to receive the BDR treatment. Note also that the opt-in rates are identical in Winter 2017/2018 as they were for Summer 2017 because there were no new enrollments.

Table 15 Opt-In Rates by Treatment[29]

Treatment	Through Summer 2017	
	Invited Customers Who Opted In (%)	Count of Customers Who Opted In (N)
PTR Only		
PTR1	4.3%	790
PTR2	2.8%	481
PTR3	6.2%	986
TOU Only		
TOU1	3.5%	932
TOU2 and TOU2xBDR[30]	3.4%	2,656
TOU3	3.7%	937
Hybrids		
TOU1xPTR2	4.5%	720
TOU2xPTR2	2.4%	489
TOU3xPTR2	4.5%	675

The opt-in rates reflect customer enrollments over three waves of recruitment. These rates varied over time, as PGE experimented and experienced different degrees of success with various marketing and messaging strategies. In general, PGE experienced greatest success in recruiting in Wave 3, as it incorporated important marketing lessons learned during Waves 1 and 2. These lessons are discussed

[29] Results presented here include both test and control participants.
[30] TOU2 and TOU2xBDR are presented together because PGE randomly assigned TOU2 customers to receive the BDR treatment.

below in the *Implementation Challenges and Lessons Learned* section. Also, PGE prioritized recruiting of certain treatments and stopped recruiting for some treatments before others. This meant that PGE did not recruit customers to some treatments during Wave 3.

The opt-in rates ranged between 2.4% and 6.2%. Overall, opt-in rates were higher for treatments that included peak-time rebates. The highest opt-in rate was for PTR3, which offered the most generous rebate of $2.25 per kWh of savings. The PTR2 and TOU2xPTR2 treatments experienced the lowest opt-in rates because PGE had stopped recruiting for these treatments after completing Wave 2. PGE customer opt-in rates were lower than those achieved by SMUD, which obtained opt-in rates ranging between 16% and 19% for a TOU and CPP program.[31] A likely explanation for the difference is that PGE customers are less familiar with the concepts of DR and time varying rates than SMUD customers. As PGE educates its residential customer population more about peak demand and its DR program offerings, it is expected that a higher percentage of PGE customers will opt into future pricing programs.

Opt-Out Rates

Table 16 provides the cumulative opt-out rates by treatment and season. These rates pertain to enrolled customers who opted-out of each treatment between June 1, 2016 and the last day of the summer or winter season (September 30, 2017 and February 28, 2018, respectively). Customers could opt out of the program by contacting PGE customer service and asking to be un-enrolled. Customers who moved residences were removed from the program but were not counted as opt-outs.[32]

[31] Potter, Jennifer, Stephen George, and Lupe R. Jimenez. 2014. *Smart Pricing Options Final Evaluation, Sacramento Municipal Utility District*, p. 106. Available at https://www.smartgrid.gov/files/SMUDCBS_Final_Evaluation_Submitted_DOE_9_9_2014.pdf

[32] Due to limitations in the availability of accurate opt-out dates across the entire evaluation period, these rates constitute an upper bound on the true opt-out rate. The true opt-out rates may be lower.

Table 16 Cumulative Opt-Out Rates by Treatment and Season

Treatment	Summer 2017		Winter 2017/2018	
	%	Count of Customers	%	Count of Customers
PTR Only				
PTR1	4.2%	15	4.5%	16
PTR2	4.6%	11	6.3%	15
PTR3	5.1%	21	5.4%	22
Opt-Outs				
PTR2-OO	1.7%	13	2.3%	18
BDR-OO	1.9%	241	3.2%	398
TOU Only				
TOU1	7.0%	28	8.0%	32
TOU2	7.3%	68	8.6%	80
TOU3	8.1%	33	8.6%	35
Hybrids				
TOU1xPTR2	9.9%	32	10.6%	34
TOU2xPTR2	9.4%	22	9.9%	23
TOU2xBDR	7.2%	63	8.3%	72
TOU3xPTR2	8.7%	26	9.7%	29

Cumulative opt-out rates through Winter 2017/2018 ranged between 2.3% and 10.6%. The most important differences in opt-out rates were between treatments of different types: opt-in vs. opt-out treatments and PTR vs. TOU or Hybrid treatments. In general, only small differences existed between treatments of a given type. For example, opt-rates ranged between 7.0% and 8.1% for TOU-only customers and 4.6% and 5.1% for PTR-only customers. Most differences in opt-out rates between treatments of a given type were random and not statistically significant.

Opt-out rates for opt-in treatments were higher than those for opt-out treatments. For opt-in treatments, opt-out rates through the end of W2017/2018 season ranged from 4.5% (PTR1) to 10.6% (TOU1xPTR2).

For the opt-out PTR2 and BDR treatments, opt-out rates were 2% and 3%, respectively. The opt-out rates were lower for opt-out treatments than opt-in treatments because many customers automatically enrolled in the program are complacent: they will neither opt in nor opt out of a program if given the opportunity. Also, opt-out customers may be less likely to know how to opt-out of treatment.

Among opt-in treatments, opt-out rates were higher for TOU and Hybrid treatments than for PTR treatments. The opt-rates for TOU and Hybrid treatments ranged between 8% and 11% through W17/18, almost twice as high as those for PTR customers. The higher opt-out rates for TOU and Hybrid customers aligns with the lower rates of customer satisfaction with these treatments as documented below in the *Customer* Experience section.

Load Impacts

The following section provides load impact estimates by Flex treatment for the Summer 2017 and Winter 2017/2018 events seasons. Table 17 summarizes the average load reductions during Flex events and on-peak TOU periods. Reporting is focused on the most current Flex event seasons due to two factors:

- The final wave of Flex recruitment occurred in March 2017. PGE did not achieve its recruitment targets until summer 2017, and previous seasons had participation levels significantly below the targets.
- During the first two pilot seasons, PGE implemented major improvements in the program delivery (e.g., in deploying events, messaging customers, and providing participants with feedback); by summer 2017, PGE had these refinements in place, and the pilot better reflected how a full-scale program will be implemented.

Load impacts from two initial Flex seasons are provided in the Appendix D. PGE plans additional research to estimate load impacts as a function of customer demographic and housing characteristics. PGE will use research about the relationships between demand savings and customer characteristics will inform future DR program design, marketing, and delivery.

Prior to the Flex pilot, PGE ran a CPP pilot between 2011 and 2013, which achieved demand savings during summer and winter afternoon events of 10% and 12%, respectively. In comparison to the Flex PTR-only treatments, the CPP pilot achieved lower savings in summer, but higher savings in winter.

Table 17 Flex Demand Savings by Treatment and Season[33]

Category	Treatment		Summer Demand Savings[34]: Planning (%)	Summer: Evaluation (%)	Summer: Abs. Precision at 90% Conf.	Summer: Evaluation (kW)	Winter Demand Savings[35]: Planning (%)	Winter: Evaluation (%) AM	Winter: Evaluation (%) PM	Winter: Abs. Precision at 90% Conf. AM	Winter: Abs. Precision at 90% Conf. PM	Winter: Evaluation (kW) AM	Winter: Evaluation (kW) PM
PTR-Only	PTR1		13%	18%	±4%	0.41	14%	13%	7%	±7%	±4%	0.23	0.13
	PTR2			22%	±6%	0.48		0%	8%	±8%	±5%	-0.01	0.14
	PTR3			17%	±4%	0.39		3%	12%	±7%	±3%	0.05	0.22
Opt-Out	PTR2-OO		6%	7%	±3%	0.16	7%	0%	6%	±5%	±3%	0.00	0.10
	BDR-OO		3%	2.30%	±1%	0.05	3%	-0.7%	1%	±1%	±1%	-0.01	0.02
TOU-Only	TOU1	On-Peak	5%	2%	±3%	0.02	6%	-1%		±4%		-0.02	
		Flex Event		-1%	±6%	-0.02		2%	0%	±7%	±5%	0.03	0.00
	TOU2	On-Peak		8%	±3%	0.12		3%		±3%		0.04	
		Flex Event		5%	±5%	0.10		2%	2%	±6%	±4%	0.04	0.04
	TOU3	On-Peak		5%	±4%	0.07		0%		±3%		0.00	
		Flex Event		6%	±6%	0.13		3%	-1%	±9%	±5%	0.05	-0.01
Hybrids	TOU1xPTR2	On-Peak	5.2% TOU; 12.9% PTR	3%	±4%	0.04	5.8% TOU; 14.2% PTR	1%		±5%		0.01	
		Flex Event		10%	±7%	0.21		10%	5%	±11%	±6%	0.17	0.08
	TOU2xPTR2	On-Peak	5.2% TOU; 12.9% PTR	24%	±5%	0.33	5.8% TOU; 14.2% PTR	5%		±5%		0.08	
		Flex Event		20%	±8%	0.43		12%	13%	±13%	±6%	0.22	0.25
	TOU2xBDR	On-Peak	5.2% TOU;	8%	±3%	0.12	5.8% TOU;	1%		±4%		0.02	

[33] Seasonal results presented only for Summer 2017 and Winter 2017/2018. Percentage demand savings estimated as kW demand savings estimate divided by average control customer demand

[34] Impact estimates are percentage demand savings during Flex peak-time events and on-peak savings for TOU rates; green indicates significance at 90%.

[35] Ibid.

		Flex Event	3.0% BDR	11%	±5%	0.23	3.3% BDR	-1%	1%	±7%	±5%	-0.02	0.02
	TOU3xPTR2	On-Peak	5.2% TOU; 12.9% PTR	9%	±5%	0.12	5.8% TOU; 14.2% PTR	4%		±4%		0.06	
		Flex Event		8%	±7%	0.17		4%	13%	±10%	±6%	0.08	0.25

Peak-Time Rebates—Summer

Figure 2 shows the kW and percentage demand savings during Flex events for opt-in PTR treatments during summer 2017. PGE tested the load impacts of three peak rebates ($0.80/kWh, $1.55/kWh, and $2.25/kWh) during seven Flex events. The PTR treatments saved between an average of 0.39 kW per customer and an average of 0.48 kW per customer, or about 20% of demand. All PTR load impacts surpassed PGE's planning estimate of 13% for summer seasons.

Despite large differences in rebate levels, significant differences did not emerge between PTR treatments in the estimated demand savings. The $0.80/kWh and the $2.25/kWh rebates produced approximately the same demand savings. This demonstrates that PGE customers reduced consumption in response to the higher opportunity cost of consuming electricity during Flex events, but the rebate amount did not determine the magnitude of the response. In a recent study of a California critical peak pricing program, Gillan (2017) made a similar finding, showing that customers were not sensitive to marginal changes in critical peak prices.[36]

Although the rebate did not influence the estimated demand savings, it affected customer satisfaction, as discussed demonstrate in the Customer Satisfaction with Flex section.

Figure 2 PTR-Only Demand Savings During Flex Events—Summer 2017[37]

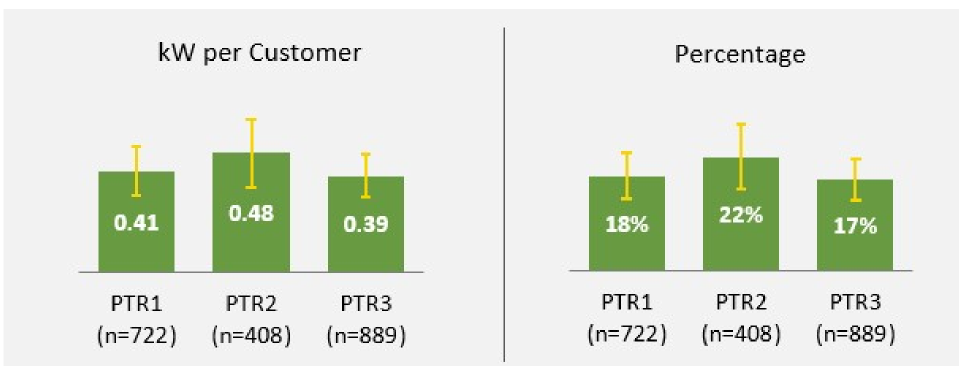


Figure 3 shows estimated PTR demand savings and ambient outdoor temperature in °F for each of seven events during summer 2017. Peak-time rebates produced similar average demand savings per customer across events, between 0.3 kW and 0.5 kW. No correlation occurred between outdoor temperatures and demand savings during events.

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[36] Gillan, James, 2017. Dynamic Pricing, Attention, and Automation: Evidence from a Field Experiment in Electricity Consumption. Energy Institute at Haas Working Paper 284. Available at: https://ei.haas.berkeley.edu/research/papers/WP%20284.pdf

[37] Figure shows estimates of average kW savings per customer and percentage kW savings relative to control group customer demand during Flex events. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% confidence intervals (CIs) estimated with standard errors clustered on customers.

Figure 3 PTR-Only Demand Savings by Flex Event—Summer 2017[38]

Peak-Time Rebates—Winter

Figure 4 shows demand savings during Winter 2017/2018 Flex events for the opt-in PTR treatments. Six afternoon PTR events and one morning event occurred. The figure presents separate savings estimates for the morning (AM) and afternoon (PM) events. Unlike the summer season, all PTR treatments during the winter season produced point estimates of savings lower than PGE's planning estimates (14%). The PTR savings estimates may have been lower than PGE expected because the Winter 2017/2018 season was milder than normal.[39]

During the morning event, opt-in PTR customers saved between 0% (PTR2) and 13% (PTR1) of demand. During the six afternoon events, opt-in PTR customers saved between 7% (PTR1) and 12% (PTR3). As in summer, no relationship between savings and the rebate amount became evident. While PTR3 customers, who received the largest rebate, saved the most during evening events, PTR1 customers, who received the smallest rebate, saved the most during the morning event.

[38] Figure shows by Flex event the average outdoor temperature during event hours and estimates of average kW savings per customer. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers.
[39] See *Mean Temperature Departures from Average* in NOAA National Climate Report for December 2017, January 2018, and February 2018. Available at: https://www.ncdc.noaa.gov/sotc/national/.

Figure 4 PTR-Only Demand Savings During Flex Events—Winter 2017/2018[40]

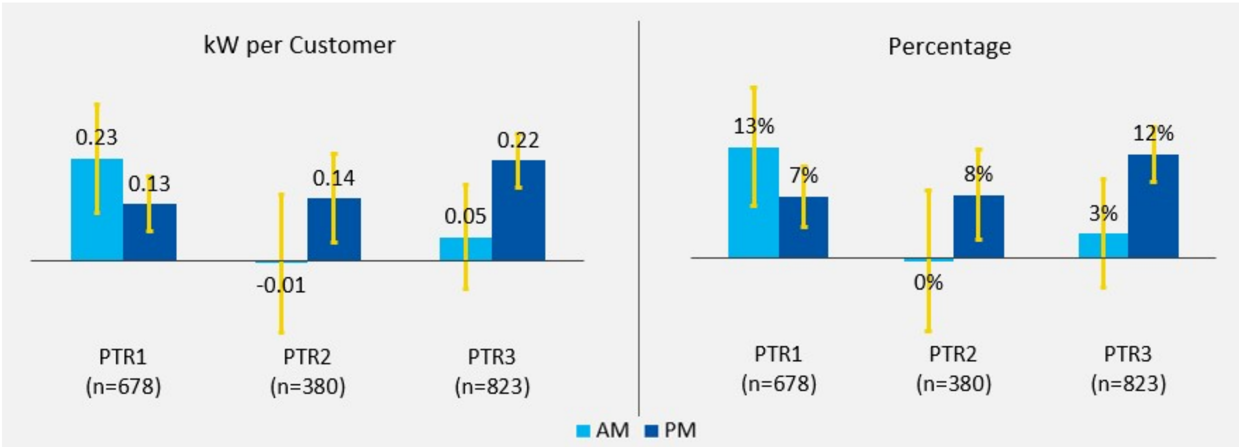
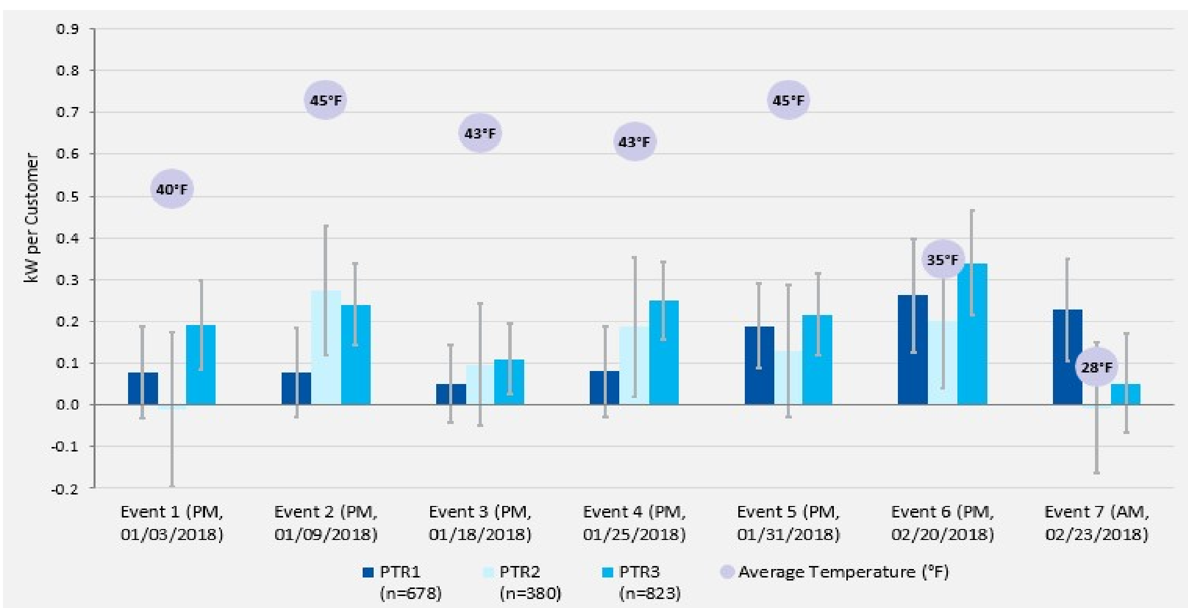


Figure 5 shows demand savings for opt-in PTR customers and outdoor ambient temperatures (°F) during each of the seven events in winter 2017/2018. There was more variation in average demand savings per customer between PTR treatments and across events in winter than summer. PTR3 customers tended to save the most and PTR1 customers the least, but this relationship did not hold for all events. As in summer, no relationship emerged between outdoor temperature and demand savings.

Figure 5 PTR-Only Demand Savings by Flex Event—Winter 2017/2018[41]



[40] Figure shows estimates of average kW savings per customer and percentage kW savings relative to control group customer demand during Flex events. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers.
[41] Figure shows by Flex event the average outdoor temperature during event hours and estimates of average kW savings per customer during Flex events. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers.

Opt-Out Treatments—Summer

PGE also tested opt-out BDR and PTR2 treatments. PGE automatically enrolled customers in these treatments but gave them opportunity to opt-out, which less than 3% of customers did. Though not all PTR-OO customers who remained in the pilot attempted to save during PTR events, as discussed below, many customers did save, including those who would not have enrolled if given the choice. Except for the rebate, the BDR and PTR treatments were similar: opt-out customers received event notifications, encouragement to reduce demand, and personalized feedback about their savings. By comparing the BDR and PTR treatments, Cadmus could isolate the incremental effect of providing a rebate on peak demand savings.

Figure 6 shows the estimated demand savings for opt-out treatments during summer 2017 Flex events. Opt-out PTR2 customers saved an average of 0.16 kW per customer (or 7% of demand); and BDR saved an average of 0.05 kW per customer (or 2% of demand). While load impacts for PTR2-OO slightly surpassed PGE's 6% planning estimate, the load impacts for BDR-OO savings fell short of PGE's planning estimate (3%).The rebate's incremental effect was about 0.12 kW per customer or 5% of demand. In addition to increasing Flex event demand savings, the rebate increased customer satisfaction with the Flex pilot. As shown in Figure 20 below, PTR2-OO participants reported being more satisfied (6 to 10 ratings) and delighted (9 to 10 ratings) than BDR-OO participants by significant margins.

Opt-out PTR2 customers saved substantially less during Flex events than opt-in PTR2 customers, who, as Figure 2 shows, saved about 20% of demand; however, the group of treated opt-out customers included a large percentage of customers who would not have opted into treatment if given the choice. These customers included *complacent* customers, who stayed in treatment after PGE automatically enrolled them, and *never-takers*, who opted out after enrollment. A back-of-the envelope calculation suggests that the average *complacent* PTR customer saved about 6% of demand during Flex events.[42]

[42] The 7% savings estimate for the opt-out PTR2 treatment represented an average of savings across the following customer types: (1) *always-takers*—customers who would opt into the pilot if given the opportunity; (2) *complacents*—customers who would neither opt-in nor opt-out of treatment if given the choice, but who nevertheless might save when enrolled; and (3) *never-takers*—customers who would never enroll and always opted out given the choice. Our estimate assumed never-takers would not save and the 22% savings estimate for opt-in PTR2 customers was a reasonable estimate of PTR2 savings for always-takers. Additionally, from Table 11 and Table 12, *always-takers* constituted about 5% of the population (i.e., average opt-in rates for PTR1, PTR2, and PTR3 treatments), and *never-takers* constituted about 3% of the population (i.e., opt-out rate for opt-out PTR2). This implies that *complacent* customers constituted 92% of the customers defaulted into PTR2 treatment; and that *complacent* customers saved an average of 6.4% of demand.

Figure 6 Opt-Out Treatments Demand Savings During Flex Events—Summer 2017[43]

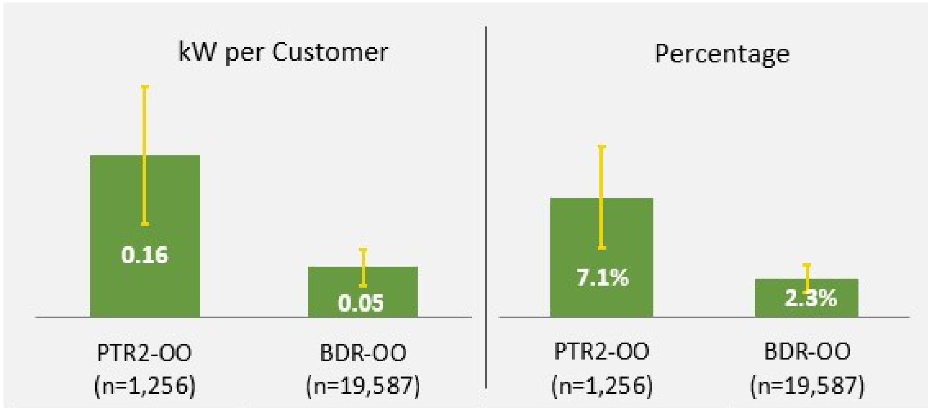
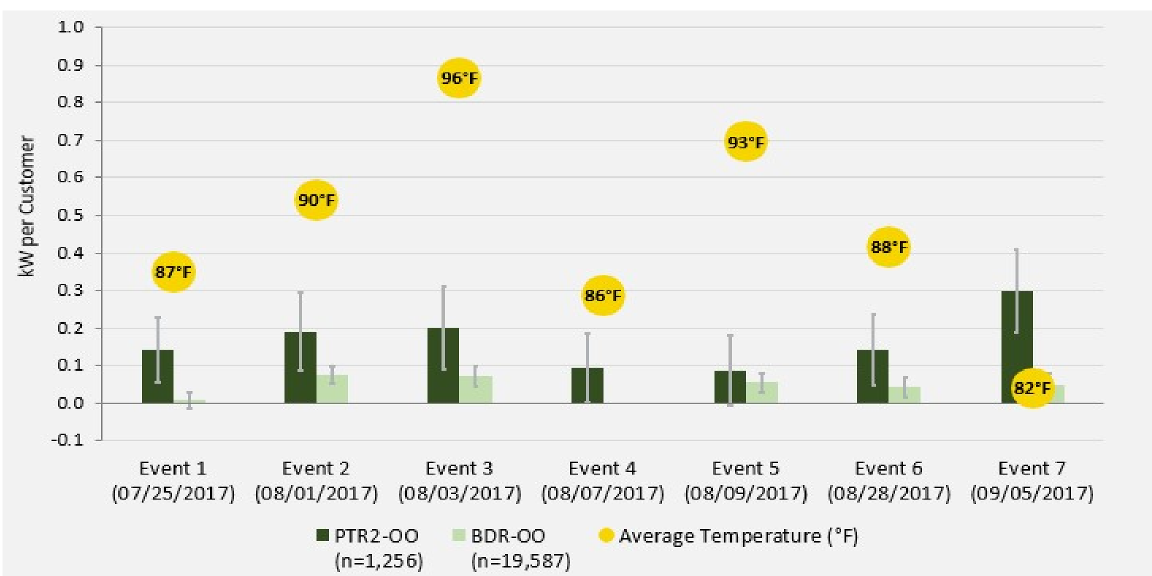


Figure 7 shows PTR2-OO and BDR-OO demand savings and ambient outdoor temperatures during Flex events for each of the seven events during summer 2017. PGE did not dispatch BDR-OO for Event 4 (August 7, 2017). Across the events, PTR2-OO produced average demand savings per treated customer between 0.1 kW per customer and 0.3 kW per customer; BDR-OO produced savings between 0.01 kW per customer and 0.08 per customer. No relationships between outdoor temperatures and savings became evident in the event impact estimates.

Figure 7 Opt-Out Treatments Demand Savings by Flex Event—Summer 2017[44]



[43] Figure shows estimates of average kW savings per customer and percentage kW savings relative to control group customer demand during Flex events. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers.

[44] Figure shows estimates of average kW savings per customer. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers. During event 4, PGE did not dispatch BDR-OO customers.

Opt-Out Treatments—Winter

Figure 8 shows demand savings estimates during winter 2017/2018 Flex events, which included six afternoon events and one morning event, for PTR2-OO and BDR-OO treatments.

During morning events, neither opt-out treatment achieved demand savings. The savings point estimates were small and statistically indistinguishable from zero. During evening events, PTR2-OO customers saved 6% of demand and BDR-OO customers saved 1% of demand, with both estimates statistically significant. For both opt-out treatments, demand savings were slightly less than PGE planning estimates for winter (7% for PTR-OO and 3% for BDR-OO). Based on a comparison of PTR2-OO and BDR-OO impacts, the rebate increased Flex events savings by about 4%. As in summer, the rebate enhanced customer satisfaction with Flex, lifting the percentage of satisfied customers by about 10%.

The opt-out PTR and BDR treatments saved less in winter than summer. One hypothesis explaining the smaller winter savings is that PGE customers had a lower tolerance for cold than heat and therefore were less willing to adjust their thermostat settings in winter. Another hypothesis holds that PGE customers had fewer opportunities to save. Many PGE customers heat with natural gas, eliminating the potential for demand savings from the largest home energy end use.

Figure 8 Opt-Out Treatments Demand Savings During Flex Event—Winter 2017/2018[45]

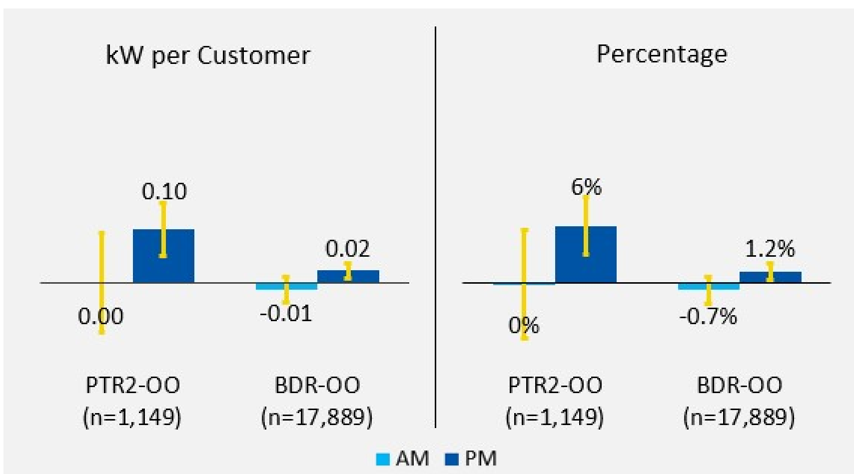
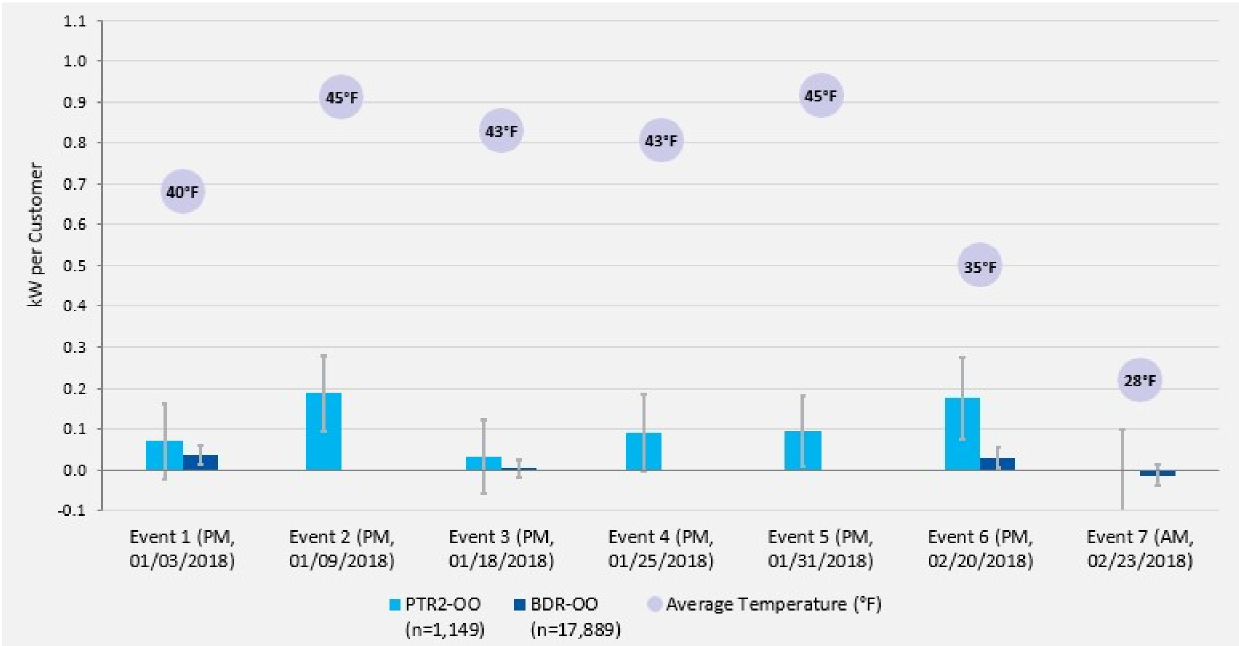


Figure 9 shows PTR2-OO and BDR-OO demand savings and ambient outdoor temperatures for each winter 2017–2018 event. PGE did not dispatch BDR-OO for events 2, 4, and 5 (January 1, 2018, January 25, 2018, and January 31, 2018). PTR2-OO demand savings ranged from zero kW per customer (Event 7) to 0.2 kW per customer (Event 2). As with opt-in PTR, no relationship emerged between outdoor temperatures and demand savings.

[45] Figure shows estimates of average kW savings per customer and percentage kW savings relative to control group customer demand during Flex events. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers.

Figure 9 Opt-Out Treatments Demand Savings by Flex Event—Winter 2017/2018[46]



PGE Payments for Savings Caused by Peak Time Rebates

PTR customers earned rebates for saving energy relative to a customer-specific baseline but were not penalized for exceeding the baseline.[47] PGE paid customers for savings whether the savings were caused by the rebate, naturally-occurring, or from random variation in the customer's consumption. Since PGE pays for some savings that are not caused by the rebate and there is no corresponding financial penalty for increasing consumption above the baseline, PGE will overpay for savings at the program level.

As Table 18 reports, in Summer 2017, PGE paid an average of between $10 and $30 in rebates per PTR customer, depending on the rebate amount. In Winter 2017/2018, PGE paid an average of $6 and $20 in rebates per PTR customer. To estimate how much of the savings that PGE paid for represented savings caused by the program, Cadmus compared the evaluation's estimate of PTR savings per customer with PGE's estimate of average PTR savings per customer from its performance calculations.

Table 18 compares the savings estimates from PGE's performance calculation and the evaluation. For PTR-only treatments, the ratio of evaluated average PTR savings per customer to performance calculated

[46] Figure shows estimates by event of average kW savings per customer. Errors bars show 90% CIs estimated with standard errors clustered on customers. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. During events 2, 4, and 5, PGE did not dispatch BDR-OO customers.

[47] The PTR is an asymmetric incentive. Customers face a higher effective marginal price for electricity equal to the sum of the rebate and the standard rate when their consumption is below the baseline and a lower effective marginal price for electricity equal to the standard rate when consumption is above the baseline.

average savings per customer ranged between 67% and 83% in summer and 25% and 44% in winter. For the PTR hybrid treatments, the ratio ranged from 37% to 108% in summer and from 27% to 74% in winter.

Table 18 Evaluated Demand Savings vs. PGE Performance-Calculated Savings – Opt-In PTR[48]

Treatment	Summer 2017			Winter 2017/2018		
	Performance-Calculated (kWh)	Evaluated Savings (kWh)	Ratio	Performance-Calculated (kWh)	Evaluated Savings (kWh)	Ratio
PTR1	12.59	9.38	75%	7.97	2.82	35%
PTR2	13.36	11.04	83%	9.20	2.33	25%
PTR3	13.27	8.91	67%	8.98	3.95	44%
TOU1xPTR2	10.20	4.73	46%	7.11	1.95	27%
TOU2xPTR2	9.27	9.96	108%	6.69	4.95	74%
TOU3xPTR2	10.33	3.85	37%	7.15	4.47	63%

These results confirm that at least some savings for which PGE paid customers were naturally occurring and not caused by the rebates. For PTR-only customers, between one-third and one-fifth of performance-calculated savings in summer and one-half and three-quarters of performance-calculated savings in winter were not attributable to the program. Note, these overestimates of savings apply only to the performance-calculated figures used to pay customers, not to the evaluated savings shown in this report.

PGE may have overpaid for savings more in winter than summer for two reasons. First, as comparison of Figure 2 and Figure 4 show, PTR customers tended to save less in winter than summer, suggesting that a higher percentage of customers who PGE estimated to have saved did not in fact save. Second, customer demand during Flex events tended to be more variable in winter than summer, which could also increase PGE's payments for savings not caused by the pilot.

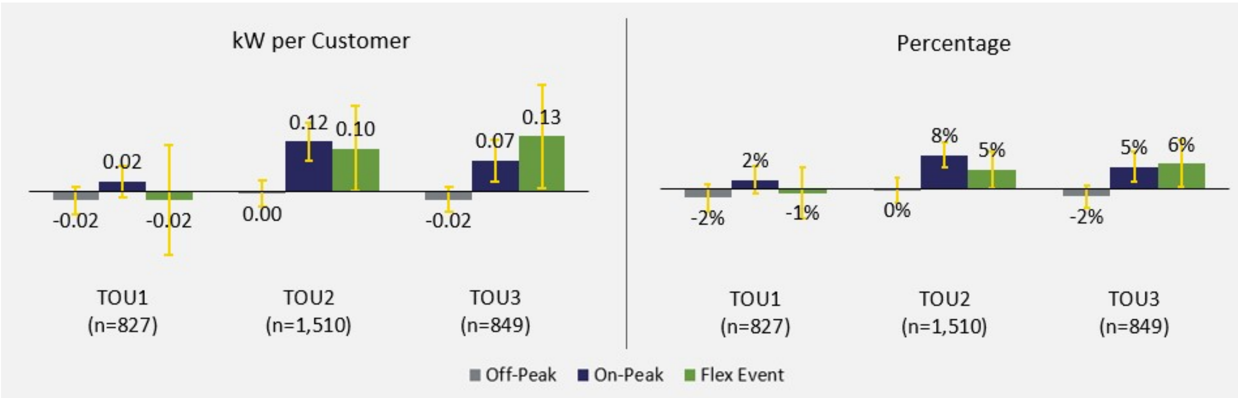
TOU-Only Treatments—Summer

Figure 10 shows kW and percentage load impacts for TOU-only treatments in summer 2017. The figures show estimated average load impacts per treated customer during off-peak hours, on-peak hours, and Flex event hours. Although TOU-only customers did not receive notification of Flex events, Cadmus measured load impacts during Flex hours to estimate impacts of TOU pricing on reducing system peak

[48] Performance-calculated savings are average savings per customer per season verified by PGE for calculating customer rebates. Evaluated savings are the average savings per customer per season estimated by Cadmus.

demand. The figures show reductions in demand or savings as positive impacts, and show load increases as negative impacts.

Figure 10 TOU-Only Demand Savings—Summer 2017[49]



Estimated load impacts for TOU1 customers were small and not statistically significant. In summer 2017, TOU1 customers reduced their consumption during on-peak hours by 2% and increased their consumption by 2% during off peak hours, but neither impact proved statistically significant, as shown by the 90% confidence intervals (CI), which were tightly estimated and included zero. TOU1 customers also did not save demand during Flex events, which proxy for hours of PGE system-peak demand.

The TOU1 rate schedule's design likely explained the small estimated impacts. The on-peak period occurred on non-holiday weekdays, from 6:00 a.m. to 10:00 p.m., covering waking hours for many customers, and making it difficult for them to shift loads from on-peak to off-peak periods. Many customers would need to adjust their routines to accommodate the TOU1 schedule or to schedule their household appliances (e.g., dishwashers, washing machines) to run at night. It remains unclear, however, how many Flex customers could schedule when their appliances would operate. In surveys, many TOU1 customers reported dissatisfaction with Flex due to the rate schedule being difficult for their households to adopt; these customers said it was not convenient or worth changing sleep schedules to do chores during off-peak periods.

While TOU1 did not yield the desired load shifting, the TOU2 and TOU3 rates, having shorter on-peak periods, did so. Both rates defined on-peak periods as hours during non-holiday weekdays, from 3:00 p.m. to 8:00 p.m. In addition, the TOU3 rate defined the mid-peak period as non-holiday weekday hours from 11:00 a.m. to 3:00 p.m. and 8:00 p.m. to 10:00 p.m. During the mid-peak period, customers faced

[49] Figure shows estimates of average kW savings per customer and percentage kW savings relative to control group customer demand during TOU off-peak, TOU on-peak, and Flex event hours (i.e. a proxy for system-peak demand hours). Reductions in demand (savings) are shown as positive values and increases in demand are shown as negative values. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers. The TOU3 rate also had a mid-peak period. During the mid-peak period, TOU3 customers demanded 0.05 kW or 5% less on average, with a 90% CI of [0.01 kW, 0.09 kW] or [1%, 8%].

a lower retail rate for electricity than the on-peak period rate but had a rate higher than the off-peak period rate.

The TOU2 and TOU3 rates produced similar off-peak and on-peak load impacts. During on-peak hours, TOU2 customers reduced demand by about 0.12 kW per customer (or 8%), and TOU3 customers reduced demand by about 0.07 kW per customer (or 5%). The difference in these estimates was not statistically significant. Only weak evidence emerged of load shifting. TOU2 customers increased off-peak consumption by less than 0.5%, and TOU3 customers increased consumption by about 2%, but neither estimate proved statistically different from zero. This suggests customers tended to reduce demand during peak periods by, for example, adjusting their thermostat settings or turning off lights, rather than shifting consumption from peak to off-peak periods by, say, delaying dishwashing and laundry. As Figure 18 shows, approximately 50% of TOU participants reported having turned off lights or adjusted thermostat settings during peak periods.

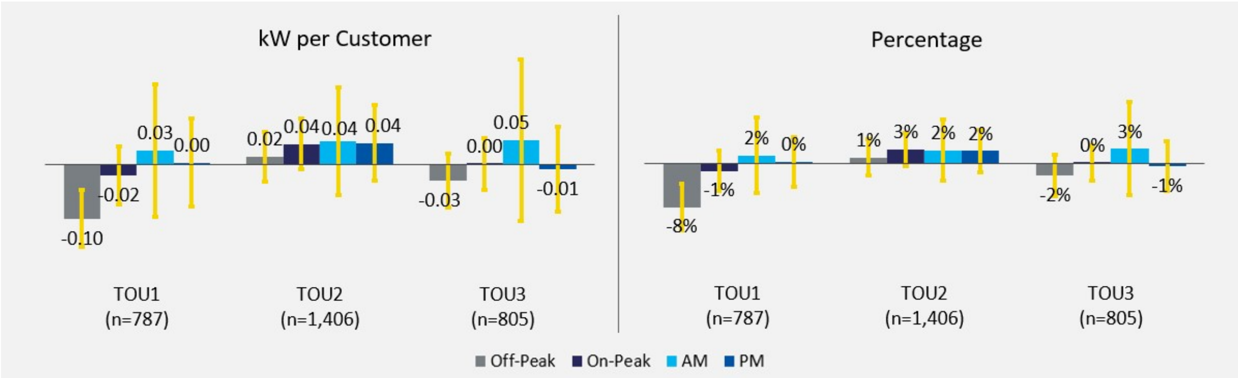
Estimated load impacts during Flex event hours (i.e., a proxy for system-peak demand hours) were about the same as those during on-peak hours. TOU2 and TOU3 customers saved about 5% and 6% of demand. Again, PGE did not notify TOU-only customers of Flex events; so, it was expected that demand savings during event hours would not be significantly greater. For TOU2 and TOU3, load impacts for on peak and Flex event periods met or surpassed the 5% PGE planning estimate.

TOU-Only Treatments—Winter

Figure 11 shows load impacts during peak, off-peak, and Flex event hours (again, a proxy for system peak demand hours) for TOU1, TOU2, and TOU3 treatments. In winter, PGE scheduled morning and afternoon on-peak periods. Although TOU-only customers were not notified of Flex events, Cadmus estimated the average TOU savings per customer during seven Flex events to assess the impacts of TOU pricing during periods approximating system peak demand.

TOU pricing produced smaller reductions in demand in winter than summer. Except for TOU1 during off-peak hours, none of the TOU-only treatments reduced loads during on-peak hours or shifted loads to off-peak hours. In general, impact estimates were small, and CIs for all estimated impacts included zero. None of the TOU-only treatments saved demand during Flex events, or the savings were too small to detect with the available sample sizes. The savings estimates were small and statistically insignificant. Peak period and Flex event saving for all TOU treatments were lower than PGE's planning estimate of 6% reduction for winter. Based on the estimated CIs, it is possible to reject the hypothesis that demand savings during on-peak and Flex hours were greater than or equal to 6% for each TOU rate.

Figure 11 TOU-Only Demand Savings—Winter 2017/2018[50]



Why did TOU2 and TOU3 customers reduce demand during peak hours and Flex events in summer but not winter? Two explanations seem possible. First, according to surveys completed with TOU customers, a significant source of peak savings comes through adjustments to thermostat settings. In winter, savings could have been achieved by setting thermostats at a lower temperature during peak periods. PGE customers, however, may have had less tolerance for cold than for heat, and therefore been less willing to make such adjustments. Second, many TOU customers heated their homes with gas (approximately 60% of TOU-only and 53% of Hybrid customers, per the Winter 2017/2018 survey), eliminating a large, potential source of savings from home heating.

TOU Conservation Impacts

TOU pricing encourages customers to shift demand from on-peak, high-price periods to off-peak, low-price periods. However, the expected effect of TOU pricing on total energy consumption is ambiguous. Depending on the customer's elasticity of demand and the changes in relative and absolute prices, total energy consumption could increase, decrease, or stay the same. In Summer 2017, the TOU2 and TOU3 treatments reduced demand during on-peak periods, but there were not statistically significant demand increases during the off-peak periods. This suggests that TOU pricing may have led to a small decrease in overall electricity consumption for the average customer.

Table 19 presents estimates of the total electricity consumptions impacts of TOU pricing in summer and winter. Cadmus estimated the impacts by regressing customer daily electricity consumption on an indicator for assignment to the test group, day-of-sample fixed effects, recruitment-wave fixed effects, customer pre-treatment average daily consumption, and daily cooling degrees. We tested the sensitivity

[50] Figure shows estimates of average kW savings per customer and percentage kW savings relative to control group customer demand during TOU off-peak, TOU on-peak, and a.m. and p.m. Flex event hours. Reductions in demand (savings) are shown as positive values and increases in demand are shown as negative values. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers. The TOU3 rate also had a mid-peak period. During the mid-peak period, TOU3 customers demanded 0.03 kW or 2% less on average, with a 90% CI of [-0.02 kW, 0.07 kW] or [-2%, 5%].

of the estimates to different model specifications and found that the estimates were robust. The impacts shown in the table are adjusted for opt-outs.

Table 19 TOU-Only Energy Conservation Impacts[51]

Treatment	Daily Energy Savings, Summer 2017		Daily Energy Savings, Winter 2017-2018	
	kWh	Abs. Precision at 90% Conf.	kWh	Abs. Precision at 90% Conf.
TOU1	0.08	±0.82	-1.27	±1.35
TOU2	0.02	±0.83	0.38	±1.21
TOU3	0.37	±0.86	-0.39	±1.14

TOU pricing did not result in statistically significant changes in energy consumption. In summer, the impacts for TOU1 and TOU2 were small and not statistically significant, as the estimated CIs included zero. TOU3 customers saved an average of 0.37 kWh per customer per day, but, as with the other TOU-only treatments, the estimate was not statistically significant. In winter, none of the energy savings estimated was statistically different from zero. The point estimates show that relative to control group customers, TOU1 and TOU3 customers increased energy consumption, while TOU2 customers reduced their consumption.

When Cadmus calculated the average daily energy savings per TOU customer using the on-peak period and off-peak period demand impact estimates in Figure 10 and Figure 11, we also obtained small and statistically insignificant savings.

Hybrid Treatments—Summer

Figure 12 shows load impacts for Hybrid treatments in summer 2017, including TOU pricing with PTR and TOU pricing with BDR.

In general, the Hybrid treatments produced load reductions during on-peak periods like those for TOU-only treatments. The TOU1xPTR2 treatment did not produce statistically significant peak savings.

Customers on TOU2xPTR2, TOU2xBDR, and TOU3xPTR2 saved, respectively, 0.33 kW per customer (24%), 0.12 kW per customer (8%), and 0.12 kW per customer (9%). The TOU2xBDR and TOU3xPTR2 impacts during on-peak hours were like those for TOU2 and TOU3 treatments. Customers on

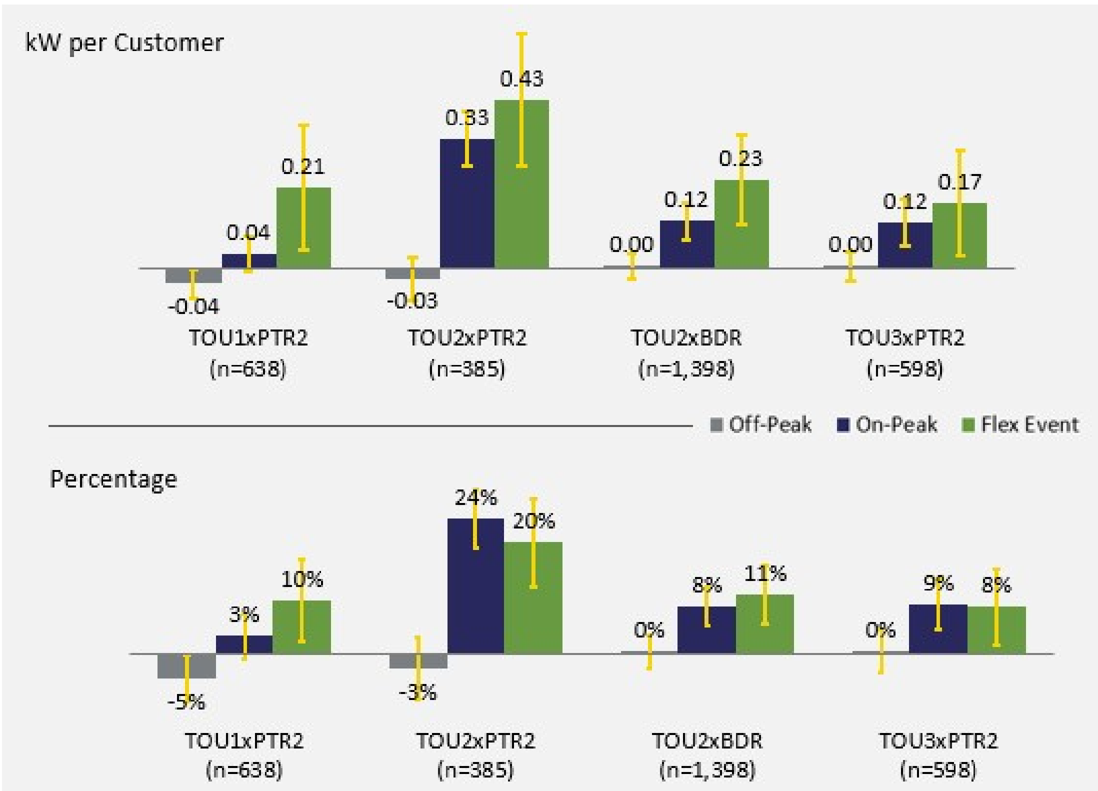
TOU2xPTR2, however, saved more than TOU2 (8%) customers. These peak savings estimates exceeded PGE's planning estimate of 5% for TOU rates in summer. None of the Hybrid treatments produced statistically significant load shifting from peak to off-peak hours. The load impact estimates for off-peak hours were close to zero and statistically insignificant. While generating approximately the same peak

[51] The table reports the average daily energy savings per treated customer. Positive values indicate energy savings. The precision was estimated based on standard errors clustered on customers.

period demand savings as the TOU-only treatments, the TOUxPTR2 treatments tended to produce higher customer satisfaction Table 37.

During Flex events, the Hybrid treatments produced savings between 8% and 20% of demand. TOU1xPTR2, TOU2xBDR, and TOU3xPTR3 yielded Flex event savings of approximately 10%, results close to and not statistically different from demand savings estimates during on-peak periods. TOU2xPTR2 saved about 20% of demand—about twice as large as Flex event savings estimates for other Hybrid treatments and four times as large as the Flex event savings for TOU2-only treatment. Except for TOU2xPTR2, the Hybrid PTR treatments did not exceed PGE's planning estimate of 13% savings for opt-in PTR treatments in summer.

Figure 12 Hybrid Demand Savings—Summer 2017[52]



In comparison to PTR2-only treatment, TOU-PTR hybrid treatments tended to generate smaller savings during Flex events (i.e., a proxy for system-peak demand hours). TOU2xPTR2 yielded approximately the same Flex event savings (20%) as PTR2 (22%), but TOU1xPTR2 and TOU3xPTR2 treatments produced

[52] Figure shows estimates of average kW savings per customer and percentage kW savings relative to control group customer demand during TOU off-peak, TOU on-peak, and a.m. and p.m. Flex event hours. Reductions in demand (savings) are shown as positive values and increases in demand are shown as negative values. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers. The TOU3 rate also had a mid-peak period. During the mid-peak period, TOU3xPTR2 customers demanded 0.10 kW or 9% less on average, with a 90% CI of [0.05, 0.15 kW] or [4%, 13%].

much smaller savings than PTR2 only (10% and 8% vs. 22%). TOU1xPTR2 and TOU3xPTR2 treatments also produced smaller Flex event savings than PTR1 (18%), which offered customers a smaller rebate per kWh of savings than PTR2.

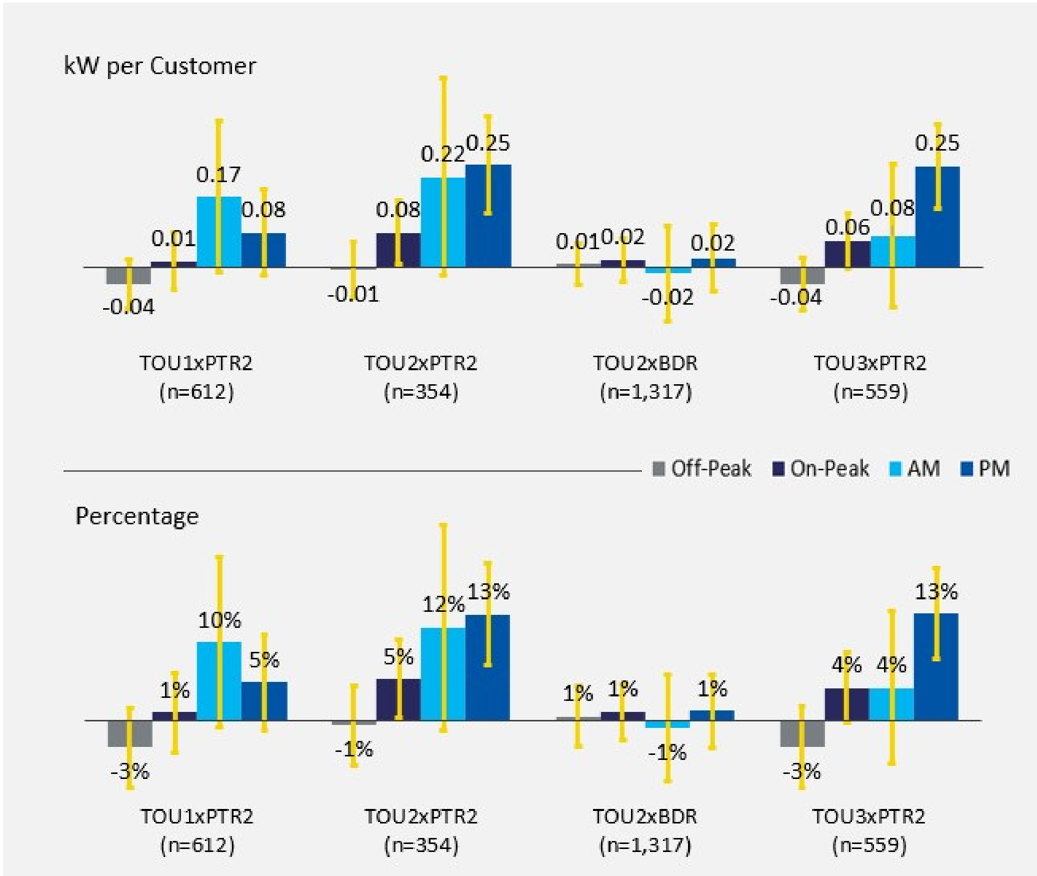
Hybrid treatments may have produced smaller Flex event savings than PTR-only for two reasons:

- Hybrid customers who reduced peak period consumption or shifted consumption to off-peak periods would have had lower baselines than PTR-only customers for calculating PTR savings, decreasing rebate payments and reducing the incentives for saving during Flex events. PGE used non-event days during Summer 2017 to establish the consumption baseline for calculating a customer's PTR savings, which would tend to result in lower baselines for TOU customers who saved during peak periods.
- Hybrid customers may have become inattentive to Flex events, having formed energy consumption habits (e.g., programming thermostats) to save demand during TOU on-peak periods that would have been costly from a time, effort, or psychic perspective to change during Flex events. For example, customers may have adjusted their thermostat settings to save during TOU on-peak periods, and it may have been easier for TOU customers simply to ignore event notifications than to make further adjustments to their settings. As discussed below, many TOUxPTR customers' surveys reported that they already conserved regularly and did not feel they needed to do more during events.

Hybrid Treatments—Winter

Figure 13 shows load impacts for TOU Hybrid treatments in Winter 2017/2018. In many ways, the results mirrored those for summer 2017, though load impacts tended to be smaller. As with TOU1-only treatment, TOU1xPTR2 treatment proved difficult for PGE customers; TOU1xPTR2 treatment did not result in peak savings or load shifting from peak to off-peak periods in winter. As discussed below, however, TOU1xPTR2 customers experienced higher satisfaction than TOU1-only customers, suggesting PTR lifted customer satisfaction. TOU2xPTR2 and TOU3xPTR2 customers reduced demand during peak periods by 0.08 kW per customer (5%) and 0.06 kW per customer (4%), but TOU2xBDR treatment did not produce statistically significant demand savings. TOU2xBDR was the only hybrid treatment that did not provide rebates to customers for reducing demand during Flex events, and it produced demand savings during on-peak periods and Flex events very similar to the savings from TOU2-only. None of the Hybrid treatments resulted in statistically significant increases in demand during off-peak hours.

Figure 13 Hybrid Demand Savings—Winter 2017/2018[53]



During Flex events, all Hybrid treatments except TOU2xBDR produced significant demand savings. During the morning Flex event, TOU1xPTR2 saved an average of 0.17 kW per customer (10%), TOU2xPTR2 saved an average of 0.22 kW per customer (12%), and TOU3xPTR2 saved an average of 0.08 (4%), though only the savings estimates for TOU2xPTR2 and TOU3xPTR2 were close to being statistically significant at the 10% level. During afternoon Flex events, TOU1xPTR2 treatment saved 0.08 kW per customer (5%) and TOU2xPTR2 and TOU3xPTR2 treatments saved 0.25 kW per customer (13%). These estimated impacts were close to those for PTR-only treatments in winter.

[53] Figure shows estimates of average kW savings per customer and percentage kW savings relative to control group customer demand during TOU off-peak, TOU on-peak, and a.m. and p.m. Flex event hours. Reductions in demand (savings) are shown as positive values and increases in demand are shown as negative values. Numbers (n) indicate the total number of test and control group customers used in the impact estimation. Errors bars show 90% CIs estimated with standard errors clustered on customers. The TOU3 rate also had a mid-peak period. During the mid-peak period, TOU3xPTR2 customers demanded 0.05 kW or 2% less on average, with a 90% CI [-0.02, 0.12 kW] or [-1%, 8%].

Hybrid Conservation Impacts

Table 20 presents estimates of the energy conservation impacts in Summer 2017 and Winter 2017/2018 for the Hybrid treatments.

Table 20 Hybrid Treatment Energy Conservation Impacts[54]

Treatment	Daily Energy Savings, Summer 2017		Daily Energy Savings, Winter 2017-2018	
	kWh	Abs. Precision at 90% Conf.	kWh	Abs. Precision at 90% Conf.
TOU1xPTR2	0.14	±1.14	0.22	±1.67
TOU2xPTR2	0.35	±1.47	0.75	±1.82
TOU2xBDR	0.36	±0.87	0.20	±1.29
TOU3xPTR2	0.70	±1.06	0.57	±1.62

The point estimates suggest that in summer and winter Hybrid treatments may have reduced energy consumption by less than an average of 0.7 kWh per customer day, but none of the estimates were statistically significant. For example, it was estimated TOU2xPTR2 treatment reduced consumption by an average of 0.35 kWh per customer per day, but the estimated CI [-1.12, 1.82] is wide and includes zero. The CIs for the other treatments are similarly wide and include zero.

When Cadmus calculated the average daily energy savings per TOU customer using the on-peak period and off-peak period demand impact estimates in Figure 12 and Figure 13 and, we also obtained small and statistically insignificant savings.

Customer Experience

The summer and winter experience surveys asked Flex customers about their awareness of rates and event notifications, efforts to reduce or shift loads, participation challenges, satisfaction with Flex, and satisfaction with PGE. Respondents rated their satisfaction on a 0–10 scale, where zero meant *extremely dissatisfied* and 10 meant *extremely satisfied*. PGE defined a 6-10 rating as *satisfied* and a 9-10 rating as *delighted*. The following section describes the major findings from the surveys.

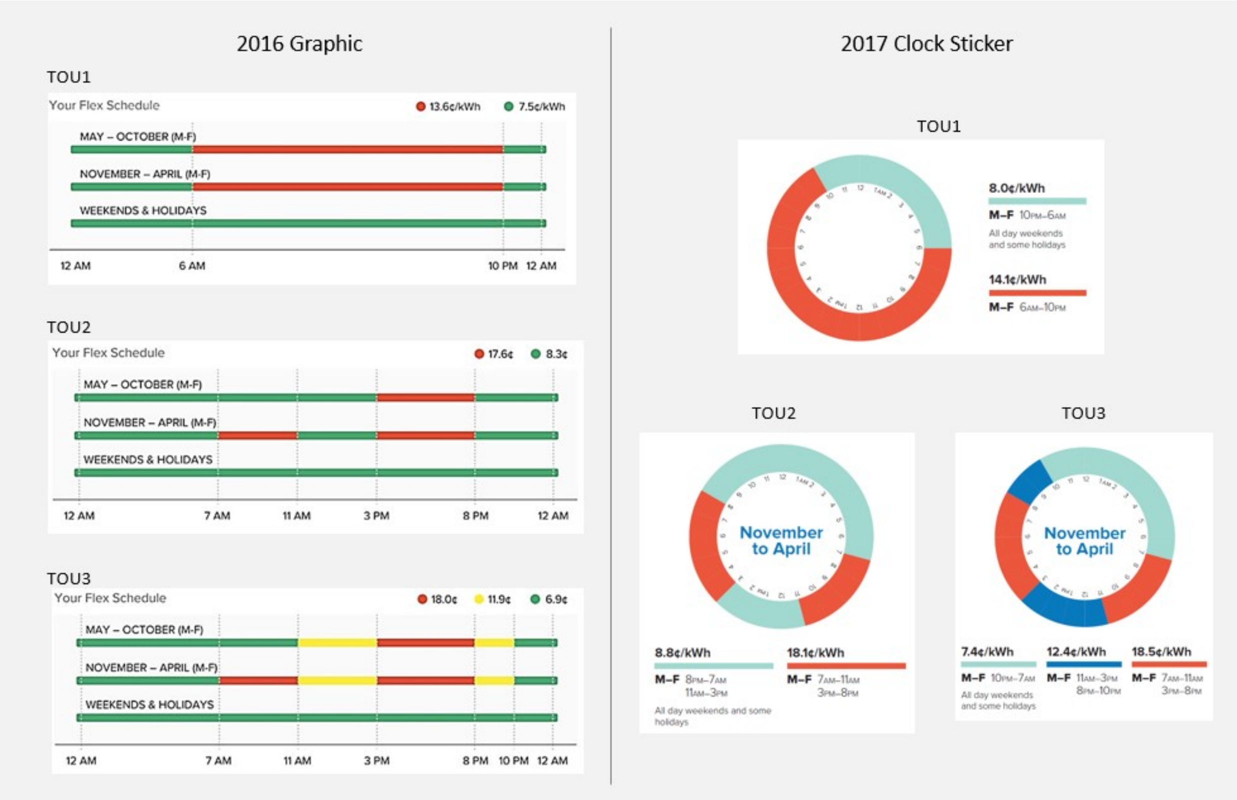
Pricing Awareness

TOU customers could manage electricity costs by either: (1) reducing consumption during high-cost periods; or (2) shifting consumption from high-cost periods to lower-cost periods. Therefore, educating TOU customers about the Flex schedule (i.e., the rates and times) would prove crucial for program success. PGE educated TOU customers in two ways. First, PGE posted rate schedules online, allowing

[54] The table reports the average daily energy savings per treated customer. Positive values indicate energy savings. The precision was estimated based on standard errors clustered on customers.

customers to review them on the Flex website. Also, in 2016, PGE distributed a rate schedule diagram to customers and, in 2017, a rate schedule clock sticker (see Figure 14).

Figure 14 Flex Schedule Educational Materials Distributed to TOU Customers

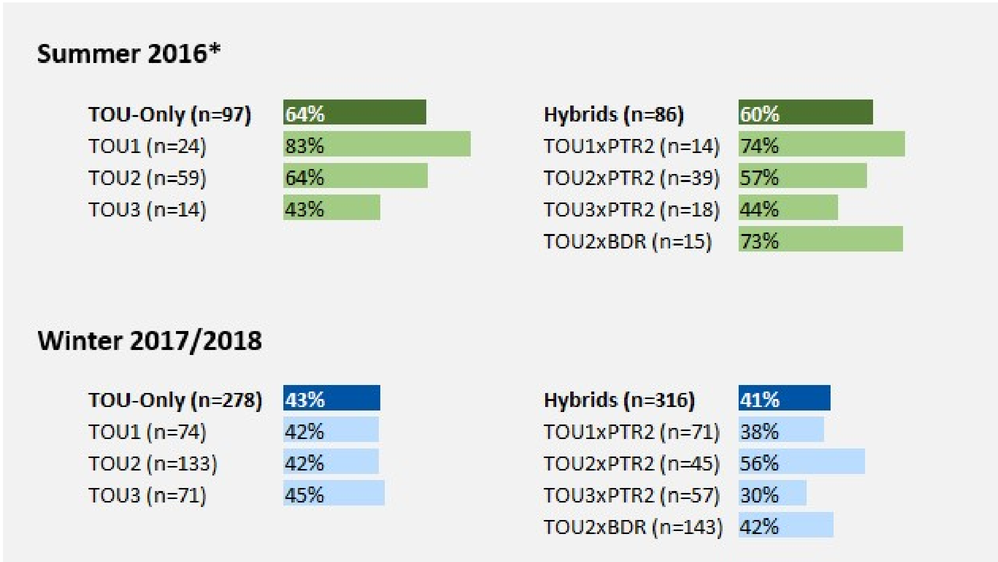


The summer and winter experience surveys asked customers in TOU-only and Hybrid treatments to identify their rate schedule from a list of three schedule images (i.e., the 2016 graphic shown in Figure 14). The surveys, administered online, displayed the 2016 rate schedule images and did not use the 2017 clock sticker images.

Figure 15 shows the percentage of respondents who correctly identified their rate schedules by season and TOU treatment. Due to the small number of respondents per treatment in the summer survey, caution should be exercised in making comparisons between treatments and seasons.

Across treatments and seasons, only 52% of respondents correctly identified their rate schedules. The relatively low rate of correct identification suggests that PGE could do more to educate customers about their TOU rates.

Figure 15 Percentage of Correct Rate Schedule Identification[55]



* The Summer 2017 experience survey did not ask the rate schedule identification question. Results from the Summer 2016 experience survey are reported here instead. Appendix F contains the survey results for Winter 2016/2017.

No significant differences emerged between TOU-only and Hybrid respondents, but in general survey respondents more successfully identified their rate schedule correctly in summer than winter: average correct identification rates were 64% for TOU-only and 60% for Hybrids in summer, while 43% for TOU only and 41% for Hybrids in winter. Across TOU treatments (except TOU3), a significantly higher percentage of summer respondents correctly identified their rate schedules than winter respondents.[56] The summer and winter surveys used the same rate schedule images from 2016. The rate schedule clock sticker that PGE distributed to customers in 2017 did not look like the images found in the survey and may have confused respondents who were used to seeing a clock graphic.

Flex Event Notifications

PGE called approximately seven Flex events per season (see Table 10 for further details). PTR, Hybrid, and BDR customers received an event notification on the day before and day of the event through their preferred communication channels (i.e., email, text, or voice message). The surveys asked customers in PTR and BDR treatments whether they remembered receiving event notifications. Figure 16 shows the percentage of respondents who recalled receiving event notifications by season and treatment.

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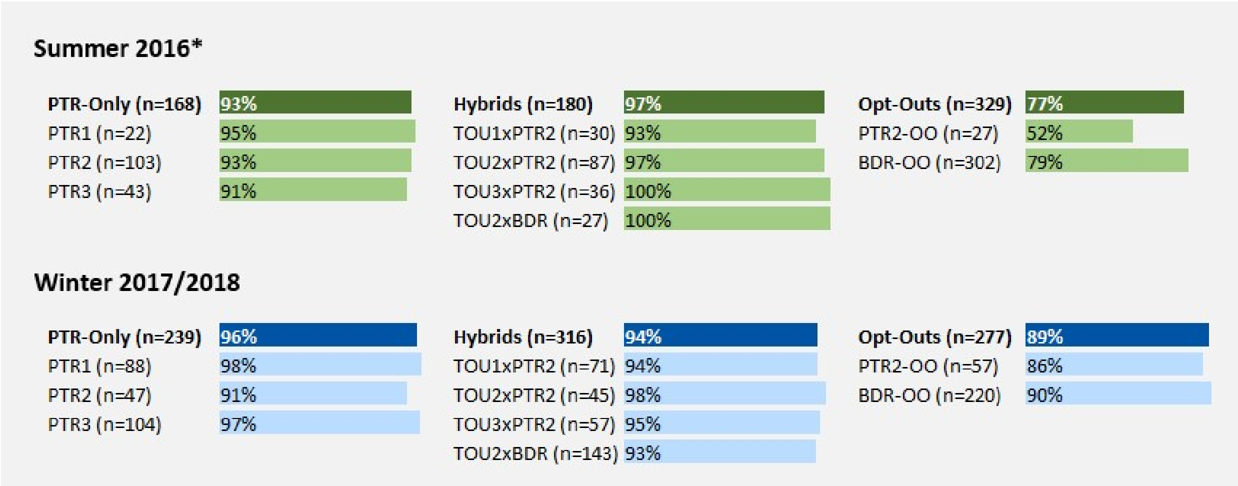
[55] Survey Question: Which image describes the rates you pay for electricity on the Flex Program?
[56] Significant difference with 90% confidence (p≤.10).

Figure 16 Percentage of Event Notification Recall[57]



* As the Summer 2017 experience survey did not ask the event notification question, results from the Summer 2016 event survey are reported here instead.

Most respondents, especially PTR-only and Hybrids, remembered being notified of events. Recall was close to 100% for Hybrid (94%–97%) and PTR-only (93%–96%) respondents but was significantly less (though still high) for Opt-Out respondents (77%–89%), suggesting those voluntarily enrolling in the program were more likely to look for notifications.[58]

The winter survey asked respondents to rate their satisfaction with their chosen event notification channels (email, text message, and/or voice mail) on a 0–10 scale, where zero meant *extremely dissatisfied* and 10 meant *extremely satisfied*. The survey question before this rating question asked respondents how they received notifications about Flex events; the response to this question determined which notification channels respondents rated on. As shown in Table 21, respondents were most satisfied with text message notifications, followed by email notifications, and voice mail notifications.

Table 21 Satisfaction with Flex Event Notifications by Channel Type[59]

Notification Channel	Satisfied (6-10 rating)	Delighted (9-10 rating)	n
Text Message	95%	77%	253
Email	88%	62%	685
Voice Mail	64%	48%	103

[57] Survey Question: Do you remember being notified of Flex Time events prior to their occurrence?
[58] The difference in recall rates between PTR or Hybrid respondents and Opt-Out respondents was significant, with 90% confidence (p≤.10).

[59] Survey Question: How satisfied were you with Flex Time event notifications? Please use a 0 to 10 scale where 0 means “extremely dissatisfied” and 10 means “extremely satisfied.” A) Satisfaction with email notification, B) Satisfaction with text notification, C) Satisfaction with voice notification.

In open-ended comments about customer satisfaction with the Flex Program, several recurring themes pertaining to event notifications emerged in the summer and winter surveys:

- ***Awareness of Changing Notification Preferences***: Several respondents did not know they could change their notification channel preferences on the Flex website and suggested that PGE allow customers to select their preferred channels. The Summer 2016 event survey also found that 48% (n= 822) of respondents did not know they could change their notification preferences on the Flex website.
- ***Notification Reminders***: Several respondents wanted more notification reminders and/or earlier notifications, varying from a few days' notice to a few weeks' notice.
- ***Accidental Changes to Notification Settings***: Twenty-four respondents said they received notifications in summer but not in winter, or their notification preference settings changed without their knowledge. PGE confirmed that it reset Wave 3 customers' notification settings after realizing it set Wave 3 customers to receive all three types of notifications (e.g., email, text, and voice); PGE reset settings to email notifications for these customers.

Efforts to Reduce or Shift Loads

PTR or BDR customers were asked to reduce loads during Flex events, while TOU customers were encouraged to reduce loads and/or shift loads from peak to off-peak hours. To facilitate these efforts, PGE provided PTR and BDR customers with energy conservation one-liner tips in event email notifications as well as event performance results addressing how their household performed; tips focused on cooling, heating, and hot water – the high energy-consuming end-uses for the residential sector. PGE provided TOU customers with load-shifting and energy conservation tips and provided household consumption performance in monthly reports.

Flex Event Participation and Behaviors

The Summer 2016 and Winter 2017/2018 experience surveys asked PTR, Hybrid, and BDR customers whether their household did anything to conserve energy during Flex events. Overall, most respondents said "yes" to participating in Flex event conservation in both seasons (68% summer, 81% winter). A significantly higher percentage of winter respondents (78%, n=832) participated in Flex event conservation than summer respondents (63%, n=677).[60] The higher participation rate in winter can be explained by the surveys used to draw the comparison and customer habituation to the program. Cadmus did not ask the Flex event participation question in the Summer 2017 experience survey and used the Summer 2016 survey data instead. This created a one-and-a-half-year gap between the Summer 2016 and Winter 2017/2018 surveys in which customers from Summer 2016 had fewer event feedback, tips, encouragement, and time to act on the tips compared to customers from Winter 2017/2018.

These self-reported Flex event participation results contradict the demand savings results whereby customers saved more during summer events than winter events. Although customers reported taking

[60] Significant difference with 90% confidence ($p \leq .10$).

more actions in winter, it may be that customers took more of the low-saving actions and less of the high-saving actions struggling to manage the high-saving actions. In open-ended comments from the Summer 2017 and Winter 2017/2018 experience surveys, 40 respondents (a mix of PTR-Only, Hybrids, and Opt-Outs) mentioned that the Flex events were more difficult to participate in during winter than summer. The following quotes from these respondents demonstrate customers' difficulty in winter compared to summer:

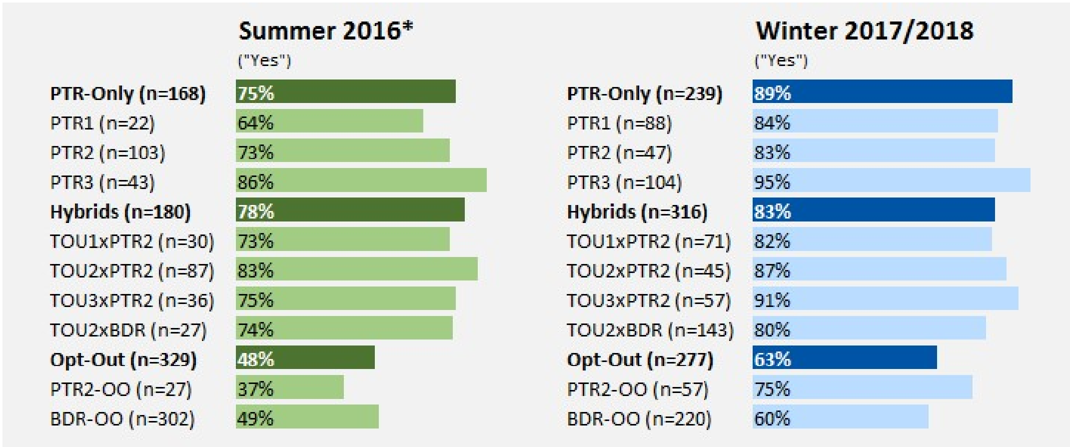
- "It is much harder to reduce use during winter Flex hours. Unless we dine out, there is no way to reduce during Flex time because I routinely aim for lower demand hours for laundry, dishwasher, etc. Driving to a restaurant or fast food place would negate the energy reduction at the house and, unlike during summer, we don't want a cold dinner."
- "Works for me in the summer. Managing AC is doable. Managing heat and light in the winter is not as workable. I think my bills are higher in the winter due to Flex."
- "We are very conscientious about shifting our energy use, and our warm weather savings reflect that. However, a household member is disabled, home most of the day, and needs the thermostat kept at 68 degrees. During the winter, that heating requirement just kills our savings."

A significantly higher percentage of Opt-In respondents (76%) than Opt-Out respondents (48%) participated in summer events and winter events (89% Opt-In, 63% Opt-Out).[61] The Opt-In customers' participation rate was higher than that of Opt-Out customers because opt-in programs typically attract the most engaged customers.

As shown in Figure 17, PTR-only respondents (75%) did not differ from Hybrid respondents (78%) in summer, but significantly differed in winter, when more PTR-only respondents (89%) than Hybrid respondents (83%) reported conserving during events.[62] In both seasons, PTR3 respondents showed the highest event participation rates.

[61] Ibid.
[62] Ibid.

Figure 17 Flex Event Energy Conservation Participation Rates



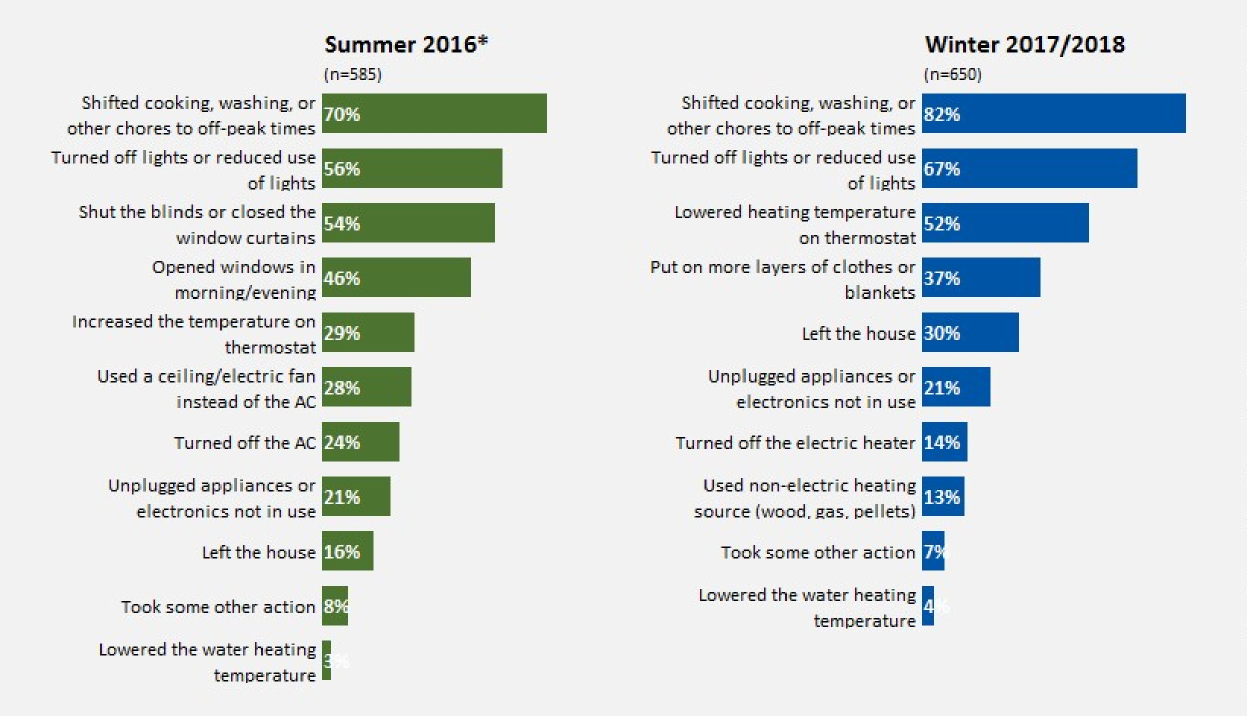
Survey Question: Did you and your household do anything to conserve energy during the Flex Time event?

* The Summer 2017 experience survey did not ask the event participation question. Results from the Summer 2016 event survey are reported here instead. Appendix F contains the survey results for Winter 2016/2017.

The surveys also asked respondents answering "yes" to participating in event energy conservation how their household conserved. Figure 18 shows self-reported customer conservation actions by season.

In both seasons, respondents most frequently reported using one of two strategies: shifting chores to off-peak times; or turning off or reducing use of lights. In summer, 70% of respondents reported shifting their chores to off-peak times, and 56% reported reducing lighting. In winter, 82% of respondents reported shifting their chores to off-peak times, and 67% reported reducing lighting. In both seasons, large percentages of respondents reported reducing use of lighting, even though savings from such behaviors will be low due to the prevalence of efficient CFLs and LEDs in residential customer homes. This presents PGE with an opportunity to educate customers about strategies for producing larger demand savings or shifting such as managing space conditioning and water heating loads. The differences between summer and winter in proportions of respondents employing these strategies were statistically significant.[27] Higher activity rates in winter aligned with findings in Figure 17, indicating event participation was higher in winter than summer. Other actions tended to differ by season, such as adjusting a thermostat's temperature up or down.

Figure 18 How Customers Conserved During Events[63]



Survey Question: How did you and your household conserve energy during Flex Time events? (Select all that apply) *The Summer 2017 experience survey did not ask the event participation question. Results from the Summer 2016 event survey are reported here instead. Appendix F contains the survey results for Winter 2016/2017.

In summer, respondents saying they did not conserve during events (n=134) most often cited the following three reasons:

1. Did not know there was an event. (36%)
2. It was too hot or feeling cool was of high priority. (29%)
3. Forgot there was an event. (18%)

In winter, respondents saying they did not conserve during events (n=86) most often cited the following three reasons:

1. The event timing did not work for them. (26%)
2. Already conserving on a regular basis, so did not feel the need to do more on event days. (24%)
3. Forgot there was an event. (17%)

Time-of-Use Participation and Behaviors

The Winter 2017/2018 experience survey asked TOU customers whether their households took actions to shift energy consumption from more expensive to less expensive times. This question was not asked

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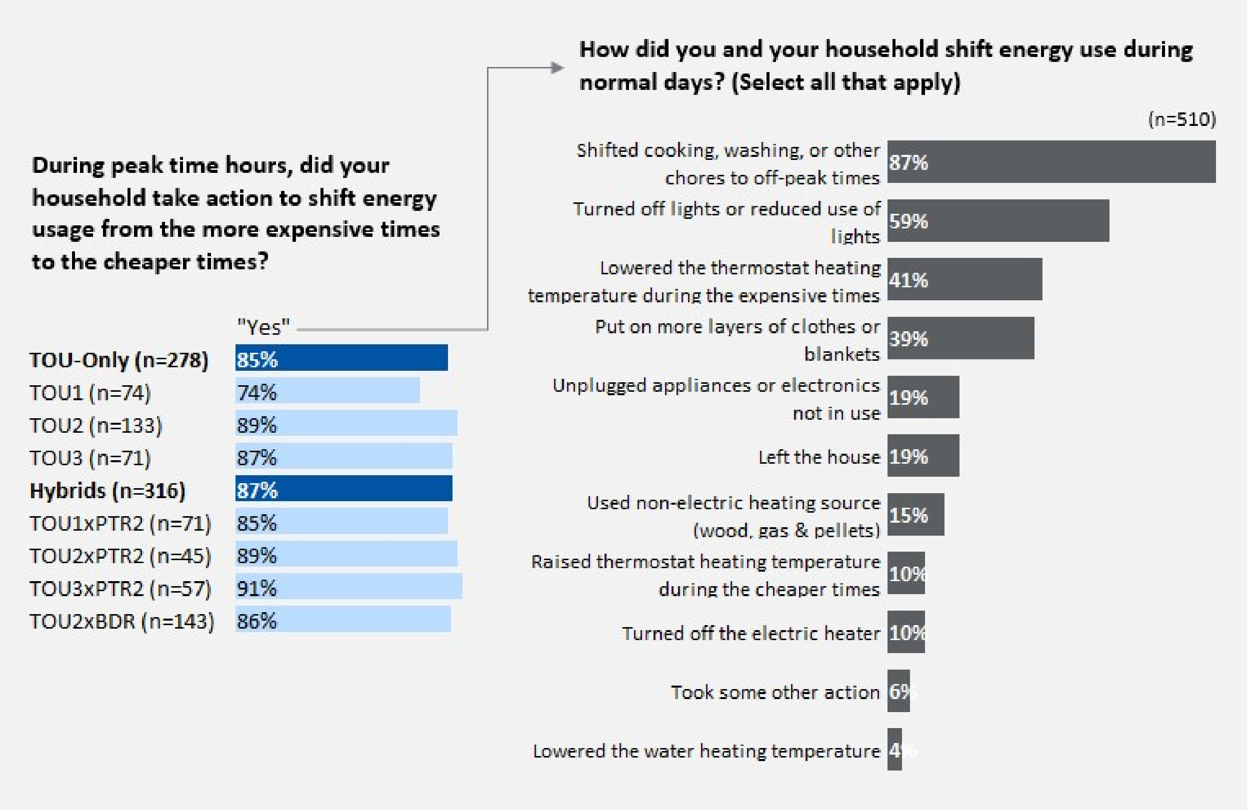
[63] This survey question was asked to customers in the event-based treatments (PTR-only, Hybrids, and Opt-Outs).

in the summer surveys. As shown in Figure 19, a similarly high percentage of TOU-only respondents (85%) and Hybrid respondents (87%) reported shifting their energy consumption. For TOU-only and

Hybrid treatments, TOU2 and TOU3 respondents showed a significantly higher percentage of shifting energy consumption than TOU1 respondents.[64] The relatively low percentage of TOU1 customers who reported shifting consumption might reflect the TOU1 rate's day/night schedule, which made load shifting challenging for customers. Among Hybrid treatments, participation rates for shifting energy consumption (87%) were not significantly different from winter event participation rates (83%).

Figure 19 Customer Efforts to Reduce Load During Normal Days – Winter 2017/2018[65]



The winter survey also asked respondents who said "yes" to shifting energy consumption how their households took action. As shown in Figure 19, respondents most frequently shifted their chores to off-peak times and turned off or reduced use of lights—the same top two actions for events. TOU respondents showed one notable behavioral difference from event-based respondents: a significantly lower percentage of TOU respondents reported leaving the house (19% vs. 30%).[29] The TOU program design encourages customers to shift or reduce energy consumption on a regular basis, making leaving

[64] Ibid.

[65] A comparison to summer is not available. The Summer 2016 and 2017 experience surveys did not ask the two load shifting questions; these two questions were added to the winter 2017/2018 experience survey.

the home an impractical strategy. In contrast, PTR and BDR program designs asked customers to shift or reduce demand on event days only, making it easier for them to leave during periods of high demand.

In winter, respondents saying they did not participate in shifting energy consumption (n=65) most often cited the following three reasons:

1. Particular members in my household make it difficult to shift energy use. (20%)
2. Feeling comfortably warm is a high priority. (14%)
3. Inconvenient/hard to remember to do every day. (14%)

Customer Satisfaction with Flex

The summer and winter experience surveys asked Flex customers to rate their overall satisfaction with the program on a 0–10 scale, where zero meant *extremely dissatisfied* and 10 meant *extremely satisfied*. Figure 20 shows the percentage of satisfied (6–10 rating) and delighted (9 –10 rating) participants across treatments for Summer 2017 and Winter 2017/2018. Appendix F contains survey results for Summer 2016 and Winter 2016/2017.

In assessing Flex satisfaction, the results from PGE's CPP pilot (2011-2013) are a useful point of reference. Using a similar 0–10 rating scale as the Flex evaluation, PGE reported that 68% of customers were satisfied (6–10 rating) and 40% of customers were delighted (9 –10 rating) with CPP. As evident below, overall, PGE customers gave the Flex pilot higher satisfaction ratings. Perhaps because of risk of or actual energy bill increases from CPP and the absence of such risk for PTR, satisfaction proved significantly lower for CPP.

Over 50% of respondents in each Flex treatment expressed satisfaction, with the highest program satisfaction observed for PTR-only (83%–86%),[66] followed by Hybrids (71%–79%), TOU-only (61%–76%), and Opt-Outs (56%–61%). Opt-In PTR2 treatment achieved the highest program satisfaction rate at 92% in the summer survey. Opt-In PTR2 (89%) and PTR3 (89%) treatments also achieved high program satisfaction rates in the winter survey. On the other hand, BDR-OO and TOU1 treatments showed the lowest satisfaction rates in the summer survey (BDR-OO 51%; TOU1 57%) and in the winter survey (TOU1 54%; BDR-OO 57%). The higher program satisfaction rates among PTR-only treatments suggest that providing financial incentives without risk of penalty boosts customer satisfaction with the program.

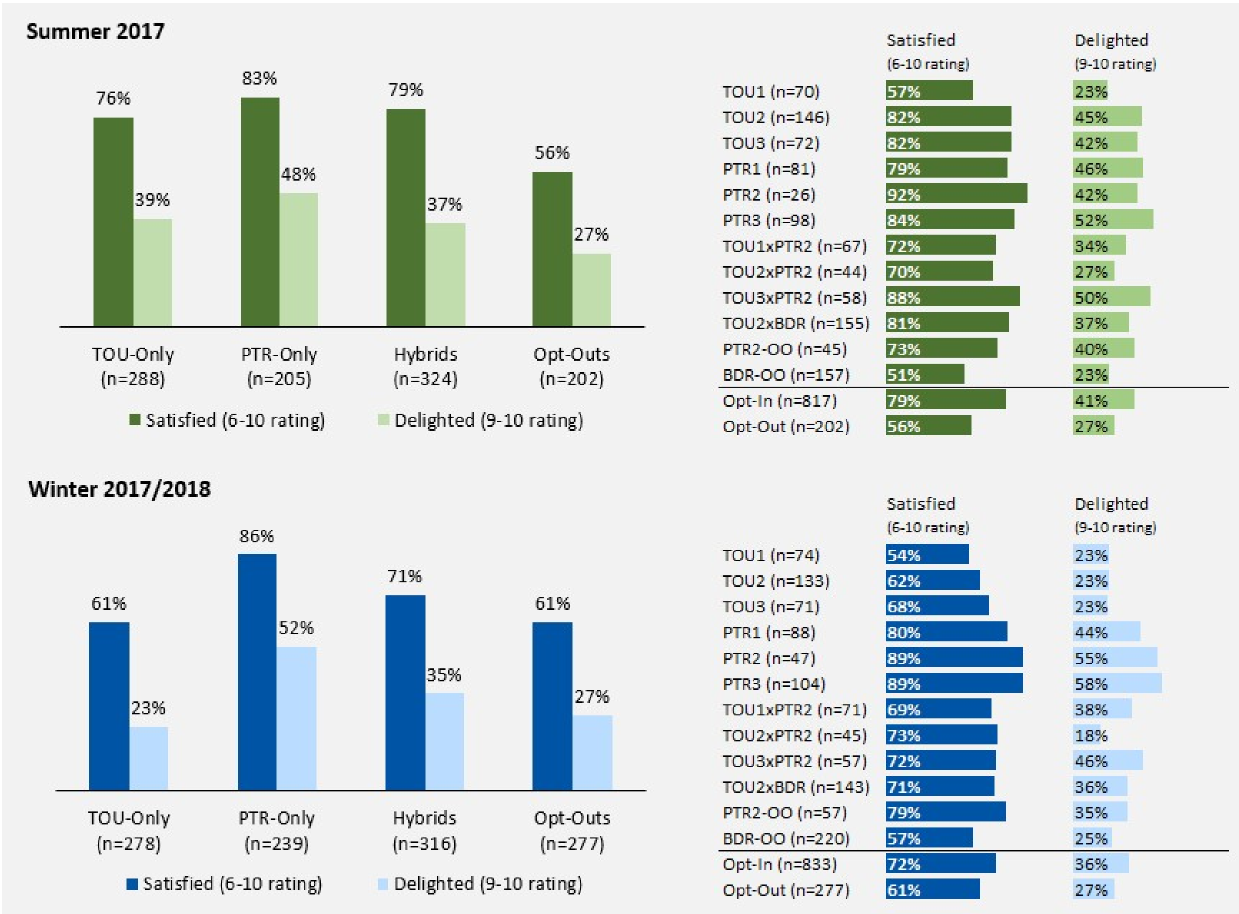
Opt-In treatments showed significantly higher program satisfaction rates than Opt-Out treatments. In the summer survey, a significantly higher percentage of Opt-In treatment respondents (79%) than Opt-out treatment (56%) respondents expressed satisfaction. [67] In the winter survey also, a significantly higher percentage of Opt-In treatment respondents (72%) than Opt-Out treatment respondents (61%) expressed satisfaction. [32] Opt-In treatments showing higher satisfaction with the program was expected

[66] In comparison to the 2013-2015 PGE CPP pilot, PGE reported that 68% of customers were satisfied (6–10 rating) and 40% of customers were delighted (9 –10 rating) with CPP

[67] Significant difference with 90% confidence (p≤.10).

as customers who opt in to a program are more engaged than customers who are automatically enrolled in a program (opt-out program design).

Figure 20 Overall Satisfaction with Flex[68]



Program satisfaction tended to be higher in summer than in winter. As shown in Figure 20, seven of the 12 treatments exhibited higher satisfaction rates in summer than winter. TOU-only and Hybrid treatments showed significantly higher satisfaction rates in summer (76%–79%) than in winter (61%–71%).[33] This seasonal pattern for TOU-only and Hybrid treatments suggests that the TOU pricing may have been more challenging for customers in winter than in summer.

Additionally, the summer and winter experience surveys asked respondents to explain their program satisfaction ratings. Satisfied respondents most often said the program delivered bill savings, helped their household manage energy use, brought education and awareness about energy conservation, and helped the environment. Respondents not satisfied most often said they saw little to no difference in their bill savings and found the Flex schedule or events difficult for their households. BDROO respondents

[68] Survey Question: Please rate your overall satisfaction with the Flex Program using a 0 to 10 scale where a zero means you are "extremely dissatisfied" and a 10 means you are "extremely satisfied."

most often mentioned the Flex events being difficult and TOU-only respondents (especially TOU1) most often mentioned the Flex schedule being difficult for their households.

Notably, respondents found the program more difficult to participate in during winter than summer, especially TOU-only and Hybrid respondents: 16% of respondents in the summer survey said the program helped them save on their electric bills, compared to 9% of respondents in the winter survey. Specifically, respondents said winter on-peak hours and event times occurred when household members were often home and needed to heat the home to stay warm. No respondents found the program more difficult in summer than in winter. PGE could lessen customer concerns about the seasonality of bill savings by encouraging them to enroll in *Equal Pay*, a payment option that allows customers to smooth their payments over months of the year. Another strategy, which PGE has already implemented, is to present cumulative, rather than monthly, bill savings to customers. Even if customers do not reduce their bills in winter, most do so over 12 months.

Among open-ended responses to the satisfaction rating question, 6% of respondents from the summer survey and 5% of respondents from the winter survey offered the following suggestions to improve the program:

- Provide a bill credit for savings instead of sending a check
- Provide more advanced Flex time event notifications
- Adjust the Flex schedule hours and/or Flex event times
- Provide more personalized information on tips and consumption data

Customer Satisfaction with PGE

The surveys asked test and control group customers to rate their overall satisfaction with PGE on a 0–10 scale, where zero meant *extremely dissatisfied* and 10 meant *extremely satisfied*. Figure 21 shows the percentage of *satisfied* (6–10 rating) and *delighted* (9–10 rating) customers across treatments and groups for Summer 2017 and Winter 2017/2018. Appendix F contains survey results for Summer 2016 and Winter 2016/2017.

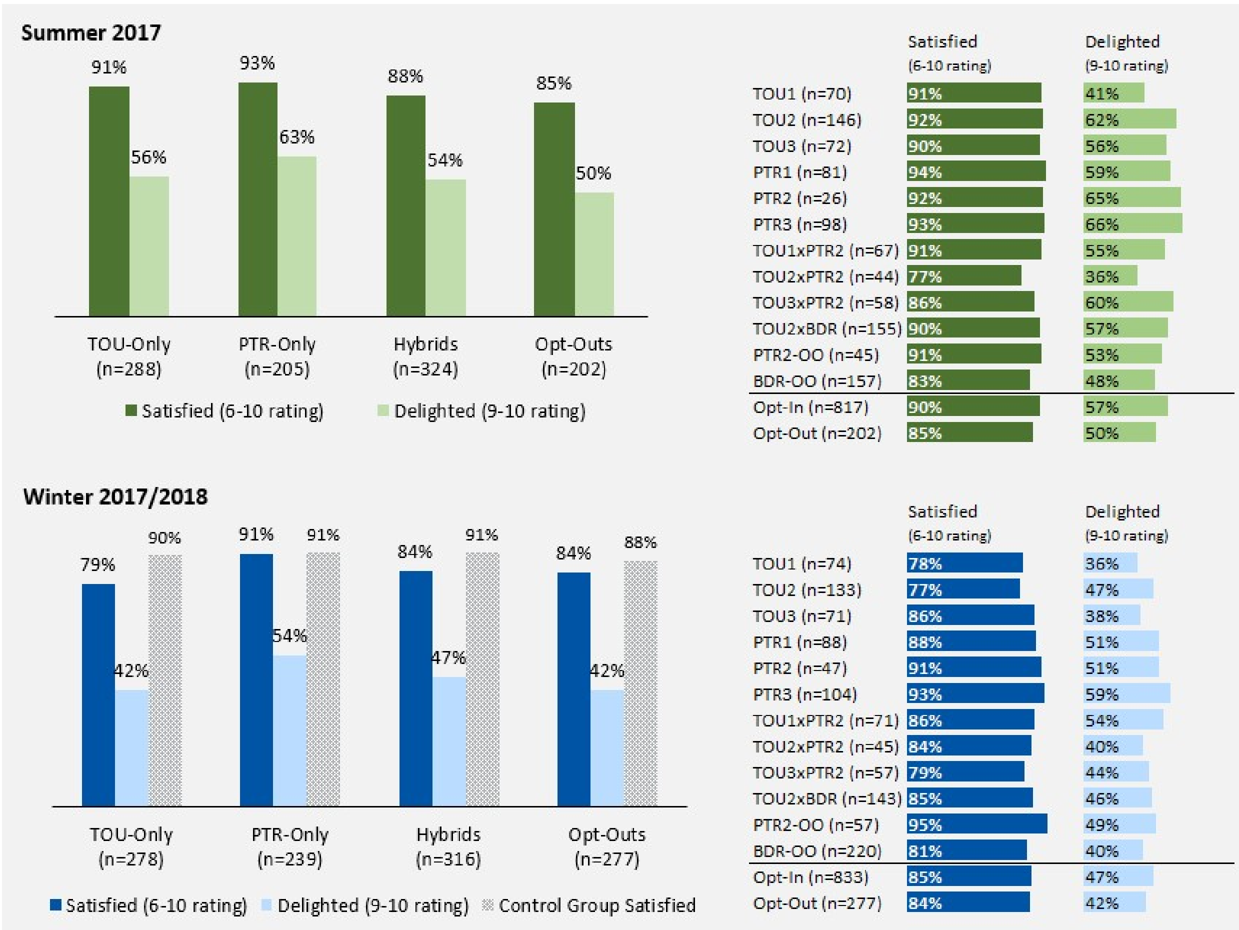
Among test group treatments, PTR-only had the highest PGE satisfaction rates. As shown in Figure 21, PTR-only had a PGE satisfaction rate of 93% in summer and 91% in winter. Opt-Outs had the lowest PGE satisfaction rates (85% in summer and 84% in winter). PGE satisfaction rates significantly differed between PTR-only and Opt-Outs in both seasons.[69] However, when combined, Opt-In customers showed no significant differences from Opt-Out customers in PGE satisfaction rates. In summer, Opt-Ins had a satisfaction rate of 90% and Opt-Outs had a satisfaction rate of 85%. In winter, Opt-Ins had a satisfaction rate of 85% and Opt-Outs had a satisfaction rate of 84%.

Customer satisfaction with PGE was lower in winter than summer. Most treatments showed a decrease in PGE satisfaction in winter, with TOU-only showing a significant decrease. TOU-only respondents

[69] Ibid.

significantly rated their satisfaction with PGE as lower in winter (79%) than in summer (91%).[70] Hybrid respondents also rated their satisfaction with PGE as lower in winter (84%) than in summer (88%), though this was not a statistically significant difference. The lower PGE satisfaction ratings in winter possibly reflected challenges in saving energy during winter. As discussed in the previous section, TOU only and Hybrid customers reported the program as more difficult to participate in during winter than summer.

Figure 21 Overall Satisfaction with PGE [71, 72]



PGE satisfaction ratings are compared between test and control groups only for winter (see the gray, hatched bars); control customers were not included in the summer survey. As shown in Figure 21, PTR only had no impact on customer satisfaction with PGE, but other treatments had a negative impact on customer satisfaction with PGE. PTR-only test group and control group both had a PGE satisfaction rate

[70] Ibid.
[71] Cadmus did not survey the control group customers in the Summer 2017 experience survey. Appendix F contains the satisfaction results for Summer 2016 and Winter 2016/2017 as well as the control group's Winter 2017/2018 satisfaction results for all 12 treatments.
[72] Survey Question: Please rate your overall satisfaction with PGE using a 0 to 10 scale where a zero means you are "extremely dissatisfied" and a 10 means you are "extremely satisfied."

of 91%. TOU-only test group had a significantly lower PGE satisfaction rate (79%) than control group (90%).[73] Hybrid test group also showed a significantly lower PGE satisfaction rate (84%) than control group (91%).[74] Opt-Out test group showed a lower PGE satisfaction rate (84%) than control group (88%), though not a statistically significant difference.

Implementation Challenges and Lessons Learned

PGE enrolled approximately 14,000 residential customers in the Flex pilot, which involved a complex RCT design using multiple treatments. Never having implemented a pilot of this scale or complexity, PGE encountered several implementation challenges, including marketing and providing feedback about demand savings to customers after events. This section documents these challenges and lessons learned, as communicated by PGE and implementation contractor program staff in interviews.

Marketing

Recruitment proceeded more slowly than expected, but still met its overall enrollment target by Summer 2017 (see Marketing and Recruitment and Table 8 for marketing and enrollment details). PGE and CLEAResult struggled at first with finding a marketing and messaging approach that resonated with customers. PGE experimented with marketing through emails, gift card rewards, postcards, and business letters as well as with messaging that emphasized economics (personal gains, including bill savings), control (taking charge of your consumption), and community (the greater good).

PGE reported the following customer conversion rates for Flex marketing channels over the course of the pilot:[75]

- 1.5% enrolled from email
- 2.5% enrolled from postcard
- 4.5% enrolled from business letter

Over the course of the pilot, PGE improved the effectiveness of its marketing through experimentation. PGE learned the types of messaging that resonated most with customers and the most effective marketing channels. It also found that offering a gift card as a reward did not increase the likelihood of enrollment. PGE reported that during the third and final recruitment wave it had enrolled 4.5% of customers receiving one well-designed email or business letter who had not received a previous Flex solicitation. According to PGE, it enrolled a high percentage of customers in the pilot after "a single touch" because of critical lessons about marketing it had learned during the previous two recruitment waves.

[73] Significant difference with 90% confidence (p≤.10).
[74] Ibid.
[75] A conversion rate measures a given marketing channel's effectiveness in spurring enrollment, calculated by taking the number of customers who enrolled from a channel and dividing this by the total number of customers that the channel reached.

PGE's experiments with marketing approaches revealed two critical lessons:

1. **Customers respond to paper (even after many emails).** Business letters and postcards enrolled customers more effectively than emails. Initially, PGE recruited customers with valid email addresses and only later opened recruitment to customers without email. Recruiting both customer sets helped the pilot program meet its enrollment targets. PGE also reported that it switched to business letters after having emailed customers as much as nine times; notably, when customers not responding by email received the business letter, they responded as if they had seen the program marketing for the first time.
2. **Customers respond to messaging about bill savings.** Business letters more successfully enrolled customers due to comparisons of standard flat rates vs. TOU rates and financial messaging about bill savings. Initially, PGE used control and community messaging in emails and postcards, which proved unsuccessful in converting customers. PGE realized that financial-focused messaging resonated more with customers as the primary participation benefit arose from the opportunity to earn bill credits or savings. Recruitment survey results (n=458) further supported this contention, indicating that saving money on electric bills was the top reason for enrollment (78%), followed by saving energy (46%), and helping the environment (28%).

Event Management

PGE encountered challenges in providing accurate and timely feedback to customers about their success in reducing or shifting loads during Flex events and in dispatching the appropriate number of events. A summary of challenges follows, along with PGE's efforts to address them:

- **PGE delivered inaccurate event savings feedback to some customers during the initial part of the Summer 2016 season.** To provide individualized feedback on event savings to participants, AutoGrid's data management platform performed consumption baseline calculations for each participating customer. During the initial Summer 2016 events, some customers received inaccurate or no feedback about their savings due to misaligned baseline calculation inputs. Inaccurate feedback or absence of feedback may have discouraged some customers from participating in future Flex events. To address these data errors, PGE and AutoGrid worked to refine the baseline calculation methodology and developed a quality control (QC) process to review event data before delivering them to customers. They began implementing the QC process in late Summer 2016.
- **PGE did not deliver event savings feedback to customers within the ideal 24-hour time frame.** PGE intended to send customers their event savings feedback within 24-hours of events, believing that each passing day could diminish the value customers gained from the feedback. PGE reported that, for the first few Summer 2016 events, it took a few days to a week to provide feedback due to the baseline calculation difficulties and inaccuracies described previously. The delay in feedback also prevented PGE from calling additional events until these issues were resolved. However, by the end of Winter 2016/2017, PGE refined its process flow and managed to achieve 48-hour delivery. Though data management and QC processes made

it difficult for PGE to achieve a shorter timeframe, PGE continued to improve its processes for delivering feedback and achieved close to a 24-hour turnaround in Summer 2017.

- **PGE dispatched too many BDR events.** PGE received feedback from some BDR customers that it dispatched too many events. As PGE does not compensate BDR customers, it is mindful of not calling upon them to reduce demand too often. As a result, while BDR saved 1%–2% of demand for thousands of customers, PGE used BDR less frequently over the pilot's course and plans to use it even less frequently in the future. In contrast, PGE is considering dispatching more PTR events in future winter seasons because it is popular with customers and effective at reducing peak demand. Moreover, PGE reported that it could have communicated better with BDR customers about their options for receiving event notifications after receiving feedback that some customers had not been aware that they could change their event notification settings.

Conclusions and Recommendations

Peak-Time Rebates

Larger rebates did not yield more Flex event savings.

Opt-In PTR customers saved about 20% of consumption during summer Flex events and between 7% and 12% of consumption during winter Flex events. No statistically significant differences in savings appeared by rebate amount. In summer, customers receiving a $0.80/kWh rebate achieved the same savings as customers receiving a $2.25/kWh rebate.

Of 12 treatments, Opt-In PTR-only customers were most satisfied with the Flex pilot.

In both seasons, Opt-In PTR-only respondents had the highest satisfaction rates with Flex (83% reported a program satisfaction score of 6 or higher on a 10-point scale in winter; 86% in summer) compared to Hybrids (71% in winter; 79% in summer) and TOU-only (61% in winter; 76% in summer).[76] Opt-In PTR2 treatment achieved the highest satisfaction rate of 92% in the summer survey. Opt-In PTR2 (89%) and PTR3 (89%) treatments also achieved high satisfaction rates in the winter survey. PTR customers may have been most satisfied as they faced no financial risk from participation. Customers could earn rebates for saving energy during Flex events but were not penalized if their consumption increased.

Larger rebates (greater than $1.55/kWh) increased customer satisfaction with the Flex pilot. PTR1 customers, who received the smallest rebate ($0.80/kWh), had lower satisfaction with Flex for both winter and summer seasons than PTR2 ($1.55/kWh) or PTR3 ($2.25/kWh) customers. In summer, 79% of PTR1 customers expressed satisfaction with the program, while 92% of PTR2 customers and 84% of PTR3 customers expressed satisfaction. In winter, PTR1 had a satisfaction rate of 80%, about 10 percentage points lower than that of PTR2 (89%) and PTR3 (89%).

[76] Respondents rated their overall satisfaction with the program on a 0–10 scale, where 0 meant *extremely dissatisfied* and 10 meant *extremely satisfied*. PGE defined a 6–10 rating as *satisfied*.

Flex event savings from peak-time rebates did not depend on outside temperatures.

A statistical relationship was not found between PTR savings and outside temperatures during Flex events in winter or summer. Outside temperatures during Flex events ranged between 82°F and 96°F in summer and 28°F and 45°F in winter.

PTR Recommendation

- When setting rebates for future PTR programs, PGE should consider the tradeoff arising from offering a higher rebate: over the lower range of rebates tested ($0.80/kWh to $1.55/kWh), there were positive effects on customer satisfaction but no impacts on Flex event savings from increasing the rebate. This suggests that larger rebates may raise customer satisfaction, but lower program cost-effectiveness.

TOU Rates

Customers under the TOU1 rate schedule encountered difficulties in shifting consumption from peak to off-peak hours.

The TOU1 rate used "day/night" off-peak and on-peak period definitions. As the on-peak period was set from 6:00 a.m. to 10:00 p.m., many customers were awake only during peak hours and asleep during off-peak hours, making load shifting inconvenient or difficult. Shifting loads would require many customers to adjust their sleep schedules or to have appliances programmed to run at night. Among TOU customers, those on the TOU1 rate had the lowest program satisfaction rates (57% in summer and

54% in winter) and did not achieve peak savings in either season. TOU1 respondents dissatisfied with Flex most often mentioned the rate schedule being difficult for their households; these respondents said it was not convenient or worth changing one's sleep time to do chores during off-peak periods.

TOU rate schedules with short peak-period definitions yielded peak savings and high satisfaction in summer.

In summer, TOU2 and TOU3 customers achieved significant savings during peak periods (8% and5%, respectively). They also saved 5%–6% during Flex event hours, which Cadmus used as a proxy for the peak capacity impact of TOU, even though TOU customers did not receive Flex event notifications or incentives. In summer, the TOU2 and TOU3 schedules had relatively short peak periods, from 3:00 p.m. to 8:00 p.m., which coincided with PGE's summer system peak and enabled customers to shift loads to off-peak periods. In summer, TOU2 and TOU3 customers had relatively high customer satisfaction ratings of 82%.

The simpler TOU rate schedule achieved the same peak period savings and satisfaction as the more complex one.

In summer, the TOU3 rate, with peak (3:00 p.m.–8:00 p.m.), mid-peak (11:00 a.m.–3:00 p.m.), and off-peak periods, reduced loads by 5% during the mid-peak period. However, no differences emerged in peak period savings between the simpler TOU2 rate, which only had peak (3:00 p.m.–8:00 p.m.) and off-peak periods, and the more complex TOU3 rate. TOU2 and TOU3 showed statistically similar program satisfaction rates in summer (TOU2 82%; TOU3 82%) and winter (TOU2 62%; TOU3 68%).

In winter, TOU customers experienced difficulties in shifting loads from peak to off-peak periods and achieving bill savings.

During winter, none of the TOU-only treatments produced statistically significant reductions in or shifts in peak-period loads. Either TOU did not affect customer loads, or the load impacts were too small to detect with the existing sample sizes. TOU customers also reported relatively low satisfaction with Flex (54%–68%) because of adverse bill impacts and the rate schedule being difficult for their households.

TOU schedules had morning *and* evening peak periods. Notably in the survey's open-ended comments, TOU-only and Hybrid customers mentioned the program was more difficult to participate in during winter than summer. Moreover, TOU-only and Hybrid treatments showed significantly lower program satisfaction rates in winter (61%–71%) than in summer (76%–79%).[77] This seasonal pattern in program satisfaction for TOU-only and Hybrid treatments suggests that the TOU aspect may be more challenging for customers in winter than in summer.

TOU Recommendations

- Unless an economic case justifies shifting customer loads from mid-peak to off-peak hours, PGE should implement the TOU2 rate schedule, which is simpler for customers to understand.
- PGE should consider redesigning the winter TOU rate schedules by removing the morning peak period. This would minimize the potential for adverse customer bill impacts and simplify the customer experience.
- PGE should redesign the TOU1 rate schedule or offer TOU1 customers enabling technology to facilitate load shifting from peak to off-peak periods.
- PGE did not test the impacts of pairing enabling technology with TOU pricing, but studies of other TOU pricing programs suggest that enabling technology such as price-responsive smart thermostats can increase load shifting. PGE should consider testing the load impacts of enabling technology in the future.
- PGE should consider enhancing customer screening during the enrollment process to determine whether a customer is a good fit for a TOU rate.
- Given TOU customers' challenges in achieving winter bill savings, PGE should offer them more education about how to save energy or shift loads from peak to off-peak periods.

Opt-Out Behavioral Demand Response

Behavior-based treatments caused PGE customers to save energy during Flex events.

[77] Significant difference with 90% confidence (p≤.10).

BDR-OO customers saved an average of 2.3% of consumption in summer and 1.2% of consumption in winter. PGE sent opt-out BDR customers Flex event alerts, encouragement to reduce consumption, and individualized post-event feedback but did not charge them higher electricity prices or provide them with rebates during Flex events, demonstrating that residential customers responded to non-price interventions.

Opt-out BDR program design yielded capacity benefits but resulted in relatively low customer satisfaction.

PGE automatically enrolled over 12,000 residential customers in the BDR-OO treatment. While average savings per treated customer were small (only 1%–2% of consumption), total program demand savings were large due to the size of the treated population. In the future, PGE can deploy the BDR program to help manage system peaks, but at the potential cost of lower customer satisfaction: only 51% of BDROO customers in winter and 57% in summer rated the program a 6 or higher on a 10-point scale.

Satisfaction ratings were likely low due to the opt-out program design and the unfamiliarity of many customers with BDR and the costs of supplying energy during utility system peaks. The program sent event notifications to many customers who had little interest in receiving them or participating in a BDR program. PGE also mentioned in the interviews that it received feedback from some BDR customers that it dispatched too many events and that these customers had not been aware that they could change their event notification settings.

BDR Recommendations

- PGE should consider using opt-out BDR for achieving capacity savings targets, given its success with BDR in reducing loads during this pilot; but it should consider possible changes to program design to increase customer satisfaction, such as:
  - Limiting the frequency of future BDR events, which would also limit the number of event notifications customers received.
  - Shortening the duration of future BDR events to lessen the burden on customers.
  - Spacing out future BDR events to avoid calling back-to-back events or multiple events in the same week.
  - Sending BDR customers a handy reminder magnet or sticker about BDR events and how to save, akin to the clock sticker PGE sent to TOU customers.
- PGE should clearly inform opt-out BDR customers that they can opt out of treatment and should make it relatively easy for customers to opt out if they do not want to participate.

Opt-Out Peak-Time Rebates

The opt-out participation program design significantly increased program participation. PGE attained a much higher participation by presenting customers with a choice to opt out of the program rather than opt in. PGE automatically enrolled approximately 1,600 customers in the PTR2-OO program. By the end of the Winter 2017/2018 season, only 2.3% of customers had opted out. In comparison, at the end of the recruitment period for opt-in PTR treatments, less than 7% of PGE customers accepted offers to participate in a PTR1 (4.3%), PTR2 (2.8%), or PTR3 (6.2%) treatment.[78] Of customers opting in to PTR treatment, between 4.5% and 6.3% subsequently opted out. The opt-out design took advantage of customers who were expected to be "complacent": they would neither opt in nor opt out of a DR program, if given the choice. Cadmus estimated that 92% of opt-out customers were complacent customers. By making participation the default choice, PGE obtained program participation and peak capacity that it would not have achieved otherwise.

The design of the pilot participation choice (opt-in vs. opt-out) presents a tradeoff between savings per customer and number of participants.

Depending on the rebate amount, opt-in PTR customers saved 17% to 21% of consumption during summer Flex events and from 7% to 12% of consumption during winter Flex events. Customers automatically enrolled in PTR2 saved an average of 7% during summer Flex events and 5% during winter Flex events.[79] Cadmus estimated that in Summer 2017, "complacent customers"—who would neither opt in nor opt out of a PTR program if given the choice—saved 6% during Flex events. While opt-in PTR customers saved more, the opt-out design enrolled many more customers. As noted above, fewer than 6% of PGE customers took up offers to participate in the PTR program. In contrast, more than 97% of customers defaulted onto PTR2-OO remained in treatment through the end of the Winter 2017/2018 season.

Adding a peak-time rebate to behavior-based DR increased Flex event demand savings and customer satisfaction.

The opt-out BDR treatment and the opt-out PTR treatment only differed in the rebate paid to customers for saving energy during Flex events. PTR customers received the same notifications, tips for saving energy, and individualized feedback about savings as BDR-OO customers. Opt-out PTR customers, however, saved significantly more during Flex events than BDR-OO customers (5% in winter and 7% in summer vs. 1% and 2%, respectively), demonstrating that the rebate lifted savings and complemented the behavior-based treatment. The rebate also increased customer satisfaction. PTR2-OO customers reported 73% program satisfaction in summer and 79% in winter—high customer satisfaction rates for customers automatically enrolled in a program. In contrast, BDR-OO customers only reported program satisfaction rates of 51% in summer and 57% in winter.

[78] PGE experimented with different marketing strategies during the first two waves and obtained higher rates of acceptance during the third wave after improving its approach. Also, PGE stopped recruiting for the opt-in PTR2 treatment after the second wave.

[79] The surveys also found that a higher percentage of opt-in (75% in summer, 89% in winter) than opt-out (37% in summer, 75% in winter) PTR2 customers reported participating in Flex events.

Opt-Out PTR Recommendation

- Given the tradeoff between savings per customer and numbers of participants, PGE should analyze whether the opt-in or opt-out PTR design proved more cost-effective, and whether each design will generate the desired aggregate DR capacity.

Hybrid Treatments

TOU pricing did not enhance (and possibly diminished) savings from PTR during Flex events and customer satisfaction (TOUxPTR vs. PTR).

During Summer Flex events, opt-in PTR customers saved 17% to 21% of consumption, but TOUxPTR customers only saved 9% to 19%[80]. During Winter Flex events, opt-in PTR customers saved 7% to 12%, but TOUxPTR customers only saved 4% to 12%. TOU pricing may cause PTR customers to become inattentive to Flex event alerts, or TOUxPTR customers may have less incentive to save energy during Flex events because their consumption baseline used for calculating rebates is lower. In summer and winter, satisfaction with Flex was 10 to 20 percentage points lower for TOUxPTR customers than for PTR-only customers.

Adding peak-time rebates to TOU pricing increased customer satisfaction and Flex event savings (TOUxPTR and TOUxBDR vs. TOU-Only).

Peak-time rebates had positive impacts on customer satisfaction for TOU customers. Depending on the TOU rate, TOU-only customers reported program satisfaction ranging from 57% to 82% in summer and 54% to 68% in winter. In contrast, TOUxPTR customers reported satisfaction levels ranging from 70% to 88% in summer and from 69% to 73% in winter, suggesting that the PTR enhanced customer satisfaction with the program.

During Flex events (i.e., hours used in this report to approximate system capacity conditions), TOUxPTR customers also saved more than TOU-only customers. In summer, TOUxPTR or TOUxBDR customers saved from 8% to 19% of Flex event demand, while TOU-only customers saved from 2% to 8%. During Winter events, TOU2xPTR2 and TOU3xPTR2 customers saved 12% of consumption, while TOU-only customers did not save any demand.

[80] The Flex event savings estimate for Hybrid customers indicates the combined effects of TOU and PTR during Flex events. The savings are estimated relative to customers who are treated with neither PTR nor TOU pricing.

Hybrid Treatment Recommendations

- If PGE's primary objective is to save demand during system peaks, it should consider enrolling more customers in PTR-only treatments than hybrid TOUxPTR treatments to maximize the impact on system peak.
- If PGE deploys TOU rates on a wide scale, it should consider pairing TOU rates with a PTR to raise customer satisfaction and Flex event savings.

Customer Experience

TOU and Hybrid customers reported higher satisfaction with the Flex pilot in summer than winter, primarily due to greater summer bill savings.

Overall, participant respondents were more satisfied with the Flex pilot in Summer 2017 (74% *satisfied*) than Winter 2017/2018 (69% *satisfied*).[81] The seasonal satisfaction differences, however, were greatest for treatments involving TOU pricing, which typically produced annual bill savings, with most or all savings occurring in summer. For TOU-only and Hybrid treatments, respondents reported significantly higher program satisfaction in summer (76%–79% *satisfied*) than in the winter (61%–71% *satisfied*).[82] Summer and winter respondents giving the program satisfied ratings most often noted that the program delivered bill savings. Respondents giving a less-than-satisfied rating most often noted seeing little to no difference in their bill savings. In summer, 16% of TOU survey respondents said they saved on their electric bills, compared to 9% of TOU survey respondents in winter. These program satisfaction results align with demand savings estimates showing participants achieved higher peak-period load reductions in summer than winter.

Although PGE automatically enrolled them, opt-out PTR and BDR customers showed high event awareness and engagement with the pilot.

As expected, customers opting into the pilot exhibited high awareness of and engagement with Flex events. Depending on the season, 93% to 96% of opt-in PTR-only respondents and 94% to 97% of opt-in Hybrid respondents remembered receiving event notifications. Also, 76% to 86% of opt-in respondents reported conserving electricity during events in both seasons. These awareness and engagement levels were higher than for BDR-OO and PTR2-OO customers automatically enrolled in the pilots. and 89% of opt-out respondents remembered receiving event notifications. Also, 48% of opt-out respondents in summer and 63% of respondents in winter reported conserving energy during these events. This suggests that PGE can engage customers in achieving demand savings who are automatically enrolled in DR programs.

[81] Respondents rated their overall satisfaction with the program on a 0–10 scale, where a zero meant *extremely dissatisfied* and a 10 meant *extremely satisfied*. PGE defined a 6–10 rating as *satisfied*.
[82] Significant differences at the 90% level (p≤.10).

PGE has an opportunity to increase peak period and Flex event demand savings from TOU rates through additional education with existing TOU customers.

TOU2 and TOU3-only and Hybrid treatments saved 5% to 8% of demand during peak periods and 8% to 20% of demand during Flex events, indicating that TOU treatments proved effective. TOU customers, however, did not have strong awareness of their rate schedules. Only about one-half of TOU and Hybrid respondents (52%) correctly identified their rate schedules from a list of three rate schedule images. That was only slightly better than results one would expect (33%) if all customers guessed at random. This suggests TOU customers could save more if they knew of their rate schedules. PGE might be able to increase TOU customer demand savings through doing additional education and outreach.

PGE identified several pilot implementation issues that negatively affected customer experiences and either corrected the issues or will correct them in future Flex deployments.

In interviews with Cadmus, PGE managers and implementation contractors described several program implementation issues:

- PTR and BDR customers received inaccurate and delayed feedback regarding their demand savings during Flex events. The inaccurate feedback may have discouraged some customers from saving, and the delay in providing feedback prevented PGE from calling additional events until these issues resolved. By the start of Winter 2016/2017, PGE had resolved the savings calculation issues and managed to deliver feedback to participants within 24 to 48 hours of events.
- Another issue concerned communication about event notification settings. Some customers complained that they received too many notifications or that the notifications did not arrive through their preferred delivery channels. Many customers reported being unaware that they could change their notification settings. In the future, PGE plans to communicate more proactively with participants about options for program communications and will simplify the process for changing the settings.

Pairing technology with Flex treatments may improve customer's ability to achieve load reduction. While the Flex pilot did not test the impacts of pairing enabling technologies, such as smart thermostats, advanced water heaters, or in-home displays, with the pricing or behavior-based treatments, other studies have found the pairing of these technologies enhances peak demand savings. The experience of TOU1 customers illustrates the potential benefits of enabling technology. TOU1 customers reported challenges in shifting loads from daytime on-peak periods to nighttime off-peak periods; programmable or price-responsive enabling technologies may facilitate shifting of loads and increase TOU1 on-peak demand savings.

Customer Experience Recommendations

- PGE should consider modifying the TOU design and delivery for the winter season to help customers save or shift more electricity consumption. This would improve customer satisfaction and increase load impacts. Modifications could include eliminating the morning on-peak period, shortening the length of the on-peak periods, or automatically enrolling TOU customers in the PTR program. A conjoint analysis of the TOU program offering could examine tradeoffs between different rate schedule designs, customer satisfaction, and load impacts.
- PGE should provide TOU customers with additional education about their rate schedules. This information should be simple and easy to understand. One idea is delivering educational information through alternative media, such as online video.
- PGE should consider opt-out DR programs as a component of its DR portfolio. The Flex pilot demonstrated that opt-out programs can reach large numbers of customers and that 50% or more of customers automatically enrolled in PTR or BDR remained engaged, as measured by self-reported rates of Flex event awareness and conservation.
- PGE should conduct test events before the start of each season to assess readiness of its customer communications and data analytics platforms. Testing will allow PGE to correct issues before the season starts, refamiliarize customers with the program, and give customers a chance to change their communications preferences
- PGE should consider conducting pilots to test the impacts of pairing enabling technologies such as smart thermostats or advanced water heaters with time-based rates or behavior-based treatments if PGE expects the technologies would be cost effective.

Marketing

Paper-based marketing and bill-savings messaging resonated most with customers.

PGE experimented with email, postcard, and business letter marketing, and found business letters achieved the highest customer marketing conversion rate (4.5%), followed by postcards (2.5%), and then email (1.5%).[83]

Business letters emphasized financial messaging (i.e., rate comparison information and a bill savings pitch). PGE initially used economic, control, and community messaging in the emails and post cards, but those approaches proved unsuccessful in enrolling customers. The recruitment survey also found a large majority of participants enrolled to save money on their electric bills (78%); far fewer respondents indicated enrolling to save energy (46%) or help the environment (28%).

[83] A conversion rate measures a given marketing channel's effectiveness in spurring enrollment, calculated by taking the number of customers who enrolled from a channel and dividing this by the total number of customers that the channel reached.

Marketing Recommendation

- PGE should consider employing business letter marketing approach for future DR programs to increase the cost-effectiveness of its marketing. This approach would include leading with bill savings and rate comparisons rather than energy savings or community as primary messages in postcards, emails, or other marketing channels.

Appendix A. Data Preparation

AMI Meter Data

The AMI data included a mix of 15- and 60-minute interval readings. Cadmus removed a small number of duplicate interval readings from the data. After summing 15-minute interval consumption data to obtain hourly interval consumption, Cadmus dropped a small number of outliers and hourly observations with one or more missing 15-minute interval readings. Specifically, we removed hourly consumption readings greater than 24 kWh from the analysis sample.[84] Also, Cadmus dropped customers with high average monthly consumption, who were unlikely to have been residential customers. We dropped a small number of customers consuming an average of 300 or more kWh per day from the analysis sample.[85]

Cadmus encountered other issues with the AMI meter data and developed solutions to address them. First, the timestamps on the AMI meter datasets were set to different time zones. Some were recorded on Coordinated Universal Time (UTC) instead of Pacific Time (UTC -8 or UTC -7) and required adjustment. In these cases, Cadmus shifted the timestamps to the correct time zone and adjusted for daylight savings time. Cadmus performed a review of the raw, average daily load shapes in each dataset before and after each adjustment to verify the timestamp adjustments.

Second, during the pretreatment period, some customers' AMI interval data were reported in integer kWh instead of in watt-hours. PGE did not switch meters of many participants to record watt-hours until the customer enrolled in the pilot. Cadmus determined these data were not truncated or rounded to the nearest kilowatt hour, but instead represented the change in kilowatt hours between intervals.[86] Since the pretreatment consumption data were measured with error, Cadmus wanted to avoid having pretreatment period hourly consumption directly enter the regression models used to estimate savings. We selected a regression approach that did not require using pretreatment period hourly consumption as a dependent or independent variable. However, to explain variation between customers in hourly consumption during the treatment period, it would be important to control for pre-treatment consumption. We determined that averaging the integer kWh over hours and making an adjustment for expected small errors produced an accurate estimate of a customer's pretreatment mean kWh per hour.

Using AMI meter data for customers with consumption reported in watt-hours, we tested the accuracy of our methodology and found that it produced accurate estimates of mean consumption. As noted

[84] Twenty-four kWh represented the maximum possible hourly energy consumption of a home with a 100-amp service. Such observations were extremely rare, and more likely reflected bad data (or commercial/industrial activity) rather than true residential consumption. This filter removed any hours with incomplete data or multiple observations for the same period. The hour in fall when DST ended was the exception to this filter, resulting in two 1:00 a.m.–2:00 a.m. periods on the same day.

[85] Customers consuming over 300 kWh per day on average unlikely lived in single-family residential homes. The 300 kWh/day bound is standard practice for evaluation of residential behavioral programs.

[86] For example, if a customer consumed 0.4 kWh per hour for each hour over a three-hour period, the meter data would show 0, 0, and 1 in the kWh field.

above, Cadmus included customer pretreatment mean consumption as an independent variable in the regressions to explain variation between customers in energy consumption during the treatment period.

Third, PGE did not provide pretreatment data for the same 12 months for all pilot customers as recruitment lasted longer than one year and PGE only retained interval meter data for the previous 13 months. The date range for the available pretreatment consumption data depended on the customer's recruitment wave. For example, for TOU customers opting into the pilot in spring 2016, PGE provided Cadmus with AMI meter interval data for calendar year 2015, but, for TOU customers opting into the pilot in spring 2017, PGE provided Cadmus with AMI meter interval data for the second half of 2015 and the first half of 2016. This complicated the calculation of each customer's pretreatment mean consumption, which would be included as a control variable.

To obtain comparable estimates of pretreatment consumption for customers from different recruitment waves, Cadmus built a regression model for each customer to predict the customer's pretreatment demand under a standard set of conditions. The standard set of conditions was defined by the specific hours and weather for which Cadmus was attempting to estimate demand savings during the treatment period. For example, to estimate TOU2 demand savings during the on-peak period in Summer 2017 analysis, Cadmus used pretreatment data to predict pretreatment consumption for each customer in the TOU2 test or control group during on-peak hours (between 3:00 p.m. and 8:00 p.m. on non-holiday weekdays) when the outside temperature equaled average outdoor temperatures during on-peak hours in 2017.

Specifically, using available pretreatment consumption data for summer or winter, Cadmus estimated individual customer regressions of hourly energy consumption on a constant and cooling or heating degree hours (HDH):

Equation 1

$$kWh_{it} = \alpha_i + \beta_i HD_{it} + \varepsilon_{it}$$

Where:

kWh_{it}	=	Electricity consumption of customer i during on-peak hour t of the summer or winter pre-treatment period.
α_i	=	Intercept for customer i indicating average consumption per hour during on-peak or off-peak hours.
β_i	=	Coefficient for customer i indicating average effect of cooling (heating) degree hours during summer (winter) on electricity consumption.
HD_{it}	=	Heating (cooling) degrees for customer i during peak or off-peak hour t using base temperature of 65°F in winter and 75°F in summer.
ε_{it}	=	Error term for consumption of customer i during peak or off-peak hour t.

Cadmus estimated the customer models by OLS and then predicted each customer's consumption for typical weather during on-peak and off-peak hours as follows:

Equation 2

$$\boldsymbol{kkkkkk}_{iiii} = a_{ip} + b_i \boldsymbol{HHHH}_{ip}$$

where:

kWh_{ip} =		Predicted mean electricity consumption for customer i during on-peak or off-peak hours during the pre-treatment period.
a_i	=	Estimated intercept for customer i indicating average consumption per hour during on-peak or off-peak hours.
b_i	=	Coefficient for customer i indicating average effect of cooling (heating) degree hours during summer (winter) on electricity consumption during on-peak or off-peak hours.2.
$HHHH_{\mathbf{ip}}$	=	Mean cooling (heating) degree hours during on-peak or off-peak hours of the treatment period.

Cadmus included the predicted pre-treatment consumption as an explanatory variable in Equation 2.

Ineligible Customers and Account Closures

A small number of customers opting into the pilot or automatically enrolled in opt-out treatments were determined ineligible for participation. Cadmus removed any customer from the analysis sample if PGE determined they were ineligible (e.g., customers with solar arrays or participants in the Rush Hour Rewards program). Cadmus applied these sample selection criteria identically to customers in the randomized test and control groups.

Also, some customers opting in or automatically enrolled in the pilot moved residences. When a customer moved, their participation in the pilot ceased, and Cadmus removed all AMI data for the period after the customer's move-out date.

Appendix B. Model Specifications

Event-Based Treatments

Cadmus estimated the demand savings from event-based treatments (PTR1-PTR3, opt-out BDR, and Opt-out PTR2) by comparing the hourly consumption of customers in each treatment's randomized test and control groups. Using data for event hours during each winter or summer season, Cadmus estimated a panel regression of customer hourly energy consumption on control variables for pretreatment consumption, hour-of-sample fixed effects, and assignment to treatment. Letting i, i=1, 2, …, N, denote customer, and t, t=1, 2, …, T, denote the Flex hour, the model took the following form:

Equation 3

$$kWh_{it} = \beta_1 Test_i + \mathbf{kWh}^{Pre}_{it}{}'\gamma + \tau_t + \varepsilon_{it}$$

Where:

kWh_{it}	=	Electricity consumption of customer i during Flex event hour t.
β_1	=	A coefficient indicating average treatment effect (in kWh) per customer per hour.
$Test_i$	=	An indicator variable for whether customer i was assigned to receive the treatment. These variable equals one if the customer was assigned to the treatment group and zero otherwise.
$\mathbf{kWh}_{Preit}$	=	A vector of variables characterizing mean consumption during the pretreatment period for customer i.
γ	=	A vector of coefficients indicating average effect of pretreatment consumption on consumption of customer i during Flex events.
τ_t	=	Error term for Flex hour t of the analysis period. Cadmus captured these effects with hour-of-the-sample fixed effects (i.e., a separate dummy variable for each Flex event hour).
ε_{it}	=	Error term for consumption of customer i and hour t.

The pretreatment consumption variables account for differences between customers in average consumption during Flex event hours. Cadmus calculated separate morning and evening pretreatment consumption means using data for hours when events typically occur (e.g., 4:00 p.m. to 7:00 p.m.) on non-holiday weekdays before the Flex season began or before the first PTR or BDR event occurred.[87] Cadmus attempted to use days that had low (winter) or high (summer) temperatures to temperatures experienced during Flex events.[88] Cadmus did not calculate mean consumption using non-event days during the DR season because of evidence from other studies showing that event-based treatment can produce savings on non-event days. The hour-of-sample fixed effects control for weather and other unobserved factors specific to each event hour.

Cadmus estimated a separate model for each treatment by OLS and clustered the standard errors on customers to account for correlation of consumption for individual customers and estimated alternative

[87] For Summer 2017, Cadmus selected days between April 1, 2017, and July 23, 2017. For Winter 2017–2018, Cadmus selected days between November 1, 2017, and December 31, 2017. In each case, the last day of the period was the last non-holiday weekday before the first event of the season.

[88] Only days where the mean temperature fell no lower than 10 degrees below the event day mean temperature.

model specifications to test the robustness of the estimates to specification changes. These alternative specifications included the following:

- Substituting day-of-the week and hour-of-the-day variables for the hour-of-the-sample fixed effects.
- Adding weather variables such as cooling degree hours (CDH) or HDH to the regression.
- Omitting pretreatment mean consumption from the regression equation.
- Adding indicator variables for a customer's recruitment wave (Wave 1, Wave 2, or Wave 3) as standalone variables and interacted with other variables.

These specification changes affected the estimated standard error, but not the point estimates of savings.

Time-of-Use Rate-Based Treatments

Cadmus estimated treatment effects for TOU rate and hybrid-TOU rate treatments by comparing consumption of customers in each treatment's randomized test and control groups. Using data on customer consumption for event and non-event hours during each winter or summer season, Cadmus estimated a panel regression of customer hourly energy consumption on control variables for pretreatment consumption, peak and off-peak hours, day-of-the-week, weather, and assignment to treatment. Again, letting i, i=1, 2, …, N, denote customer, and t, t=1, 2, …, T, denote the Flex hour, the TOU and TOU-hybrid treatment models took the following form:

Equation 4

$$kWh_{it} = \alpha + \gamma_1\ OffPeak_t + \gamma_2 Peak_t + \beta_1 Test_i{*}OffPeak_t + \beta_2 Test_i{*}Peak_t + \beta_3 Treatment_i{*}OffPeak_t{*}Wkend_t +$$

$$\mathbf{kWh}_{it}'\gamma + \varepsilon_{it}$$

Where:

$(kWh/hour)_{it}$ = Electricity consumption of customer i during hour t of the summer or winter treatment period.

α = Intercept indicating baseline average consumption (kWh) per customer per TOU weekend (off-peak) hour.

γ_1 ` = Coefficient on $OffPeak_t$ indicating baseline average consumption (kWh) per customer per TOU off-peak period hour.

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$Offpeak_t$ = An indicator variable for whether the hour is a TOU off-peak period weekday hour. This variable equal one if the hour was not a peak period hour or weekend hour and zero otherwise.

γ_2	=	Coefficient on $Peak_t$ indicating baseline average consumption per customer (kWh) per TOU peak period hour.
$Peak_t$	=	An indicator variable for whether the hour is a TOU peak period hour. This variable equal one if the hour was a peak period hour and zero otherwise.
$Test_i$	=	An indicator variable for whether customer i was assigned to receive the treatment. This variable equal one if the customer was assigned to the treatment group and zero otherwise.
β_1	=	Coefficient on $Treatment_i$*$OffPeak_t$ indicating average TOU treatment effect per customer during off-peak period hours in kWh per hour.
β_2	=	Coefficient on $Treatment_i$*$Peak_t$ indicating average TOU treatment effect per customer during peak period hours in kWh per hour.
β_3	=	Coefficient on $Treatment_i$*$OffPeak_t$*$Wkend_t$ indicating average TOU treatment effect per customer during period weekend hours in kWh per hour.
$Wkend_t$	=	An indicator variable for whether the hour is a weekend (TOU off-peak) hour. This variable equal one if the hour was a weekend period hour and zero otherwise.
$\mathbf{kWh}_{Preit}$	=	A vector of variables characterizing mean consumption during the pretreatment period for customer i. This vector included mean off-peak period mean hourly consumption interacted with *$Offpeak_t$*, on-peak period means hourly consumption interacted with *$Peak_t$*, and weekend (non-peak period) mean hourly consumption interacted with *$Wkend_t$*.
γ	=	A vector of coefficients indicating average effect of pretreatment kWh on consumption of customer i.
ε_{it}	=	Error term for consumption of customer i and hour t.

In the regression equation, the omitted variable is the indicator for the weekend (off-peak) period. The main coefficients of interest are β_1, β_2, and β_3, which indicate, respectively, TOU treatment effects during off-peak, peak, and weekend hours.

Cadmus estimated a separate model for each TOU treatment by OLS and clustered the standard errors on customers. To estimate the treatment effect for the TOU3 rate, which included a mid-peak period, Cadmus added an indicator variable for the mid-peak period to the specification. Again, because of the random assignment of customers to test and control groups, the regression was expected to produce an unbiased estimate of the treatment effect.

Cadmus estimated the following alternative model specifications to test the robustness of the TOU treatment effect estimates to specification changes:

- Substituting hour-of-sample fixed effects for the peak hour and off-peak hour variables.
- Adding weather variables such as CDH or HDH to the regression.
- Omitting pretreatment mean consumption from the regression equation.
- Adding indicator variables for a customer's recruitment wave (Wave 1, Wave 2, or Wave 3) as standalone variables and interacted with other variables.

The point estimates of savings proved robust to these specification changes. The main effect was to increase or decrease the estimated standard errors.

Hybrid TOU Treatments

To estimate treatment effects for the hybrid treatments such as TOU1xPTR2 or TOU2xBDR, in Equation 2, Cadmus substituted *Peak***Event* and *Peak**(1-*Event*) *indicator* variables for the *Peak* variable, thereby allowing the effects of *Peak* and *Peak***Test* to depend on whether the hour was a Flex event hour. The *Event* variable equals 1 if the hour is a Flex event hour and equals zero otherwise.

Appendix C. Equivalency Checks and Analysis Sample Summary Statistics

Table 22 presents results from tests of differences in pre-treatment consumption between the randomized test and control groups for each treatment. Cadmus regressed customer mean pretreatment consumption on an indicator variable for assignment to the test group and separate indicator variables for the different recruitment waves. For the PTR-only, opt-in PTR, and BDR treatments, Cadmus presents balance tests of demand in hours that would have qualified as Flex events during the pretreatment period. For the TOU-based treatments, Cadmus presents separate balance tests of demand in on-peak period and off-peak period hours during the pre-treatment period.

Table 22 Balance Tests for Flex Pilot Randomized Test and Control Groups[89]

	Summer 2017					Winter 2017/2018				
Treatment	N	Control Group kW	ΔkW (T-C)	Std. Error	T-stat	N	Control Group kW	ΔkW (T-C)	Std. Error	T-stat
PTR1	722	1.543	0.127	0.086	1.48	678	0.828	0.020	0.058	0.34
PTR2	408	1.528	0.167	0.116	1.44	380	0.892	0.062	0.092	0.68
PTR3	889	1.608	-0.061	0.076	0.80	823	0.871	-0.047	0.055	0.85
PTR-OO	1,256	1.588	0.057	0.068	0.84	1,149	0.876	0.032	0.050	0.65
BDR	19,587	1.644	-0.006	0.017	0.35	17,889	0.891	-0.006	0.013	0.44
TOU1										
Peak	827	0.932	0.036	0.033	1.09	787	1.459	-0.007	0.052	0.14
Off-Peak	827	0.799	0.037	0.029	1.28	787	1.326	-0.001	0.048	0.01
TOU2										
Peak	1,510	1.209	0.023	0.033	0.70	1,406	1.481	-0.004	0.040	0.09
Off-Peak	1,510	0.951	-0.023	0.025	0.93	1,406	1.320	-0.011	0.037	0.30
TOU3										
Peak	849	1.059	0.002	0.027	0.07	805	1.499	-0.010	0.037	0.27
Off-Peak	849	0.889	-0.020	0.022	0.90	805	1.372	-0.010	0.035	0.29
TOU1xPTR2										
Peak	638	0.981	0.025	0.044	0.57	612	1.451	0.018	0.059	0.30
Off-Peak	638	0.784	0.012	0.037	0.33	612	1.264	0.033	0.055	0.60
TOU2xPTR2										
Peak	385	1.051	0.181	0.064	2.83	354	1.551	-0.073	0.076	0.96
Off-Peak	385	0.899	-0.015	0.042	0.36	354	1.302	-0.074	0.064	1.16
TOU2xBDR										
Peak	1,398	1.209	-0.018	0.071	0.25	1,317	1.481	0.000	0.082	0.00
Off-Peak	1,398	0.951	-0.015	0.056	0.27	1,317	1.320	0.038	0.079	0.48
TOU3xPTR2										
Peak	598	1.076	0.027	0.034	0.80	559	1.501	-0.009	0.045	0.20
Off-Peak	598.0	0.802	-0.009	0.022	0.41	559	1.300	-0.017	0.038	0.45

[89] N is number of test and control group customers. For PTR, PTR-OO, and BDR treatments, pre-treatment demand was average kW during event hours on 10 warmest (summer) or coldest (winter) non-holiday weekdays during for 60 days preceding start of treatment. For TOU and Hybrid treatments, pre-treatment demand was predicted average demand during on-peak (off-peak) hours and was estimated with a separate regression for each customer of hourly demand during peak (off-peak) period hours for summer (winter) in the year before start of treatment. Difference between test and control group demand estimated with regression of customer mean pre-treatment demand on an indicator variable for assignment to the test group and separate indicator variables for the different recruitment waves.

The results of the balance tests show the test and control groups for almost all treatments and periods were well balanced on mean pre-treatment consumption, as expected from the random assignment to treatment. The only statistically significant difference was for the TOU2xPTR2 treatment.

Table 23 presents the sample mean and standard deviation of electricity demand during Summer 2017 and Winter 2017/2018 Flex events for test and control group customers in the PTR-only, opt-in PTR, and opt-in BDR treatments.

Table 23 Analysis Sample Summary Statistics for PTR and BDR Treatments[90]

		Summer 2017			Winter 2017/2018		
Treatment		N	Mean	Std. Dev.	N	Mean	Std. Dev.
PTR1							
	Control	8,577	2.273	1.756	6,780	1.719	1.526
	Test	8,541	2.039	1.823	6,780	1.625	1.551
PTR2							
	Control	4,446	2.222	1.898	3,500	1.826	1.792
	Test	5,178	1.939	1.781	4,100	1.802	1.727
PTR3							
	Control	10,472	2.248	1.838	8,260	1.774	1.639
	Test	10,584	1.818	1.727	8,200	1.505	1.484
PTR-OO							
	Control	15,098	2.287	1.896	11,880	1.841	1.656
	Test	14,508	2.196	1.846	11,094	1.819	1.724
BDR							
	Control	230,912	2.243	1.860	107,210	1.915	1.791
	Test	231,371	2.193	1.840	107,373	1.891	1.803

Table 24 presents sample means and standard deviations of electricity demand during Summer 2017 and Winter 2017/2018 on-peak and off-peak hours for test and control group customers in the TOU and Hybrid treatments.

[90] Table shows sample means and standard deviations of demand during Flex event hours for event-based treatments. N is the number of observations of hourly demand for customers.

Table 24 Analysis Sample Summary Statistics for TOU and Hybrid Treatments[91]

		Off-peak			On-Peak		
Summer 2017							
Treatment		N	Mean	Std. Dev.	N	Mean	Std. Dev.
TOU1							
	Control	625,512	0.954	1.036	559,632	1.101	1.158
	Treatment	604,901	1.038	1.180	541,227	1.155	1.216
TOU2							
	Control	1,270,420	1.042	1.203	219,965	1.417	1.447
	Treatment	4,463,949	0.990	1.077	772,815	1.306	1.365
TOU3							
	Control	1,008,796	1.019	1.125	174,680	1.352	1.365
	Treatment	1,033,528	0.972	1.099	178,925	1.281	1.297
TOU1xPTR2							
	Control	448,735	0.916	1.014	401,584	1.114	1.193
	Treatment	509,200	0.955	1.100	455,600	1.122	1.234
TOU2xPTR2							
	Control	407,496	0.988	1.088	70,560	1.370	1.376
	Treatment	510,935	0.989	1.050	88,465	1.389	1.345
TOU2xBDR							
	Control	1,270,420	1.042	1.203	219,965	1.417	1.447
	Treatment	2,092,450	0.978	1.072	362,270	1.264	1.339
TOU3xPTR2							
	Control	686,774	0.957	1.030	118,895	1.335	1.318
	Treatment	755,520	0.935	1.041	130,800	1.292	1.388
Winter 2017/2018							
Treatment		N	Mean	Std. Dev.	N	Mean	Std. Dev.
TOU1							
	Control	438,002	1.237	1.321	372,556	1.422	1.467
	Treatment	397,696	1.309	1.347	338,224	1.428	1.377
TOU2							
	Control	720,000	1.344	1.452	251,054	1.520	1.478
	Treatment	2,543,971	1.292	1.381	887,119	1.433	1.450

[91] Table shows sample means and standard deviations of demand during TOU on-peak and off-peak periods for TOU and Hybrid treatments. N is the number of observations of hourly demand for customers.

TOU3							
	Control	606,091	1.314	1.384	211,341	1.466	1.420
	Treatment	569,966	1.309	1.469	198,737	1.439	1.508
TOU1xPTR2							
	Control	306,386	1.221	1.366	260,568	1.450	1.515
	Treatment	344,911	1.272	1.394	293,392	1.466	1.501
TOU2xPTR2							
	Control	239,910	1.363	1.453	83,639	1.607	1.621
	Treatment	277,087	1.213	1.250	96,624	1.402	1.310
TOU2xBDR							
	Control	720,000	1.344	1.452	251,054	1.520	1.478
	Treatment	2,543,971	1.292	1.381	887,119	1.433	1.450
TOU3xPTR2							
	Control	398,239	1.294	1.392	138,865	1.526	1.535
	Treatment	419,036	1.242	1.371	146,113	1.442	1.475

Appendix D. Load Impact Estimates for Summer 2016 and Winter 2016/2017

Table 25 presents savings estimates for Flex treatments during summer 2016, which was the pilot's first season. At the beginning of summer 2016, PGE had not completed customer recruitment, and many of the treatments were not fully enrolled. As a result, the sample sizes were small, and the savings estimates were not precise and not statistically different from zero for many treatments. Almost all TOU impact estimates were statistically insignificant.

Table 25 Flex Evaluation Findings by Treatment – Summer 2016[92]

Category	Treatment		Summer 2016				
			N of customers	PGE Planning Savings Estimate	Evaluation		
					Savings (%)	Abs. Precision at 90% Conf.	Savings (kW)
PTR-Only	PTR1		131	13%	34%	±11%	0.65
	PTR2		447		29%	±7%	0.53
	PTR3		198		33%	±10%	0.65
Opt-Out	PTR2-OO		737	6%	17%	±5%	0.37
	BDR-OO		11,618	3%	1.3%	±1.2%	0.03
TOU-Only	TOU1	On-Peak	241	5%	3%	±6%	0.03
		Flex Event			4%	±15%	0.08
	TOU2	On-Peak	847		1%	±4%	0.01
		Flex Event			2%	±8%	0.03
	TOU3	On-Peak	232		-7%	±10%	-0.08
		Flex Event			-21%	±17%	-0.33
Hybrids	TOU1xPTR2	On-Peak	242	12.9% PTR; 5.2% TOU	6%	±8%	0.05
		Flex Event			3%	±18%	0.05
	TOU2xPTR2	On-Peak	468	12.9% PTR; 5.2% TOU	-2%	±4%	-0.02
		Flex Event			5%	±9%	0.09
	TOU2xBDR	On-Peak	561	3.0% BDR; 5.2% TOU	1%	±4%	0.01
		Flex Event			0%	±10%	0.00
	TOU3xPTR2	On-Peak	245	12.9% PTR; 5.2% TOU	1%	±7%	0.01
		Flex Event			0%	±15%	0.00

[92] n is the number of customers included in the impact analysis. All estimates were obtained through OLS regression analysis, with standard errors clustered on customers. Green denotes the estimate was statistically significant at the 10% level.

Table 26 presents savings estimates for Flex treatments during winter 2016/2017, which was the pilot's first winter season. At the beginning of this season, PGE had still not completed customer recruitment, and many of the treatments had not met their enrollment targets. As a result, the sample sizes were small, and the savings estimates were not precise and not statistically different from zero for many treatments.

Table 26 Flex Evaluation Findings by Treatment—Winter 2016/2017[93]

Category	Treatment		N of customers	PGE Planning Savings Estimate	Winter 2016/2017					
					Evaluation					
					AM			PM		
					Savings (%)	Abs. Precision at 90% Conf.	Savings (kW)	Savings (%)	Abs. Precision at 90% Conf.	Savings (kW)
PTR-Only	PTR1		289	14%	6%	±10%	0.09	6%	±7%	0.13
	PTR2		408		-2%	±9%	-0.03	3%	±7%	0.07
	PTR3		420		1%	±8%	0.01	14%	±7%	0.31
Opt-Out	PTR2-OO		680	7%	-3%	±6%	-0.05	-4%	±5%	-0.09
	BDR-OO		10,665	3%	0.5%	±2%	0.01	0%	±1%	0.01
TOU-Only	TOU1	On-Peak	256	6%	1%	±5%	0.01	1%	±5%	0.01
		Flex Event			-4%	±9%	-0.07	3%	±8%	0.08
	TOU2	On-Peak	919		4%	4%	0.06	4%	±4%	0.06
		Flex Event			2%	±6%	0.04	2%	±5%	0.05
	TOU3	On-Peak	268		-8%	6%	-0.14	-8%	±6%	-0.14
		Flex Event			-17%	13%	-0.30	-14%	±11%	-0.30
Hybrids	TOU1xPTR2	On-Peak	236	14.2% PTR;	13%	9%	0.21	13%	±9%	0.21
		Flex Event		5.8% TOU	17%	14%	0.30	9%	±10%	0.19
	TOU2xPTR2	On-Peak	408	14.2% PTR;	7%	±5%	0.13	7%	±5%	0.13
		Flex Event		5.8% TOU	11%	9%	0.20	7%	±7%	0.15
	TOU2xBDR	On-Peak	615	3.3% BDR;	0%	±5%	0.00	0%	±5%	0.00
		Flex Event		5.8% TOU	-8%	±9%	-0.14	0%	±7%	0.00
	TOU3xPTR2	On-Peak	278	14.2% PTR;	2%	±5%	0.04	2%	±5%	0.04
		Flex Event		5.8% TOU	-2%	±11%	-0.03	8%	±8%	0.17

93 n is the number of customers included in the impact analysis. All estimates were obtained through OLS regression analysis, with standard errors clustered on customers. Green denotes the estimate was statistically significant at the 10% level.

Appendix E. Survey Design and Samples

This appendix describes the six customer surveys and samples that Cadmus designed and administered.

Recruitment Survey

Because opt-in control customers were denied enrollment, Cadmus fielded the recruitment survey only to treatment customers in the 10 opt-in treatments. Test group customers in the two opt-out treatments did not receive the recruitment survey as these customers were automatically enrolled rather than recruited. The recruitment survey asked questions about how customers heard about Flex, their familiarity with TOU pricing, reasons for enrolling, and their satisfaction with PGE. Table 27 shows the number of test group customers contacted for the recruitment survey and the response rate.

Table 27 Recruitment Survey Sample and Response Rate

Treatment	Test Group		
	Number of Contacted	Number of Completes	Response Rate
TOU1	62	35	56%
TOU2	158	77	49%
TOU3	49	23	47%
PTR1	38	23	61%
PTR2	144	76	53%
PTR3	65	35	54%
TOU1xPTR2	53	30	57%
TOU2xPTR2	164	80	49%
TOU3xPTR2	58	36	62%
TOU2xBDR	74	43	58%
Total	**865**	**458**	**53%**

Summer 2016 Event Survey

Cadmus fielded the event survey with test customers in the nine treatments with an event component.

PGE and Cadmus also decided to field the event survey with control customers in the PTR2-OO and BDR-OO treatments to obtain a baseline metric for satisfaction with PGE. The event survey asked test customers about event notifications, whether they did anything to reduce consumption during the events, and their satisfaction with Flex and PGE. The event survey asked control customers about their familiarity with peak demand, whether they did anything to reduce consumption during days associated with peak demand, and their satisfaction with PGE. Table 28 shows the number of customers contacted for the event survey and the response rate.

Table 28 Event Survey Sample and Response Rate – Summer 2016

Treatment	Test Group			Control Group		
	Number of Contacted	Number of Completes	Response Rate	Number of Contacted	Number of Completes	Response Rate
PTR1	68	22	32%	–	–	–
PTR2	246	103	42%	–	–	–
PTR3	105	43	41%	–	–	–
TOU1xPTR2	90	30	33%	–	–	–
TOU2xPTR2	255	87	34%	–	–	–
TOU3xPTR2	94	36	38%	–	–	–
TOU2xBDR	111	27	24%	–	–	–
PTR2-OO	277	27	10%	269	36	13%
BDR-OO	3,333	302	9%	3,333	353	11%
Total	**4,579**	**677**	**15%**	**3,602**	**389**	**11%**

Summer and Winter Experience Surveys

After the end of each season, Cadmus fielded the experience survey with test customers in all 12 treatments. The experience survey asked questions about events, pricing awareness, load-reducing behaviors, participation barriers, satisfaction with the program, satisfaction with PGE, and suggestions for program improvements. Control customers were also surveyed during the winter seasons to supply comparative data for satisfaction with PGE. Table 29, Table 30, Table 31, and Table 32 show survey samples and response rates for each of the four seasonal experience surveys.

Table 29 Experience Survey Sample and Response Rate – Summer 2016

Treatment	Test Group		
	Number of Contacted	Number of Completes	Response Rate
TOU1	65	13	20%
TOU2	242	57	24%
TOU3	100	32	32%
PTR1	96	24	25%
PTR2	335	59	18%
PTR3	95	14	15%
TOU1xPTR2	88	19	22%
TOU2xPTR2	243	68	28%
TOU3xPTR2	93	18	19%
TOU2xBDR	110	15	14%
PTR2-OO	218	11	5%
BDR-OO	3,333	108	3%
Total	**5,018**	**438**	**9%**

Table 30 Experience Survey Sample and Response Rate – Winter 2016/2017

Treatment	Test Group			Control Group		
	Number of Contacted	Number of Completes	Response Rate	Number of Contacted	Number of Completes	Response Rate
TOU1	110	18	16%	–	–	–
TOU2	402	66	16%	–	–	–
TOU3	115	19	17%	–	–	–
PTR1	103	24	23%	–	–	–
PTR2	206	61	30%	–	–	–
PTR3	157	40	25%	–	–	–
TOU1xPTR2	94	17	18%	–	–	–
TOU2xPTR2	203	39	19%	–	–	–
TOU3xPTR2	110	26	24%	–	–	–
TOU2xBDR	159	18	11%	–	–	–
PTR2-OO	346	28	8%	396	42	11%
BDR-OO	3,333	132	4%	3,333	303	9%
Total	**5,338**	**488**	**9%**	**3,729**	**345**	**9%**

Table 31 Experience Survey Sample and Response Rate – Summer 2017

Treatment	Test Group		
	Number of Contacted	Number of Completes	Response Rate
TOU1	342	70	20%
TOU2	781	146	19%
TOU3	365	72	20%
PTR1	306	81	26%
PTR2	188	26	14%
PTR3	358	98	27%
TOU1xPTR2	285	67	24%
TOU2xPTR2	177	44	25%
TOU3xPTR2	260	58	22%
TOU2xBDR	766	155	20%
PTR2-OO	562	45	8%
BDR-OO	3,333	157	5%
Total	**7,723**	**1,019**	**13%**

Table 32 Experience Survey Sample and Response Rate – Winter 2017/2018

Treatment	Test Group			Control Group		
	Number of Contacted	Number of Completes	Response Rate	Number of Contacted	Number of Completes	Response Rate
TOU1	318	74	23%	389	83	21%
TOU2	746	133	18%	388	79	20%
TOU3	338	71	21%	389	88	23%
PTR1	289	88	30%	295	77	26%
PTR2	181	47	26%	169	43	25%
PTR3	339	104	31%	351	83	24%
TOU1xPTR2	275	71	26%	265	53	20%
TOU2xPTR2	172	45	26%	153	41	27%
TOU3xPTR2	251	57	23%	248	52	21%
TOU2xBDR	726	143	20%	–	–	–
PTR2-OO	507	57	11%	593	53	9%
BDR-OO	3,333	220	7%	3,333	309	9%
Total	**7,475**	**1,110**	**15%**	**6,573**	**961**	**15%**

Appendix F. Additional Survey Results

Table 33, Table 34, Table 35, Table 36, Table 37, Table 38, Table 39, Table 40, Table 41, Table 42, and Table 43 provide additional survey results, which the report's main body does not include.

Table 33 Percentage of Correct Rate Schedule Identification – Winter 2016/2017[94]

Treatment	% Who Correctly Identified Their Rate Schedule	n
TOU-Only	**63%**	**103**
TOU1	78%	18
TOU2	58%	66
TOU3	53%	19
Hybrids	**65%**	**100**
TOU1xPTR2	76%	17
TOU2xPTR2	79%	39
TOU3xPTR2	50%	26
TOU2xBDR	56%	18
All	**64%**	**203**

[94] Survey Question: Which image describes the rates you pay for electricity on the Flex Program?

Table 34 Flex Event Energy Conservation Participation Rates – Winter 2016/2017[95]

Treatment	% Who Responded "Yes" to Conserving During Events	n
PTR-Only	**79%**	**125**
PTR1	79%	24
PTR2	75%	61
PTR3	85%	40
Hybrids	**81%**	**100**
TOU1xPTR2	94%	17
TOU2xPTR2	82%	39
TOU3xPTR2	92%	26
TOU2xBDR	50%	18
Opt-Outs	**64%**	**160**
BDR-OO	64%	132
PTR2-OO	61%	28
All	**73%**	**385**

Table 35 How Participants Conserved During Flex Events – Winter 2016/2017[96]

Action Taken	% (n=313)
Shifted cooking, washing, or other chores to off-peak times	77%
Turned off lights or reduced use of lights	70%
Adjusted the heating thermostat settings by lowering the temperature	53%
Put on more layers of clothes or blankets	43%
Left the house	28%
Unplugged appliances or electronics not in use	25%
Used non-electric heating source such as wood, gas, and pellets	17%
Turned off the electric heater	15%
Lowered the water heating temperature	7%
Took some other action	7%

[95] Survey Question: Did you and your household do anything to conserve energy during "Flex Time" events?
[96] Survey Question: How did you and your household conserve energy during "Flex Time" events? (Select all that apply).

Table 36 Overall Satisfaction with Flex – Summer 2016[97]

Treatment	Test Group			
	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n
TOU-Only	**7.0**	**31%**	**68%**	**97**
TOU1	5.4	17%	38%	24
TOU2	7.3	34%	76%	59
TOU3	8.1	43%	86%	14
PTR-Only	**7.5**	**41%**	**78%**	**102**
PTR1	7.5	46%	85%	13
PTR2	7.0	33%	72%	57
PTR3	8.3	53%	88%	32
Hybrids	**7.1**	**32%**	**73%**	**120**
TOU1xPTR2	6.3	32%	63%	19
TOU2xPTR2	7.5	38%	79%	68
TOU3xPTR2	6.6	17%	56%	18
TOU2xBDR	6.7	20%	73%	15
Opt-Outs	**6.4**	**18%**	**53%**	**119**
BDR-OO	6.4	17%	54%	108
PTR2-OO	6.4	27%	45%	11
All	**7.0**	**30%**	**68%**	**438**

[97] Survey Question: Please rate your overall satisfaction with the Flex Program using a 0 to 10 scale where a zero means you are "extremely dissatisfied" and a 10 means you are "extremely satisfied."

Table 37 Overall Satisfaction with Flex – Winter 2016/2017[98]

Treatment	Test Group			
	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n
TOU-Only	**4.4**	**17%**	**33%**	**103**
TOU1	2.8	6%	28%	18
TOU2	4.4	15%	27%	66
TOU3	6.0	32%	58%	19
PTR-Only	**7.3**	**41%**	**78%**	**125**
PTR1	5.8	17%	63%	24
PTR2	7.3	36%	77%	61
PTR3	8.3	63%	90%	40
Hybrids	**5.9**	**20%**	**58%**	**100**
TOU1xPTR2	6.5	24%	71%	17
TOU2xPTR2	5.7	13%	54%	39
TOU3xPTR2	7.0	38%	69%	26
TOU2xBDR	4.3	6%	39%	18
Opt-Outs	**6.4**	**26%**	**63%**	**160**
BDR-OO	6.3	22%	64%	132
PTR2-OO	6.7	43%	57%	28
All	**6.1**	**26%**	**59%**	**488**

[98] Survey Question: Please rate your overall satisfaction with the Flex Program using a 0 to 10 scale where a zero means you are “extremely dissatisfied” and a 10 means you are “extremely satisfied.”

Table 38 Overall Satisfaction with Flex – Summer 2017[99]

Treatment	Test Group			
	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n
TOU-Only	**7.4**	**39%**	**76%**	**288**
TOU1	6.5	23%	57%	70
TOU2	7.7	45%	82%	146
TOU3	7.8	42%	82%	72
PTR-Only	**8.1**	**48%**	**83%**	**205**
PTR1	7.9	46%	79%	81
PTR2	8.0	42%	92%	26
PTR3	8.2	52%	84%	98
Hybrids	**7.5**	**37%**	**79%**	**324**
TOU1xPTR2	7.2	34%	72%	67
TOU2xPTR2	6.9	27%	70%	44
TOU3xPTR2	8.0	50%	88%	58
TOU2xBDR	7.6	37%	81%	155
Opt-Outs	**6.4**	**27%**	**56%**	**202**
BDR-OO	6.1	23%	51%	157
PTR2-OO	7.8	40%	73%	45
All	**7.4**	**38%**	**74%**	**1,019**

[99] Survey Question: Please rate your overall satisfaction with the Flex Program using a 0 to 10 scale where a zero means you are “extremely dissatisfied” and a 10 means you are “extremely satisfied.”

Table 39 Overall Satisfaction with Flex – Winter 2017/2018[100]

Treatment	Test Group			
	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n
TOU-Only	**6.3**	**23%**	**61%**	**278**
TOU1	5.9	23%	54%	74
TOU2	6.5	23%	62%	133
TOU3	6.2	23%	68%	71
PTR-Only	**8.1**	**52%**	**86%**	**239**
PTR1	7.7	44%	80%	88
PTR2	8.2	55%	89%	47
PTR3	8.3	58%	89%	104
Hybrids	**6.9**	**35%**	**71%**	**316**
TOU1xPTR2	6.9	38%	69%	71
TOU2xPTR2	6.7	18%	73%	45
TOU3xPTR2	7.1	46%	72%	57
TOU2xBDR	7.0	36%	71%	143
Opt-Outs	**6.4**	**27%**	**61%**	**277**
BDR-OO	6.2	25%	57%	220
PTR2-OO	7.3	35%	79%	57
All	**6.9**	**34%**	**69%**	**1,110**

[100] Survey Question: Please rate your overall satisfaction with the Flex Program using a 0 to 10 scale where a zero means you are "extremely dissatisfied" and a 10 means you are "extremely satisfied."

Table 40 Overall Satisfaction with PGE – Summer 2016[101]

Treatment	Test Group			
	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n
TOU-Only	**8.2**	**43%**	**93%**	**97**
TOU1	8.2	33%	92%	24
TOU2	8.2	44%	93%	59
TOU3	8.6	57%	93%	14
PTR-Only	**8.1**	**44%**	**89%**	**102**
PTR1	8.4	46%	92%	13
PTR2	7.8	37%	88%	57
PTR3	8.5	56%	91%	32
Hybrids	**7.9**	**40%**	**88%**	**120**
TOU1xPTR2	7.9	47%	84%	19
TOU2xPTR2	8.1	43%	88%	68
TOU3xPTR2	7.5	39%	89%	18
TOU2xBDR	7.6	20%	93%	15
Opt-Outs	**7.6**	**45%**	**80%**	**119**
BDR-OO	7.6	45%	80%	108
PTR2-OO	7.5	36%	82%	11
All	**7.9**	**43%**	**87%**	**438**

[101] Survey Question: Please rate your overall satisfaction with PGE using a 0 to 10 scale where a zero means you are "extremely dissatisfied" and a 10 means you are "extremely satisfied."

Table 41 Overall Satisfaction with PGE – Winter 2016/2017[102]

Treatment	Test Group				Control Group			
	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n
TOU-Only	**7.1**	**28%**	**78%**	**103**	**–**	**–**	**–**	**–**
TOU1	6.4	17%	72%	18	–	–	–	–
TOU2	7.3	30%	79%	66	–	–	–	–
TOU3	7.4	32%	79%	19	–	–	–	–
PTR-Only	**8.0**	**46%**	**87%**	**125**	**–**	**–**	**–**	**–**
PTR1	7.8	42%	88%	24	–	–	–	–
PTR2	7.9	46%	85%	61	–	–	–	–
PTR3	8.3	50%	90%	40	–	–	–	–
Hybrids	**7.5**	**35%**	**82%**	**100**	**–**	**–**	**–**	**–**
TOU1xPTR2	7.7	47%	88%	17	–	–	–	–
TOU2xPTR2	7.2	28%	79%	39	–	–	–	–
TOU3xPTR2	8.2	50%	88%	26	–	–	–	–
TOU2xBDR	6.8	17%	72%	18	–	–	–	–
Opt-Outs	**7.6**	**39%**	**83%**	**160**	**8.2**	**47%**	**90%**	**345**
BDR-OO	7.7	39%	83%	132	8.2	46%	91%	303
PTR2-OO	7.4	39%	79%	28	8.1	55%	88%	42
All	**7.6**	**38%**	**83%**	**488**	**8.2**	**47%**	**90%**	**345**

[102] Survey Question: Please rate your overall satisfaction with PGE using a 0 to 10 scale where a zero means you are "extremely dissatisfied" and a 10 means you are "extremely satisfied."

Table 42 Overall Satisfaction with PGE – Summer 2017[103]

Treatment	Test Group			
	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n
TOU-Only	**8.4**	**56%**	**91%**	**288**
TOU1	8.0	41%	91%	70
TOU2	8.5	62%	92%	146
TOU3	8.5	56%	90%	72
PTR-Only	**8.7**	**63%**	**93%**	**205**
PTR1	8.5	59%	94%	81
PTR2	8.7	65%	92%	26
PTR3	8.8	66%	93%	98
Hybrids	**8.3**	**54%**	**88%**	**324**
TOU1xPTR2	8.6	55%	91%	67
TOU2xPTR2	7.4	36%	77%	44
TOU3xPTR2	8.3	60%	86%	58
TOU2xBDR	8.5	57%	90%	155
Opt-Outs	**8.1**	**50%**	**85%**	**202**
BDR-OO	8.0	48%	83%	157
PTR2-OO	8.3	53%	91%	45
All	**8.4**	**56%**	**89%**	**1,019**

[103] Survey Question: Please rate your overall satisfaction with PGE using a 0 to 10 scale where a zero means you are "extremely dissatisfied" and a 10 means you are "extremely satisfied."

Table 43 Overall Satisfaction with PGE – Winter 2017/2018[104]

Treatment	Test Group				Control Group			
	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n	Mean Rating	% Delighted (9–10 Rating)	% Satisfied (6–10 Rating)	n
TOU-Only	**7.7**	**42%**	**79%**	**278**	**8.4**	**55%**	**90%**	**250**
TOU1	7.3	36%	78%	74	8.2	52%	87%	83
TOU2	7.8	47%	77%	133	8.8	65%	96%	79
TOU3	7.8	38%	86%	71	8.2	50%	86%	88
PTR-Only	**8.5**	**54%**	**91%**	**239**	**8.4**	**53%**	**91%**	**203**
PTR1	8.4	51%	88%	88	8.3	47%	91%	77
PTR2	8.3	51%	91%	47	8.2	49%	88%	43
PTR3	8.7	59%	93%	104	8.5	61%	93%	83
Hybrids	**7.9**	**47%**	**84%**	**316**	**8.2**	**51%**	**91%**	**146**
TOU1xPTR2	8.2	54%	86%	71	7.9	51%	89%	53
TOU2xPTR2	7.7	40%	84%	45	8.4	54%	95%	41
TOU3xPTR2	7.7	44%	79%	57	8.4	50%	90%	52
TOU2xBDR	7.9	46%	85%	143	–	–	–	–
Opt-Outs	**7.8**	**42%**	**84%**	**277**	**8.2**	**49%**	**88%**	**362**
BDR-OO	7.7	40%	81%	220	8.2	50%	89%	309
PTR2-OO	8.3	49%	95%	57	7.7	42%	81%	53
All	**8.0**	**46%**	**84%**	**1,110**	**8.3**	**52%**	**89%**	**961**

[104] Survey Question: Please rate your overall satisfaction with PGE using a 0 to 10 scale where a zero means you are "extremely dissatisfied" and a 10 means you are "extremely satisfied."

Appendix B – FLEX Customer Satisfaction Surveys

Overall Report

PGE Flex 2.0 2019 Recruitment Survey (AM)

July 22, 2019 11:40 AM PDT

A1 - Before we start asking you about your program enrollment, please rate your …

#	Field		Choice Count
1	0 – Extremely dissatisfied	1%	7
2	1	0%	2
3	2	0%	2
4	3	1%	5
5	4	1%	4
6	5	6%	40
7	6	4%	28
8	7	11%	79
9	8	18%	130
10	9	18%	130
11	10 – Extremely satisfied	34%	242
12	Don't know	6%	45
			714

Showing rows 1 - 13 of 13

B1 - How did you hear about Peak Time Rebates? Select all that apply.

#	Field	Choice Count	
1	Email from PGE	44%	312
2	Mail from PGE	19%	137
3	PGE website	34%	240
7	Home canvasser	1%	10
8	Community event	1%	4
4	Family/friend/co-worker/neighbor	2%	13
5	Other (Please describe)	10%	68
6	Don't know	1%	5
			715

Showing rows 1 - 9 of 9

B1_7_TEXT - Other (Please describe)

Other (Please describe)
over the phone with a csr agent
Customer Service Representative
While talking to customer service rep about other matter.was asked if I would be interested.
Customer service rep referred me over the phone
PGE representative
I just moved to OR. I was informed of this program when I called to start up service.

Other (Please describe)

When changing addresses the pge representative told me about the program
PGE customer service
From Pge over the phone
The nice lady that helped me
Part of my bill information.
Called in to customer service for billing question
Newsletter included in bill.
Was told about it when I recently set up an account when I moved to Oregon from California.
described in a magazine
PGE worker when I called to start new service.
Past client
PGE representitive, when I called to move my service to my new house.
I called and she told me about it
Spoke directly with PGE.
I called in to discuss options of lowering our expenses
Asked by phone agent when changing addresses
Been on it before
Told about it when activating my service

Other (Please describe)
Phone call
My wife
New homeowner and was asked
called in to pay bill, agent gave me info.
nest
Agent
PGE phone rep
From someone on the phone.
Call center
I talked to a representative over the phone, Very professional and friendly.
Nest?
Over the phone with a pge customer service person.
On phone during set up
PGE Customer Service Representative
I signed up at the time I opened the account.
I called for new service and was told about the program.
Service transfer technician
From the PGE customer service via phone

Other (Please describe)
PGE enrollment of service
Person on the phone
Talking with a PGE representative.
I also asked questions during Hillsboro Electric avenue grand opening
pge employee when i called to move my service to new location
PGE disconnection notice email
I called PGE on another matter, and the lady I spoke with told me about this program. And actually it started that same day.
customer service at PGE while I was asking about installing a heat pump
While speaking with a PGE agent about my bill.
Earth Day Fair
I'm not actually sure how I got put on this email list but I'm interested in learning about the program....
I got a call about it a few months ago
Called PGE billing and agent mentioned it to me.
Pge customer service call
Pge rep
Was on a call with PGE
My Nest thermostat?

Other (Please describe)
Milwaukie farmers market
When I contacted Customer Service for another issue
Pge customer service
Tesla atore
When I called in the rep told me about them
From PGE customer service rep when turning on power at new home
On the phone with pge
Nest email
Was in the flex trial run plan.

B1_7_TEXT - Topics

#	Field		Choice Count
1	PGE customer service representative	75%	51
2	Other	12%	8
3	Nest	6%	4
4	Community event	4%	3
5	Email from PGE	1%	1
6	Mail from PGE	1%	1
			68

Showing rows 1 - 7 of 7

C1 - Why did you enroll in Peak Time Rebates? Select all that apply.

#	Field		Choice Count
1	To reduce my energy bill by earning bill credits	89%	636
2	To support more use of renewables	45%	318
4	To avoid increased emissions from peak period power generation	44%	314
3	To reduce the need to build new power plants	29%	207
5	I had a positive experience with other PGE programs	11%	82
6	Other (Please describe)	2%	17
7	Don't know	1%	5
			714

Showing rows 1 - 8 of 8

C1_8_TEXT - Other (Please describe)

Other (Please describe)
I enrolled to experience how it actually worked.
Why not
Seemed simple enough with no obligation
To demonstrate to PGE that distributed renewables and significant demand response are the only solution to the significant capacity shortfall in the next decade.
I didn't enroll I just got this email assuming I did
My wife signed up

Other (Please describe)

To see if my household can use less energy

To do one more little thing to help offset the insanity of the current White House beliefs regarding climate change.

PGE rep said it didn’t cost anything or require reduced use at set times all the time

To try any method possible to reduce my home's carbon footprint.

$$ REBATES

To pay less on a monthly bill and to charge my car at off-peak hours.

Wanted to participate in a new and innovative program

To help decrease peak hours demand for the area.

All of the above

To reduce co2 emissions to the extent I can.

Help save energy as much as possible

C1_8_TEXT - Topics

#	Field	Choice Count	
1	Other	41%	7
2	To avoid increased emissions from peak period power generation	24%	4
3	To reduce my energy bill by earning bill credits	18%	3
4	Co-applicant issue	12%	2
5	It looks simple or easy to do	12%	2
6	To reduce the need to build new power plants	12%	2
7	I had a positive experience with other PGE programs	6%	1
8	To support more use of renewables	6%	1
			17

Showing rows 1 - 9 of 9

D1 - Please tell us if you agree or disagree with the following statements about yo…

#	Field	Completely agree		Somewhat agree		Neutral		Somewhat disagree		Completely disagree	
1	How the program works was clear to me	37%	258	37%	262	15%	103	6%	42	2%	17
2	The benefits of participating were clear to me	45%	316	34%	241	12%	86	5%	32	2%	14
3	It was easy to enroll	83%	580	11%	79	3%	24	1%	6	0%	0
4	The customer service representative was knowledgeable about the program	61%	68	13%	15	11%	12	0%	0	4%	4
5	The person who enrolled me at my home or a community event was knowledgeable about the program	100%	5	0%	0	0%	0	0%	0	0%	0

Showing rows 1 - 5 of 5

D2 - What could PGE have done to improve your enrollment experience?

What could PGE have done to improve your enrollment experience?
It's probably just me being dumb.
That I have enrolled is news to me. I have NO experience with the program that I am aware of.
I don't remember signing up for the program. I looked up information while filling out this survey and the program sounds good to me.
give examples of how the program works or how individuals use it.
Be more detailed about the program.
Explain some details
There was an online glitch
Need more info
let me know if it was making any difference to my bill
I am supposed to get some sort of notification as to when peak times are so I can avoid them but have not seen anything yet. It is not to clear as to how and when the notifications will start.
Explain it better
didn't even know i enrolled in peak time whatever
More information about what to do
Maybe a e mail with more detailed info
Clearly state program rules/benefits
i live in a condo and dont control my heat. is it possible to send out site specific info?

What could PGE have done to improve your enrollment experience?

Offer bill credits....I use power during off peak hours.

Na

Nothing, I could have read the info more thoroughly

I still don't know how to use this. How will they contact me? The only way is by text. I don't have internet at my place.

A little more detail on your website.

Provide more information about how the program works. Include graphics or diagrams

There could be more explanation of what the off peak times.

I really have no idea how this program works, or what the benefits are. I just thought that I could make a difference and I trusted PGE to walk me through it.

Explain the program to me.

More clearly explain what happens during peak times and how I can participate

Explained how the program works and is beneficial on the website.

I signed up for the program and found out that I am not eligible for the $$ REBATES. I was told that I can be un-enrolled and it appears that I am still in the program. I am very disappointed with the whole program and PGE! Please un-enroll me.

Been more clear

The flyer that came in the mail did not explain how to enroll.

I don’t have a recollection of this particular program.

I didnt see where I could find out more about the program.

What could PGE have done to improve your enrollment experience?

I still don't know how this program works

Not sure how I got enrolled, so I assume enrollment is very easy......would like more info though.

Explain in more detail

Turning on peak time notifications, was not labeled correctly.

The flyer was vague. I had to call and ask questions of your representative to fully understand the program. I feel the flyer was simply a teaser, but after talking to your rep, I think I get it. If there will be added benefit of not building more power plants and using more renewable energy, that will be great. I didn't realize that was part of the larger objective.

Seems like a complex system and I’m unclear whether it will actually show how much I change my usage

More info about how it works once I enrolled

Offer a link to more details on the program

More detailed explanation

The enrollment through nest was not clear. I got lots of error messages and after reaching out to support it turned out that even though my enrollement errored out, it was successful.

I do not understand the rebate process or when peak time is. I read the webpage, but still uncertain about how the program works.

D2 - Topics

#	Field	Choice Count	
1	Provide/improve customer education	79%	34
2	Co-applicant issue/Customer unaware of enrollment	12%	5
3	No suggestion	5%	2
4	For PGE to follow up	2%	1
5	Not applicable	2%	1
6	Problem with PGE enrollment website	2%	1
			43

Showing rows 1 - 7 of 7

E1 - When outside temperatures are unusually hot or cold, PGE customer deman…

#	Field	Choice Count	
1	Yes	88%	628
2	No	12%	86
			714

Showing rows 1 - 3 of 3

E2 - PGE will notify Peak Time Rebates customers in advance about when a peak…

#	Field	Choice Count	
3	Shift cooking, washing, or other chores to off-peak times	92%	660
4	Turn off lights or reduce use of lights	81%	581
1	Manually adjust thermostat settings before or during events	68%	484
2	Reprogram thermostat settings to reduce energy during typical event hours	27%	196
6	Leave the house	22%	159
5	Adjust water heater temperature settings	10%	72
9	Avoid charging my electric or plug-in hybrid vehicle at home	7%	52
7	Other (Please describe)	3%	25
8	Don't know	1%	4
			715

Showing rows 1 - 10 of 10

E2_9_TEXT - Other (Please describe)

Other (Please describe)
Plug in car in low demand time.
Turn off the AC in summer. Use my woodstove, rather than furnace in winter.
reduce electric use whenever possible
No TV or laundry or dishwasher.

Other (Please describe)

Monitor usage at event time in order to calculate ability to reduce demand in the moment, however it may be happening right then.

Turn off vampires

Read a book instead of watching TV. Use phones on battery rather than charge, etc.

Use Power Wall

increase use of wood heat

Change settings in my home automation controller to reduce usage during the peak hours. Support for automatic demand response for home owners would be helpful since my controller (Universal Devices isy-994) supports ADR

Unplug computers and appliances

Developing sustainable environment in and around my property while learning new techniques and maintaining the old growth "hopefully " canopy.

All in all, just preparing to be aware during a peak period - our home has radiant heat w/o AC - our heat is turned off in all 4 zones by the end of may and not on again until the end of October. That being said, it's not becoming for us to have sleep/home/away settings due to the nature of what it takes for a boiler to increase our home temperatures. That being said, however, 3/4 zones heat to 67 degrees, while the 4th less used zone only heats to 55 degrees. For summer high temps, I may consider altering our use of a room air conditioner, however, we seldom use it already. Time will tell!

NONE OF THE ABOVE, SHAM PROGRAM!

For the summer months my Thermostat is turned off. Charge BEV on off peak hours. My Lights are all LED. My hot water is Natural Gas. Doing Laundry and Dishes at different times are the things that will help the most.

Ask husband to avoid use of power tools.

Don’t use tv

Turn off the air conditioner.

Other (Please describe)

Our heat is gas so thermometer adjustment doesn't apply as much to us (I know it still uses electricity to function).

Unplug unnecessary devices

I have no idea how to really make a difference. I am not convinced

I plan to recharge my plug-in hybrid car during off-peak hours. I may also change the charger to 220 rather than 110. Speaking of, it would be nice for PGE to offer me an incentive to do so.

Decrease use of electronics, such as the TV and computer, during peak hours.

Unplug appliances

limit opening the refrigerator, freezer

E2_9_TEXT - Topics

#	Field	Choice Count	
1	Unplug unnecessary devices	32%	8
2	Other	20%	5
3	Avoid charging my electric or plug-in hybrid vehicle during peak hours	16%	4
4	Decrease use of air-conditioner	12%	3
5	Decrease use of white goods	12%	3
6	Increase use of wood heat	8%	2
7	Not applicable	8%	2
8	Don't know	4%	1
			25

Showing rows 1 - 9 of 9

F1 - Please tell us if you agree or disagree with the following statements about the…

#	Field	Completely agree		Somewhat agree		Neutral		Somewhat disagree		Completely disagree	
1	My household will need to change its energy-use habits under this program	18%	123	45%	318	19%	136	10%	70	3%	24
2	I expect it will be easy to shift electricity usage from peak event to non-event hours	28%	199	47%	331	16%	110	6%	39	1%	6
3	I am worried that peak time events will be called when I need to use energy the most	6%	43	28%	195	31%	216	17%	116	13%	91
4	I am expecting to earn $1 to $5 rebate dollars per event	19%	135	21%	150	26%	180	3%	20	2%	16
5	I am expecting to earn $6 to $10 rebate dollars per event	12%	85	15%	104	30%	210	8%	53	7%	50
6	I am expecting to earn more than $10 rebate dollars per event	10%	74	10%	73	30%	210	9%	63	11%	81
7	I understand my program participation enables use of more renewable energy sources and helps keep rates low for all	43%	301	34%	242	14%	98	2%	14	1%	8

Showing rows 1 - 7 of 7

F2 - What concerns or questions do you have about the Peak Time Rebates progr…

What concerns or questions do you have about the Peak Time Rebates program,...
How will I be notified about when peak time rebates will be in effect
no concerns
where will it show if I have earned rebates or not ?
Any subjects to fees?
Not sure how or when its to kick in..
I didn't know it will enable more renewable energy sources! I am really happy it will.
N/A
I want to see if this helps. If not, I am worried I won't be able to switch back to regular usage.
None
I am interested to now how much of a rebate I'll receive as my energy bill is so high in the cold months.
If it actually works.
none
None
Because we are new to the state, we need to wait and see how this program will work for us.
none
None!

What concerns or questions do you have about the Peak Time Rebates program,...

None

I have yet to be notified of a peak time. This email is my only correspondence directly with PGE. About how far in advance will the notice be of a peak time? Thank you.

What if you already are a conserver vs other people, how will one get to benefit.

None

Not sure

None

Nearly all of my electric usage is fixed and on a regular schedule. I like the idea of knowing when to try to change my schedule, as opposed to trying to shift all my usage, every day, to off-peak hours. That is more likely to succeed. However, it still may not be possible to shift my usage.

I hope it will be worth my effort in terms of lowering my bill.

I don’t have central ac and have gas heat so I’m not sure how much I’ll affected

None

will i know about the event with enough advance notice to be able to do what is needed?

I already try to conserve so any savings I receive is great.

I don't understand what basis they use to determine how much I lowered my consumption. Is it an average of compared to my last year consumption?

my usage is so low already I doubt if I can help much

How the usage reduction is calculated for sure--by the usage in place immediately prior to the event?

None at this time

What concerns or questions do you have about the Peak Time Rebates program,...

How will I know if I’m within the temperature I need to be when it’s time to adjust so that I can earn the maximum rebate?

Nothing

We should all probably try to reduce peak time use every day, and get some kind of reward for that, but calculating it would probably be difficult.

I don't remember the details, so I plan to learn more over time. It would be nice to know more about how much energy is used by various appliances. Also ideas about reducing use. (for example, when it is hot, I put my laundry on indoor folding drying racks overnight to dry and then toss in the drier for 5 minutes so it isn't crunchy. That way I use the drier for 5 minutes, not 60 minutes.)

I don’t know how much I will actually get as a rebate or discount if I participate

That I won't actually be able to reduce my usage and earn credits.

When I turned up my Nest thermostat past the peak-time-set temperature, I couldn't turn it back down to the pre-set temperature without being kicked out of the rewards for the period.

None

My husbands reaction to no AC😂

Have never received notification yet

None

Have a good day

We aren't heavy users anyway, so I'm unclear how much we can save/earn.

When will the program start? I have not seen any notifications since enrolling.

None. I already have TOU, so it shouldn’t cause us any problems to participate.

My only concern is whether this program will work for us. We don't particularly "waste" energy now.

What concerns or questions do you have about the Peak Time Rebates program,...

Could this program result in a higher bill if I was unable to survive a peak event without AC?

None

My home will be too hot during hot peak times to reduce my a/c use much.

our boiler system/radiant hot water is for our whole building, which i dont control. i feel like i can participate minimally with when i turn on my lights or tv, but not sure that i'm making a difference.

I'm concerned that PGE will be unable to fully understand and share the grid-wide benefit of this program and will not roll it out to all participants.

How easy it will e to earn money. And how much is needed to do to earn it.

I have no idea what this is all about didn't know I signed up is this going to cost me money

Anyone in the household getting sick from turning the air conditioner down during extremely hot days

None

1) That the rebate will not be as large as I would like 2) I won't see the notice in time to make changes

I used to have a Nest thermostat which would automatically adjust my settings during these peak time rebates. Now that I have moved, I'm not sure if my new device can do the same thing.

Again, how will I know? Text?

My only concern is that if the outdoor temp is extremely hot, I would have to run my AC due to my health issues - I would try to reduce the usage of course

Work in heated or cold environment.

How often do you expect the peak time to happen ?

How does PGE know (with any accuracy) that I took action? I may be sitting here sweating, while it looks to PGE that I did nothing.

What concerns or questions do you have about the Peak Time Rebates program,...

None

If we already try to use energy wisely, the benefit is less, because you are comparing us to ourselves, not other users.

Will there be bill or usage reports showing what my usage was leading up to these events, and then the reduction during the event? Where is the accountability on your side in terms of me knowing just how much I did or did not reduce my usage? Do I just have to trust what you say, or can you provide data to back up the rebate (or lack thereof) for each usage period?

none

None

I wonder if we will be able to make a difference when compared to our normal usage because I think we are already on the low end of use. But we will see!

How quickly will I know that i qualifies for a rebate?

I can't remember if the rep let me know how much notice I will receive before Peak Time happens.

None

well I have never been notified about one yet so i don't know when they will happen

I am not sure what will make a difference. I need a list or something to follow.

Tolerating colder indoor temps for peak time compliance is not a problem for residents of my home. But when outdoor temperature goes above 86° F, parts of the house become too hot for the elderly and\or health challenged here.

The current situation with my property are, water pump and pressure tank issues. Repairs have been made and tank needs updated . Thinking of adding 2 breakers to panel to avoid overload.

That I won't be correctly notified. I was told it would be by e-mail because my cell is for emergencies. That option wasn't listed on the site.

What concerns or questions do you have about the Peak Time Rebates program,...

How much less energy will we have to use to get a rebate? How are the rebates calculated? What is the purpose of the program?

None

That creature comfort will supersede a desire to conserve energy. When both hot and cold, humans have the option for relief. I am not confident that my roommate has the discipline to balance discomfort and the greater good.

None

It's unclear how much of a rebate can be made and at what rate that rebate generation is calculated. Especially when I'm already pretty conscious about my energy usage and how low it is.

None. Anxious to see how it works

Have to experience first

That it will be in the high 90 degrees or higher outside and I'll be punished for using air conditioning like we were in Arizona.

I would like to know how much energy I saved by making smart choices during peak times

Rather or not my home's energy trend shows we've used more energy during previous peak periods... our home naturally stays fairly cool/comfortable during the summer with proper window management during the evening and overnight, along with being covered by shade > 80% of the day. In the winter, our radiant heat does a good job of warming the contents of our home and cycles less frequently + having 3/4 zones only heat to 67 degrees and the other less used space at 55 degrees, I'm not sure we'll have a way to decrease energy... that being said, if we're already under the baseline of not using too much energy, will we still received any credit?

FRAUD

Learning more about it and getting into the habit of it

I have rooftop solar, and my net usage over the summer months is negative. I'm not sure how this program will impact me.

I am simply not sure how much it will save me on my bill.

What concerns or questions do you have about the Peak Time Rebates program,...

None at this time; I want to see how it works.
I'm concerned we already use too low an amount of energy to see a difference in our price
None
None at this time.
There will be some catch and that what I do will not apply for any credit
That I am missing something.
If we already had low use during peak energy times, will we need to be even lower than our personal use history to receive a rebate? Or will our use be compared to neighborhood/similar households?
None
I worry I will do all of the effort but not get anything for it, or very little (like less than 3 dollars)
Right now I have the air conditioner or the thermostat completely turned off. How will this affect me. During peak time
Primarily around what options we have to shift hot water heater around peak energy automatically.
Let’s save the planet!
How will this be measured? Is this based off of how high energy use was in our home last year?
None now
none
None

What concerns or questions do you have about the Peak Time Rebates program,...

We are already very careful about our energy usage. I am not sure we will be able to reduce our usage any more than we already do, even at peak usage events. For example, we keep our house at 68D/58N during the winter and have only turned on our air conditioner once in over 20 years. So I don't really expect to see any reductions, but maybe we will!

wish it was automatic like I have experienced in MN

I find this whole program confusing

None

None

None

It is not clear to me how the change in my energy use will be calculated. Is it based on my home's metered energy use during the peak time period? Or is it based on average consumption for similar homes?

N/A

One of my concerns is that my partner will not be as motivated as I am to make changes because they prefer the convenience of using energy when needed.

None

None

None

We have a baby now whose bedroom is upstairs (former attic space) if it’s really hot we will still keep his room cool or warm

I have not received a peak times notification so I have no idea how the program is supposed to function.

I hope being a a part of this program won't actually cost me more. If we are unable to successfully lower our usage, will we be penalized because of high normal usage, rather than the lower usage during the peak hours that you want us to use?

What concerns or questions do you have about the Peak Time Rebates program,...

Whether my other household members will help

Since enrollment, I haven't heard anything else about the program so I don't even know that it's functioning. If it was a "future" program, it was not discussed as such. It sounded like it was being implemented as soon as I agreed to participate.

lookimg for additional ways to reduce energy consumption beyond what I am already doing

I would like to see the amount earned clearly stated, how the actual $$ amount is calculated.

None, I hope to make permanent changes to help the environment.

No concerns

None at this time yet

If I already avoid peak times will that help with a higher rebate?

None

N/A

won't be worth the effort, won't reduce my electric bill. I just moved into this house that is 25 years old and my electric bill was a shock, so I'm hopeful this program may help

None. Waiting to see when it occurs...

That it might be too hot or too cold when I'm trying to work from home. I'm not sure how this program will work, but I'm willing to try it.

F2 - Topics

#	Field	Choice Count	
1	None	43%	58
2	No benefit to the low-energy consumers	10%	13
3	Event notifications	9%	12
4	Baseline or usage reduction calculation	7%	10
5	Other	7%	10
6	Ability to reduce/shift usage	5%	7
7	The temperature	5%	7
8	Bill credit amount	4%	6
9	Tips and ideas on ways to reduce/shift	3%	4
10	Confusion with Nest RHR program	2%	3
11	Qualifying for a bill credit	2%	3
12	Higher bills	1%	2
13	Cannot understand comment	1%	1
14	Unaware of enrollment/co-applicant issue	1%	1
			136

Showing rows 1 - 15 of 15

G1 - Peak Time Rebates is a program whose goal is to shift energy use to hours o…

#	Field	Choice Count	
1	Very motivated	53%	380
2	Somewhat motivated	44%	314
3	Not too motivated	2%	15
4	Not at all motivated	0%	1
5	Don't know	1%	4
			714

Showing rows 1 - 6 of 6

G2 - Does your household currently own these products? Please answer Yes or N…

#	Field	Yes		No		Don't know		Total
1	Smart thermostat (ex: Nest, Ecobee, Lyric)	22%	157	74%	528	4%	27	712
2	Voice-assisted smart speaker (ex: Amazon Echo, Google Home, Sonos One, Apple HomePod)	24%	170	76%	537	0%	2	709
3	Smart light bulbs or switches (ex: Philips Hue, Lifx, Lutron, TP-Link)	29%	204	67%	472	4%	31	707
4	Electric water heater	52%	368	40%	279	8%	57	704
5	Smart refrigerator, dishwasher, or other networked kitchen appliance	10%	69	86%	603	5%	33	705

Showing rows 1 - 5 of 5

H1 - Does your household have a plug-in electric or hybrid vehicle? Select all that …

#	Field	Choice Count	
1	Yes, a plug-in electric vehicle	4%	25
2	Yes, a plug-in hybrid vehicle	2%	15
3	No	94%	672
4	Don’t know	0%	0
			712

Showing rows 1 - 5 of 5

H2 - Do you own or rent your home?

#	Field		Choice Count
1	Own	71%	506
2	Rent/lease	28%	201
3	Other (Please describe)	1%	5
4	Don't know	0%	0
			712

Showing rows 1 - 5 of 5

H2_5_TEXT - Other (Please describe)

Other (Please describe)
Buying it privately from my ex-mother in law
Owner is in Alaska I currently live on property to keep an eye on it and maintain.
Mother in law owns home
Live in apartment complex
We are just now buying

H2_5_TEXT - Topics

#	Field	Choice Count	
1	Rent/lease	100%	5

Showing rows 1 - 1 of 1

H3 - How many people, including yourself, live in this home?

#	Field		Choice Count
1	Number of people:	97%	688
2	Prefer not to answer	3%	22
			710

Showing rows 1 - 3 of 3

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Number of people: - Text	1.00	11.00	2.84	1.48	2.18	688

H4 - What is the highest level of education completed by the primary wage earner …

#	Field	Choice Count	
1	Grade school	0%	2
2	Some high school	2%	11
3	Completed high school degree (GED)	7%	48
4	Some college or technical college	19%	136
5	Completed technical college	8%	60
6	Completed 4-year college	27%	193
7	Post-graduate work or degree	33%	234
8	Don’t know	0%	0
9	Prefer not to answer	4%	29
			713

Showing rows 1 - 10 of 10

H5 - What type of cooling system is used the most at this home?

#	Field	Choice Count	
1	Ductless heat pump or mini-split system	4%	30
2	Central forced-air heat pump	12%	85
3	Central forced-air conditioning	35%	246
4	Evaporative cooler or swamp cooler	0%	3
5	Window/wall air conditioner	13%	96
6	Portable air conditioner	11%	77
7	Portable electric fan or ceiling fan	14%	98
8	Whole house fan	2%	11
9	No cooling system	5%	37
10	Other (Please describe)	3%	24
11	Don't know	1%	5
			712

Showing rows 1 - 12 of 12

H5_12_TEXT - Other (Please describe)

Other (Please describe)
Fans and fan on furnace
central heating gas furnace
Fans in window at night

Other (Please describe)

Central forced air, but the heat ex change is to a ground loop (geo-thermal)

ceiling fan, portable AC, house stays comfortable if shuttered up (most of the time)

Room ceiling fan and windows openable to cooling cross-winds, as available.

We have central AC, but use a window air conditioner in the bedroom at night so we don't have to keep the central air on.

I have central forced air conditioning but I go to the ceiling fans, portable electric fans as much as possible

electric heat pump

Portable AC and portable electric fans

Geothermal

Both forced air and one in-window air conditioner

ducted heat pump

Box fan

We have just bought the house and may install an A/C or heat pump.. otherwise nothing there now

---

Wall air Conditioner, Ceiling Fans and Box Fans

Portable AC unit and portable fan/ceiling fan

also use wall mount air conditioners

Portable AC and portable fan used equally

Other (Please describe)
Centrally ducted mini-split heat pump
Ceiling fan
Portable air conditioner for bedroom only.
Heat pump combined with my forced-air furnace

H6 - What type of heating system is used the most at this home?

#	Field	Choice Count	
1	Electric – baseboard	7%	51
2	Electric – wall heater with fans	11%	78
3	Electric – central forced-air furnace	9%	65
4	Electric – central forced-air heat pump	9%	66
5	Electric – ductless heat pump or mini-split system	3%	22
6	Electric – radiant floor heating	1%	5
7	Electric – portable heater	2%	16
8	Natural gas – forced-air furnace	44%	310
9	Natural gas – hot water/steam upright radiator or baseboard	0%	1
10	Natural gas – boiler or hot water tank upright radiator or baseboard	0%	3
11	Natural gas – stove or fireplace insert	1%	7
12	Oil – central forced-air furnace	1%	9
13	Oil – hot water/steam upright radiator or baseboard	0%	0
14	Bottled gas propane, butane, or kerosene – central forced-air furnace	0%	3
15	Bottled gas propane, butane, or kerosene – portable heater	0%	0
16	Wood or pellet stove fireplace	4%	28
17	Solar with electric or gas backup	0%	0
18	No heating system	0%	2
19	Other (Please describe)	4%	25
20	Don’t know	3%	21

#	Field	Choice Count
		712

Showing rows 1 - 21 of 21

H6_21_TEXT - Other (Please describe)

Other (Please describe)
Natural gas, but I'm unsure of type
Heat pump with forced air gas furnace back up.
Have wood stove fireplace also and use space heaters as heating only in part of house
Electric - Radiant ceiling heat and one electric wall heater with fans
ceiling heat
geo-thermal
Hybrid Central Forced Air Furnace
Wood stove insert and Electric Central air heat pump.
Geothermal
ducted hyper-heat pump, no other heating
supplement heating with wood stove
Geothermal heat/cooling
Converting to gas

Other (Please describe)
We will be converting from oil to either electric heat pump or gas furnace
Natural gas boiler multi-zone radiant floor heat
Electric radiant ceiling heat and 1 electric in wall heater
Infrared heater.
Natural gas forced air furnace AND electric heat pump.
electric up by the ceiling
Centrally ducted mini-split heat pump
Electric - mounted on wall
Ceiling heat
Ceiling heat
My heat pump that uses our ducts heats unless it gets too cold, then the furnace turns on.

H7 - How old are you?

#	Field		Choice Count
1	18-24	2%	15
2	25-34	16%	115
3	35-44	24%	170
4	45-54	16%	114
5	55-64	18%	125
6	Over 64	21%	152
7	Prefer not to answer	3%	22
			713

Showing rows 1 - 8 of 8

H8 - Do you consider yourself to be…?

#	Field	Choice Count	
1	Caucasian or White	79%	560
2	African American or Black	1%	6
3	American Indian, Native American, or Aleut Eskimo	2%	14
4	Asian, Asian American or Pacific Islander	4%	28
5	Middle Eastern	0%	2
6	Hispanic or Latino	3%	24
7	Multi-racial or multi-ethnic	3%	21
8	Other (Please describe)	1%	6
9	Prefer not to answer	7%	52
			713

Showing rows 1 - 10 of 10

H8_10_TEXT - Other (Please describe)

Other (Please describe)
Italian-American
Human

Mixed African American and white
Irish American

Other (Please describe)
Tongan

TREATMENT

#	Field	Choice Count	
1	PTR	100%	718

Showing rows 1 - 1 of 1

PERSONA

#	Field		Choice Count
1	Borderliners	20%	142
2	Low Engagers	20%	141
3	Middle Movers	19%	140
4	Fast Growers	17%	119
5	Big Impactors	14%	99
6	NULL	11%	77
			718

Showing rows 1 - 7 of 7

TBSUBSTATION

#	Field		Choice Count
1	NULL	97%	694
2	ISLAND	2%	11
3	DELAWARE	1%	7
4	ROSEWAY	1%	6
			718

Showing rows 1 - 5 of 5

ENROLLCHANNEL

#	Field		Choice Count
1	Online	79%	569
2	Phone	16%	117
3	Conversion or Other	4%	27
4	Green Mountain	1%	5
			718

Showing rows 1 - 5 of 5

SEGMENT

#	Field	Choice Count	
1	Totally Tech	32%	233
2	Innovative Investors	26%	187
3	Sensible Savers	20%	147
4	Continually Connected	12%	89
5	Simply Service	8%	61
6	NULL	0%	1
			718

Showing rows 1 - 7 of 7

SURVEY-TAKING DEVICE

#	Field	Choice Count	
1	mobile	59%	426
2	other	41%	292
			718

Showing rows 1 - 3 of 3

End of Report

Appendix C – Cadmus Evaluation of PGE's Rush Hour Rewards 2015-2016

MEMORANDUM

To: Josh Keeling and Alex Reedin, Portland General Electric

Cc: Dyon Martin and Roch Naleway, Portland General Electric

From: Scott Reeves and Jim Stewart, Cadmus

Subject: PGE Rush Hour Rewards Findings Summary

Date: December 27, 2016

This memo presents the methodology and findings from Cadmus' evaluation of PGE's smart thermostat pilot program—Rush Hour Rewards (RHR)—for winter 2015/2016 and summer 2016.

Findings Overview

The evaluation produced several key findings regarding the first two seasons:

- ***Program Delivery/Enrollment***. In October 2015, PGE's RHR pilot launched on schedule, quickly surpassing its enrollment targets of 300 heating and 700 cooling participants for 2016. As of September 2016, the program had enrolled 398 heating and 2,492 cooling customers.
- ***Program Impacts***. The RHR pilot achieved significant demand reductions per customer during RHR events. Load reductions averaged between 0.4 and 0.6 kW per customer during winter events and about 0.8 kW per customer during summer events.
- ***Customer Experience***. Winter and summer participants reported high satisfaction levels with a variety of RHR outcomes, including comfort during events, Nest thermostats, participation incentives, and with the program overall. Customers reported higher satisfaction levels after participation.

Recommendations

Based on evaluation of program performance during the first two pilot seasons, Cadmus offers the following recommendations for consideration:

- RHR impacts on customer peak demand and satisfaction support the continuation and possible expansion of the RHR program. Cadmus did not estimate the cost-effectiveness of the RHR program, but the estimates of demand savings per customer were large and in line with PGE's expectations. PGE reported that for a range of assumptions about measure life, the RHR program would prove cost-effective.[105]

- PGE should continue to evaluate the RHR program for a second year, including both summer and winter seasons. PGE could refine its first-year assessment of DR capacity benefits and cost-effectiveness and identify additional opportunities for improving the program implementation.
- PGE should expand the program to include customers with electric furnaces. Expanding eligibility for the program would provide PGE with additional DR capacity.
- PGE should expand the program to include customers with other brands of connected thermostats. Expanding eligibility for the program would provide PGE with additional DR capacity.
- PGE should make improvements to its meter data management system and customer information system to increase its participation tracking and meter data storage and processing capabilities.
- PGE should work with the Energy Trust of Oregon to explore opportunities for achieving energy efficiency savings occurring through this program. Integrating efficiency and peak demand savings may increase the cost-effectiveness of smart thermostat programs and allow the programs to reach low and moderate-income customers.

Program Description

In October 2015, PGE launched a smart thermostat pilot program for residential customers who installed a Nest learning thermostat. Nest, the thermostat manufacturer and DR service provider, markets the program and manages the branded RHR portal for PGE. This portal allows PGE to manage loads during RHR events by adjusting temperature setpoints on participants' Nest thermostats. This primary objective of this pilot evaluation was to measure demand reduction during summer and winter RHR events. Although Nest thermostats may provide energy efficiency savings that occur on peak, this study did not measure these savings.

Outreach and Eligibility

Nest markets the program to residential customers with Nest-brand learning thermostats. Because Nest can communicate with its customers through the thermostat and Nest software, Nest primarily delivers marketing of PGE's RHR program through monthly/seasonal notifications to owners or to those newly purchasing and installing Nest thermostats. Nest thermostats assist in targeting eligible customers by collecting data about connected HVAC equipment and about customers' heating and cooling profiles, which can be used to identify homes that employ qualifying equipment.

[105] The cost-effectiveness of RHR depends on retaining participants for long enough to obtain sufficient demand response capacity benefits to cover the programs initial fixed costs, which include one-time incentive payments to customers, PGE investments in computer hardware and software, and set-up fees to program implementers. As smart thermostat programs are relatively new offerings, there is not much industry data on customer retention.

PGE provides significant marketing support for the program through several mediums, including PGE's program webpage, targeted emails to PGE customers on hot summer days, bill inserts, and social media. PGE's marketing and communication channels generated more than 40% of the traffic to Nest's PGE-specific RHR registration page.

Participants may enroll for the summer season, winter season, or both, depending on their qualifying equipment. Summertime participants must have electric central air conditioning or heat pumps; wintertime participants must have electric forced-air furnaces or heat pumps, although the program primarily enrolled heat pump customers during the first winter season. Nest cannot currently identify electric forced-air furnace customers based on how the Nest thermostat is wired. Verification of an electric forced air furnace requires analysis of the customer's energy use.

Customer Incentives

PGE customers received an incentive of $25 upon enrollment, with additional incentives of $25 per winter/summer season, depending on whether their heating or cooling equipment qualifies. Participants with heat pumps could receive up to $50 per year, while customers with central air conditioning or central electric furnaces receive $25 per year. Customers must participate in at least 50% of RHR events per season to qualify for the seasonal incentive payments.

To verify customers, meet criteria to receive incentives, Nest currently provides PGE with a list of active customers and program enrollment dates. PGE then uses these data and the number of overlapping events to calculate incentive payments. Additionally, Nest supplied PGE with a list of customers whose thermostats did not maintain an Internet connection for the event season. Going forward, a more robust verification of customer participation is under development, including a customer retention process to lure customers back into participation as well as an unenrollment process for customers who choose not to participate.

Event Delivery

Once a customer enrolled in RHR, Nest notified the customer of upcoming "Rush Hours" (i.e., DR events) and of events in progress. Notifications arrived through the Nest app and through an icon that appeared on the thermostat's display. PGE decided when to call events, which were activated using the utility's interface with the Nest RHR platform.

Afternoon events required PGE to notify intent to dispatch the event by 10:00 a.m. on the same day. All morning events required PGE to send dispatch notices by 7:00 p.m. of the previous day. Customers that tried to control their thermostats in a way contrary to the desired response (e.g., setting a lower temperature during a summer event) received a "speedbump" notification, reminding them that an electricity "Rush Hour" was in effect, and asking them to confirm that they wanted to change their setpoints (though this did not prevent them from doing so).

Nest algorithms determined the specific load control response of each customer's thermostat, based on the household's usage profile (as recorded by the Nest thermostat). If the algorithm deemed it efficient, the thermostat preconditioned the home for up to an hour in advance of an event. Note that preconditioning was not efficient for homes with usage profiles indicating a high thermal loss rate.

The OPUC requires PGE to call a minimum of six events per season (though PGE may call up to 10 events), with events scheduled to last three consecutive hours and occurring on weekday (non-holiday) afternoons, when seasonal weather increases peak demand (i.e., on cold days during winter and warm days during summer).

Event Schedule

Table 44 shows the event days, times, and average temperatures for the summer and winter seasons.

Table 44 RHR Seasonal Event Dates and Times[106]

Event	Winter			Summer		
	Date	Hours	Avg. Event Temp.	Date	Hours	Avg. Event Temp.
1	Dec 29	4:00 p.m. - 7:00 p.m.	38	Jul 27	4:00 p.m. - 7:00 p.m.	86
2	Dec 30	4:00 p.m. - 7:00 p.m.	36	Jul 29	4:00 p.m. - 7:00 p.m.	89
3	Jan 4	4:00 p.m. - 7:00 p.m.	34	Aug 4	4:00 p.m. - 7:00 p.m.	87
4	Jan 6	4:00 p.m. - 7:00 p.m.	39	Aug 11	4:00 p.m. - 7:00 p.m.	87
5	Feb 1	4:00 p.m. - 7:00 p.m.	44	Aug 12	4:00 p.m. - 7:00 p.m.	93
6	Feb 9	7:00 a.m. - 10:00 a.m.	45	Aug 18	4:00 p.m. - 7:00 p.m.	94
7	Feb 17	5:00 p.m. - 8:00 p.m.	50	Aug 19	4:00 p.m. - 7:00 p.m.	95
8	Feb 26	5:00 p.m. - 8:00 p.m.	50	Aug 25	4:00 p.m. - 7:00 p.m.	90
9				Aug 26	3:00 p.m. - 6:00 p.m.	94

Research Objectives

PGE outlined the following objectives related to pilot delivery and evaluation research:

- Implement the program over five seasons (i.e., winter 2016, summer 2016, winter 2017, summer 2017, winter 2018), with six to 10 events per season
- Measure the impact of events on customers' comfort and satisfaction
- Measure the demand reduction capacity, any preconditioning or rebound effects, and cost-effectiveness
- Determine the best strategies for scaling the pilot program into a mass market program
- Achieve positive customer experiences

[106] This analysis excludes one early summer season event (June 6, 2016) given that participating customers not yet been assigned to treatment or control groups at the time.

This memo focuses on reporting load impacts and findings, drawn from customer surveys from the first winter and summer seasons. Although smart thermostats may provide energy savings, this pilot evaluation did not seek to measure energy savings.

Methodology

Research Design

To estimate thermostat controls' impacts, Cadmus worked with PGE to implement the pilot as a RCT.[107] The RCT involved randomly assigning program participants (i.e., residential customers with Nest thermostats meeting eligibility requirements) to a treatment group or a control group. Treatment group customers experienced RHR load control events, while control group customers did not. An RCT, serving as the gold standard in program evaluation, was expected to produce an unbiased estimate of the pilot's impacts on energy demand.

Cadmus randomly assigned program participants to the treatment or control group, and then conducted tests to verify that the randomized treatment and control groups had statistically equivalent pretreatment consumption.

Data Sources

Cadmus used the following data sources in performing the analysis:

- ***Participant enrollment data***, provided by PGE, tracked enrollment for treatment group and control group customers. These data included participant name, contact information (e.g., address), a unique customer identifier (i.e., point of delivery [POD] ID), and an enrollment date.
- ***Interval consumption data***, provided by PGE for all enrolled participants. For post-enrollment periods, these included watt-hour electricity consumption at 15-minute-intervals, measured using AMI meters. For historical usage periods (prior to enrollment), only hourly data were available. The pre-enrollment data recorded customer kWh consumption (Watt hours truncated at the thousands place) from December 2014 through September 2016.
- ***Local weather data***, including hourly average temperatures from December 2014 through September 2016 for seven National Oceanic and Atmospheric Administration (NOAA) weather stations. The team used zip codes to identify weather stations nearest each participant's home and merged the weather data with the participant's billing data.

Customer Enrollment and Random Assignment

Since PGE's launch of RHR, customers have continuously enrolled in the pilot. Initially, PGE targeted enrollment of 300 winter-season participants (with heat pumps or electric heat) and 700 summer-season

[107] This design followed recommendations by the *U.S. Department of Energy's Uniform Method Project Behavior-Based Program Evaluation Protocols* and EPRI's *Consumer Behavior Study Evaluation Guidelines*.

participants (using heat pumps or central air conditioning). By the summer season's end, the program had enrolled 398 winter participants and 2,492 summer participants.

At the beginning of each season, Cadmus randomly assigned all program participants to the treatment group or control group, and then used pretreatment monthly consumption data and post-treatment consumption data on non-event days to verify that the changes did not result in statistically significant electric consumption differences between the randomized treatment and control groups. Customers signing up after initial random assignments were randomly assigned on a rolling basis to the treatment or the control group.[108]

Savings Estimation

Cadmus performed a difference-in-differences panel regression analysis of the hourly energy consumption of treatment and control group customers to estimate the RHR load impacts. The analysis compared the average consumption change between event and non-event hours for treatment group customers, with the average consumption change between event and non-event hours for control group customers. Cadmus estimated the impacts in the two hours before, three hours during, and eight hours after each event. The regression included independent variables for customer pre-treatment consumption, customer demand for heating or cooling (i.e., HDH or CDH), the hour of the day, and the day of the week. The regression analysis will likely result in an unbiased estimate of load control impacts due to random assignment of customers to treatment. This memo's appendix presents the specific model used to estimate these impacts.

Participant Surveys

Cadmus administered several surveys to assess customers' experiences. These included the following:

- A baseline survey to assess customer recruitment (fielded during enrollment);
- An event survey to assess customer awareness, thermal comfort, and behaviors during RHR events
- An end-of-season survey design to assess overall program experience.

These surveys asked customers about their satisfaction with the program, their perceptions about marketing effectiveness, their motivations for and barriers to participating, awareness of DR and RHR events, and energy-use attitudes and behaviors about space heating and cooling. The surveys also included a battery of demographic questions.

[108] Using a power analysis, Cadmus determined the appropriate sample sizes to detect the program's impact. As enrollment increases, Cadmus will reassess these thresholds prior to making seasonal reassignments and allocations of the minimum control group sizes required to detect the expected impacts.

Analysis Sample

Data Screening

Starting with a census treatment and control group participants, Cadmus excluded the following customers from the analysis sample:

- Customers who could not be matched to AMI data
- Net-metering customers
- Customers without consumption data reported to watt-hours (i.e., kWh to three decimal places) during the treatment period[109]

Table 45 Sample Disposition—Winter

Screen	Treatment		Control		Overall	
	Accounts Remaining	Percent Remaining	Accounts Remaining	Percent Remaining	Accounts Remaining	Percent Remaining
Original PODIDs[110]	104	100%	131	100%	235	100%
Matched to Consumption Data	104	100%	131	100%	235	100%
Net Metering Customers	104	100%	131	100%	235	100%
Insufficient kW data (e.g., integer values)[111]	85	82%	107	82%	193	82%
Final Analysis Group	**85**	**82%**	**107**	**82%**	**193**	**82%**

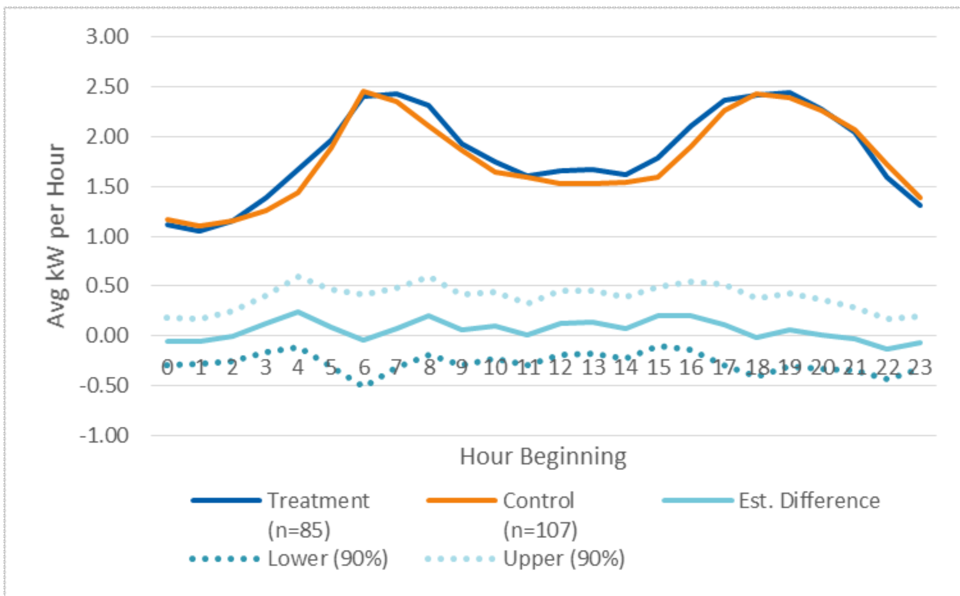
[109] Prior to program enrollment, customer meters recorded kW-hour interval consumption at integer values. Upon program enrollment, PGE attempted to switch customer meters to record watt-hour interval consumption to three decimal places. Due to communication problems, however, not all customer meters switched over.
[110] Original PODIDs reflect total enrolled customers participating in at least one seasonal event.
[111] Given continuous program enrollment and event-specific attrition (due to insufficient meter data during specific event hours), the number of customers with valid data varied between event hours. This value represented the maximum, where event-specific attrition ranged from 22 to 30 customers for the treatment group and from 28 to 40 customers for the control group.

Table 46 Sample Disposition—Summer

Screen	Treatment		Control		Overall	
	Accounts Remaining	Percent Remaining	Accounts Remaining	Percent Remaining	Accounts Remaining	Percent Remaining
Original PODIDs[112]	1,577	100%	915	100%	2,492	100%
Matched to Consumption Data	1,559	99%	901	98%	2,460	99%
Net Metering Customers	1,549	98%	892	97%	2,441	98%
Missing 2015 data	1,519	96%	857	94%	2,376	95%
Insufficient kW data (e.g., integer values)[113]	1,436	91%	790	86%	2,226	89%
Final Analysis Group	**1,436**	**91%**	**790**	**86%**	**2,226**	**89%**

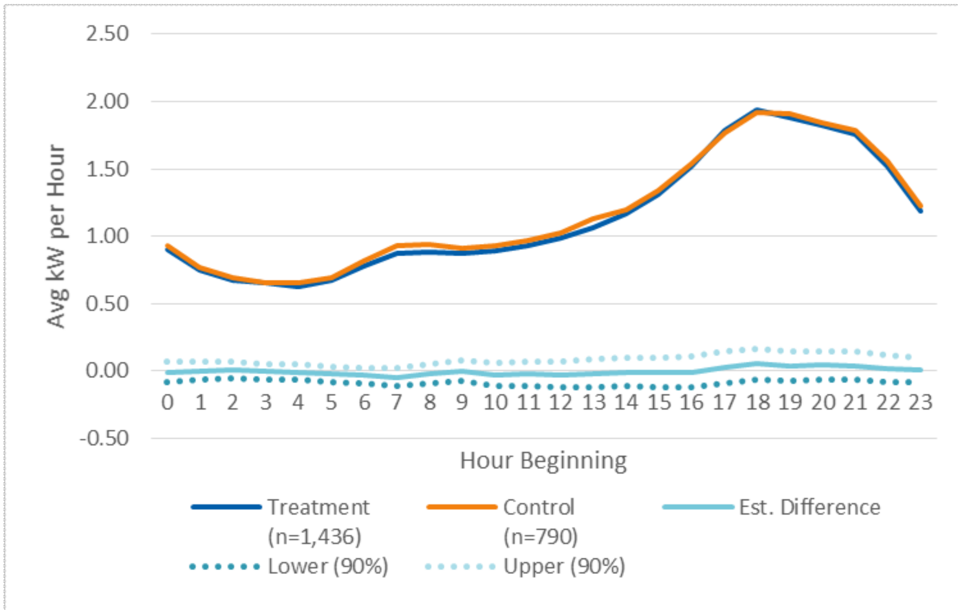
Figure 21 and Figure 22 compare average hourly consumption for treatment and control group customers on non-holiday, non-event weekday hours during each season. Cadmus did not find statistically significant differences in consumption during any hours of the winter or summer seasons. This suggests that the randomization resulted in well-balanced treatment and control groups.

Figure 22 Comparison of Consumption Between Treatment and Control Groups—Winter[114]



[112] Original PODIDs reflect total enrolled customers participating in at least one seasonal event.
[113] Given continuous program enrollment and event-specific attrition (occurring due to insufficient meter data during specific event hours), the number of customers with valid data varied between event hours. This value represented the maximum, while event-specific attrition ranged from 121 to 162 customers for the treatment group and 87 to 128 customers for the control group.
[114] The figure shows average consumption per customer, per hour, on non-event, non-holiday weekday hours for randomly assigned treatment and control groups.

Figure 23 Comparison of Consumption between Treatment and Control Groups—Summer[115]



Impact Findings

Figure 23 and Figure 24 show estimates of average load impacts per hour, per treatment group customer for winter and summer RHR events. The figures show average impact estimates by season (i.e., winter and summer) and event start times due as estimated baselines and load impacts depend on the hour-of-day.

[115] Ibid.

Figure 24 Average Winter Season Impacts, by Event Start Time

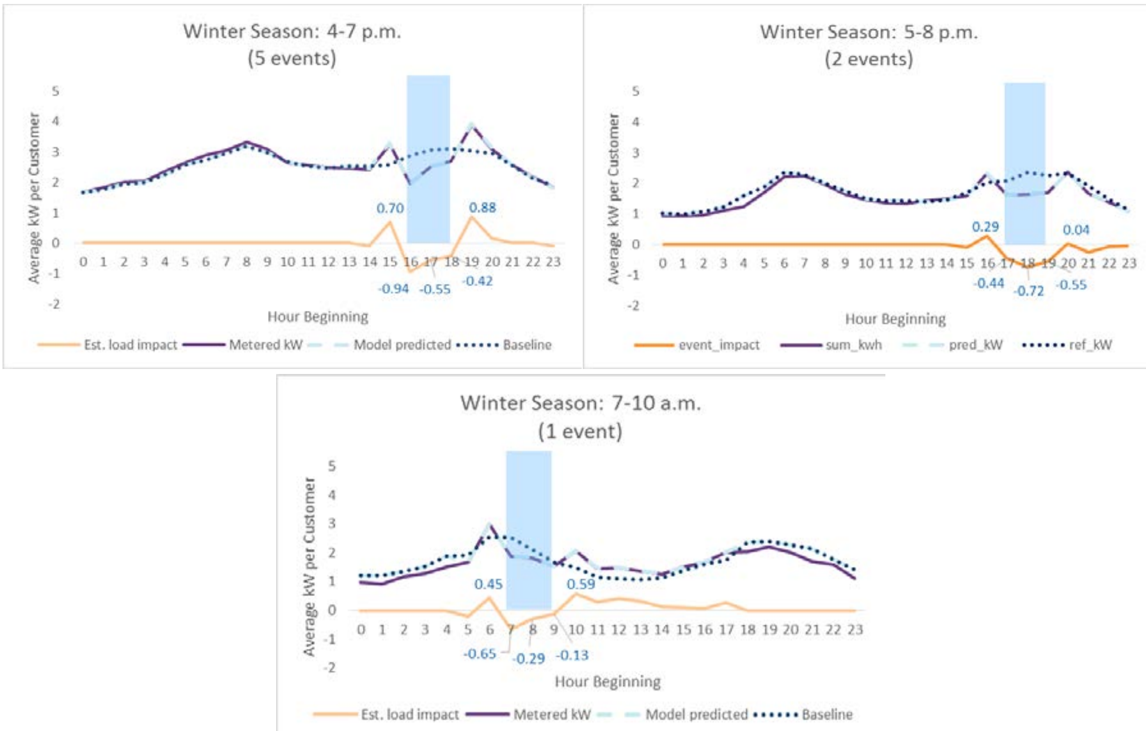
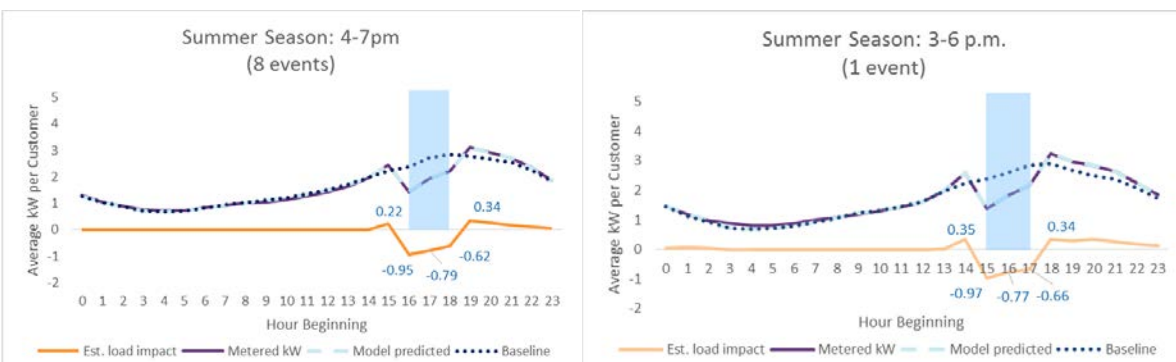


Figure 25. Average Summer Season Impacts, by Event Start Time



During winter, events started at 7:00 a.m., 4:00 p.m., or 5:00 p.m. During summer, events started at 3:00 p.m. or 4:00 p.m. This document's appendix reports estimate of average load impacts per customer for each hour of each event.

Table 47 provides estimated impacts in a table.

Table 47 PGE RHR Impact Summary, by Season and Event Starting Time[116]

Event Hour	Winter (kW per customer)			Summer (kW per customer)	
	4:00 p.m. - 7:00 p.m. (5 events)	5:00 p.m. - 8:00 p.m. (2 events)	7:00 a.m. - 10:00 a.m. (1 event)	4:00 p.m. – 7:00 p.m. (8 events)	3:00 p.m. – 6:00 p.m. (1 event)
Pre-Hour 1	0.70	0.29	0.45	0.22	0.35
Event Hour 1	***-0.94***	***-0.44***	***-0.65***	***-0.95***	***-0.97***
Event Hour 2	***-0.55***	***-0.72***	***-0.29***	***-0.79***	***-0.77***
Event Hour 3	***-0.42***	***-0.55***	***-0.13***	***-0.62***	***-0.66***
Post Hour 1	0.88	0.04	0.59	0.34	0.34
Post Hour 2	0.16	-0.26	0.29	0.25	0.29
Post Hour 3	0.01	-0.07	0.40	0.18	0.33
Post Hour 4	0.01	-0.04	0.31	0.10	0.26
Avg. kW Reduction	**-0.64**	**-0.57**	**-0.36**	**-0.79**	**-0.80**
Avg. kWh Reduction[117]	**-0.15**	**-1.75**	**0.97**	**-1.27**	**-0.83**
Min kW	**-0.42**	**-0.44**	**-0.13**	**-0.62**	**-0.66**
Max kW	**-0.94**	**-0.72**	**-0.65**	**-0.95**	**-0.97**

The RHR program achieved large demand reductions during summer and winter events. Depending on event start times, load reductions averaged from 0.4 kW and 0.6 kW per customer in winter. Load reductions averaged about 0.8 kW per customer in summer. Based on the participation in each event and the estimates of kWh savings per customer per event, the program achieved total kWh savings of 16,999 kWh for summer and 305 kWh for winter.

Typically, the first event hour yielded the largest demand reductions. During winter, the load reduction during the first event hour averaged between 0.4 kW and 0.9 kW per customer. During summer, the first-hour load reduction per customer averaged about 1 kW per customer. Only winter events initiated at 5:00 p.m. achieved higher average load reductions during the second event hour (0.7 kW per customer) than the first event hour (0.4 kW per customer). For all other event starting times, load impacts decreased during the second and third event hours. Estimated load impacts were 33% to 50% lower in the second event hour and 33% to 80% lower in the third event hour.[118]

[116] All winter and summer event hour impacts were significant at the 5% level, except for hours 2 and 3 for the 7:00–10:00 a.m. event.

[117] These estimates represent the average energy impact per customer, per event, including the hour immediately preceding the first event hour and the four hours immediately following the last event hour.

[118] This degradation likely reflected drift in home interior temperatures during events due to passive heat loss that caused space conditioning units to resume operation. For example, in summer during event hours, interior temperatures rise until reaching the RHR-adjusted thermostat setpoint. At that point, air conditioning units turn on again and run periodically to maintain the home interior at the adjusted temperature. In poorly insulated homes, interior home temperatures drift more quickly to the RHR-adjusted setpoint, and average load impact are lower. In more thermally resistant homes, interior temperatures drift more slowly, with greater average load impacts.

As expected, RHR pre-cooling or pre-heating during the hour immediately preceding the first event hour increased consumption above baseline. During winter, pre-heating increased average demand per customer between 0.3 and 0.7 kW. During summer, pre-cooling raised average demand per customer between 0.2 and 0.4 kW.

Consumption rebounded when events ended, given heating or air conditioning units operated to return the homes to their programmed temperature setpoints. During winter, rebound increased average demand per customer between 0.6 kW and 0.8 kW during the first hour. During summer, rebound increased average demand by about 0.3 kW. In general, rebound lasted one or two hours.

Table 48 presents the estimated impacts as a percentage of baseline demand.

Table 48 PGE RHR Impact Summary—Percent Reduction, by Season and Event

Event Hour	Winter			Summer	
	4:00 p.m.- 7:00 p.m. (5 events)	5:00 p.m. - 8:00 p.m. (2 events)	7:00 a.m. - 10:00 a.m. (1 event)	4:00 p.m.- 7:00 p.m. (8 events)	3:00 p.m. - 6:00 p.m. (1 event)
Pre-Hour 1	27%	14%	17%	10%	15%
Event Hour 1	***-33%***	***-21%***	***-26%***	***-40%***	***-41%***
Event Hour 2	***-18%***	***-30%***	***-14%***	***-29%***	***-30%***
Event Hour 3	***-13%***	***-24%***	***-8%***	***-22%***	***-23%***
Post Hour 1	29%	2%	39%	12%	12%
Post Hour 2	5%	-13%	25%	10%	11%
Post Hour 3	0%	-4%	36%	7%	13%
Post Hour 4	1%	-3%	29%	5%	11%
Avg. Event % Reduction	**-21%**	**-25%**	**-16%**	**-30%**	**-31%**

During winter, the RHR pilot reduced average demand by 20%–33% during the first event hour, 15%–30% during the second event hour, and about 10%–25% during the third event hour. During summer, the pilot reduced demand by about 40% during the first event hour, 30% during the second event hour, and 20% during the third event hour. Pre-cooling or pre-heating during the hour preceding the first event hour increased demand by 10%–30%. After most events ended, demand rebounded 10%–40% above expected levels.

Planning Assumptions

Cadmus recommends that for resource planning purposes PGE should assume an average demand reduction of 0.7 kW per RHR customer at the meter for winter and 0.8 kW per RHR customer at the meter for summer.[119] This recommendation assumes:

[119] These estimates are based on the average impacts during the 4 p.m. to 7 p.m. periods for both winter and summer seasons, as these were the most frequent event hours.

- In winter, future events will be called on non-holiday weekdays between 4:00 p.m. and 7:00 p.m.
- In summer, future events will be called on non-holiday weekdays between 4:00 p.m. and 7:00 p.m.
- Outside temperatures during future RHR events will be like those experienced during RHR events in winter 2015/2016 and summer 2016.
- Future RHR program participants will have space heating and cooling equipment like that of participants in 2015 and 2016.
- Nest will implement the RHR program similarly in the future.

When applying these capacity assumptions, PGE should keep in mind the following:

- The recommended assumptions do not account for energy losses from transmission and distribution. Accounting for line losses of 7% would marginally increase the assumed impacts to 0.75 kW per RHR customer for winter and 0.85 kW per RHR customer for summer.
- The recommended assumptions represent the approximate average impact across the three hours of a RHR event. It is expected that the load reduction during the first hour will be largest and the load reduction during the third hour will be smallest. For example, in summer, PGE may achieve a load reduction greater than 0.8 kW per customer during the first hour and less than 0.8 kW during the third hour.

Cadmus recommends that PGE update its planning assumptions after evaluating the RHR program in winter 2016/2017 and summer 2017.

Customer Experience Findings

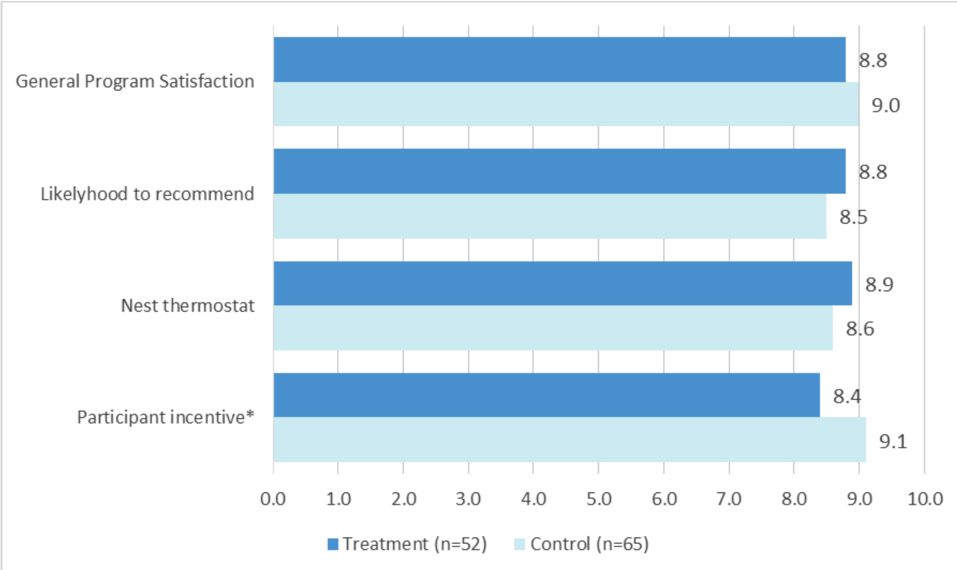
Throughout the pilot, survey response rates proved to be extremely high, with each survey yielding a 50% or higher response rate.

Customer Satisfaction

An important question concerns RHR's effect on customer satisfaction, regarding the program and PGE. Figure 25 and Figure 26 show customer satisfaction ratings for treatment and control groups.[120]

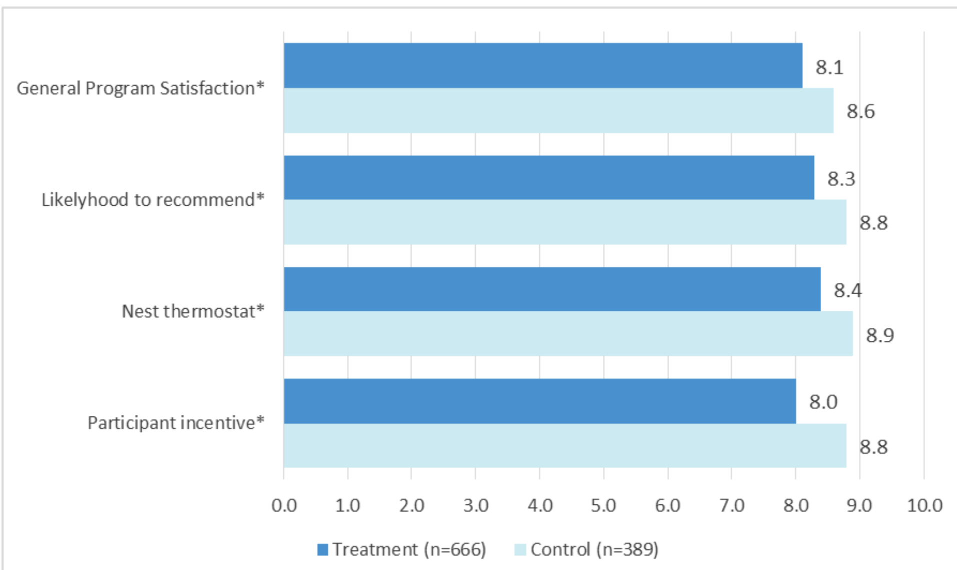
[120] The recruitment surveys did not include these ratings because, at that time, participants had neither yet received program treatment assignments nor experienced program activity.

Figure 26 Winter Post-Season Program Satisfaction and Likelihood to Recommend



* Statistically significant difference between treatment and control groups with 90% confidence.

Figure 27 Summer Post-Season Program Satisfaction and Likelihood to Recommend



* Statistically significant difference between treatment and control groups with 90% confidence.

RHR participants rated the program very positively. In winter and summer, the RHR program, Nest thermostat, and incentives received high average ratings of 8 or greater on a 10-point scale from treatment and control group customers.

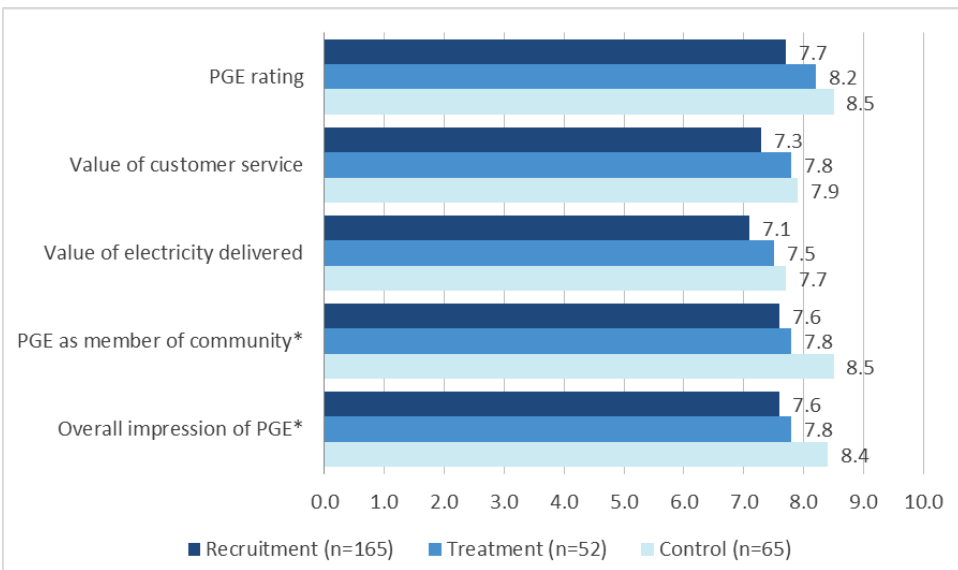
In winter, a clear pattern did not emerge for customer satisfaction between treatment and control group customers. Treatment group customers were more likely to recommend the program and to rate the Nest thermostat higher, but the only statistically significant difference was with satisfaction with the program incentive.

In summer, control group customers rated the program more highly in each category than treatment group customers. All differences were statistically significant. The control group awarded ratings about 0.5 points higher than did the treatment group.

In both winter and summer, incentive payments prompted the greatest satisfaction difference between treatment and control groups. This substantial difference may reflect control customers receiving participation benefits (i.e., the incentives) without experiencing the costs (i.e., temporary loss of thermostat control).

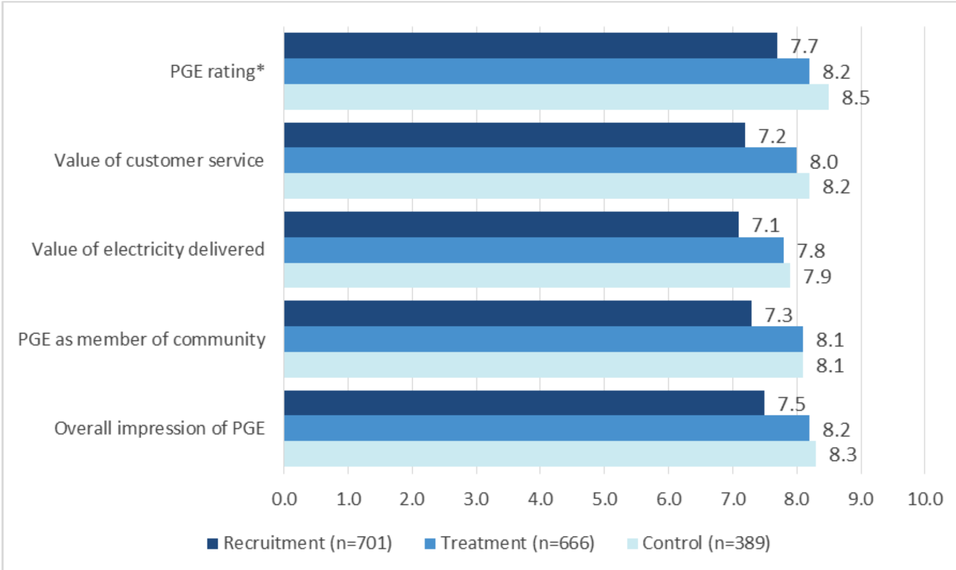
Figure 27 (winter participants) and Figure 28 (summer participants) show satisfaction with PGE ratings, beginning from the recruitment period (after enrollment but before events began) and after the event season. The figures show separate post-season ratings for the treatment and control groups.

Figure 28 Winter Pre- and Post-Season Satisfaction with PGE



* Statistically significant difference between treatment and control groups with 90% confidence.

Figure 29 Summer Pre- and Post-Season Satisfaction with PGE



* Statistically significant difference between treatment and control groups with 90% confidence.

Customers gave PGE high satisfaction ratings. Though satisfaction became higher after participating, without surveys of nonparticipant customers, it is difficult to determine whether this increase represents a program effect or another time-varying factor.

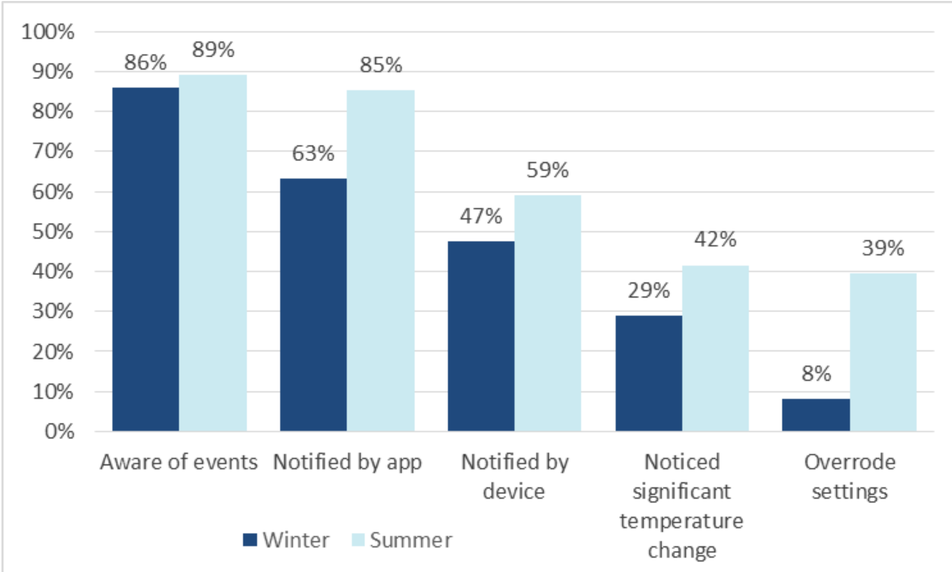
In every category, the control group rated PGE at least as high as the treatment group. Many of the differences, however, were small and statistically insignificant, suggesting that participating in the treatment group did not significantly diminish satisfaction levels.

Awareness and Behavioral Response to Events

Figure 29 compares event awareness and behavioral responses of treatment group customers for the winter and summer seasons.[121] Awareness of RHR events achieved almost 90% for both summer and winter. Summer participants proved more likely to recall notifications by app and the device icon and were more likely to notice a temperature change and to override an event.

[121] Winter results derive from a survey of 50 treatment group customers, conducted immediately following a February 2016 RHR event. Summer results came from a survey of 666 treatment group customers after the season's end. Both surveys asked similarly worded customer-experience questions about the season and not about specific events.

Figure 30 Awareness and Response to Events in Winter and Summer



When asked if households took actions to keep warm during winter events, 41% of respondents reported putting on warmer clothes, 3% reported using secondary heating equipment, and 3% reported using the fireplace. When asked if the household did anything to keep cool during typical summer events, 33% of respondents reported wearing lighter or less clothing, 25% drank cool beverages, 24% moved to a cooler part of the house, and 21% turned on electric fans. Fewer than 1% of respondents turned on room air conditioners.

Appendix

Regression Model Specification

Cadmus used the following model specification to determine event-specific demand savings.

Equation 5

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

Where:

kWh_{it} = Electricity consumption in kWh of customer *i* during hour *t*.

$Hour_{kt}$ = Indicator variable for hour of the day. The variable equals one if hour t is the kth hour of the day, k=0, 1, 2, …, 23, and equals zero, otherwise.

β_k = Average load impact (kWh/hour) per customer of hour *k* on customer consumption.

DH_{it} = Heating or CDH for customer *i* in hour *t* for a given base temperature.

γ_k = Average effect per customer of a CDH on customer consumption in hour k.

μ_k = Average effect per customer of peak pre-treatment consumption on customer consumption in hour k.

$PreTPeakkWh_{it}$ = Average peak consumption per hour of customer i during the pre-treatment period.

$I(Event=1)_{mjt}$ = Indicator variable for RHR event hour. This variable equal one if hour t is the jth hour, j=1,2,…,3, of event m, m=1, 2, …, M, where M=8 for winter and M=9 for summer and equals zero otherwise.

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

$I(Treat=1)_i$ = Indicator variable for assignment to treatment group. This variable equal one if customer I was randomly assigned to the treatment group and equals zero otherwise.

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

φ_{mn} = Average load impact (kWh/hour) per customer during post-event hour n of event m. This load impact affects treatment and control group customers.

$I(PostEvent=1)_{nmt}$ = Indicator variable for post-event hour. This variable equal one if hour t is the nth hour after the event, n=1,2,…,N, of event m, m=1, 2, …, M, and equals zero 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. This load impact affects treatment and control group customers.

$I(PreEvent=1)_{mlt}$ = Indicator variable for pre-event hour. This variable equal one if hour t is the lth hour before the event, l=1,2,…,L, of event m, m=1, 2, …, M, and equals zero 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 panel model by OLS, clustering the standard errors on customers to allow within-customer correlation of hourly electricity consumption.

Detailed Impact Results

Figure 30 and Figure 31 provide detailed specific-event day impacts for the winter and summer seasons, respectively.

Figure 31 Winter Season Demand Reduction by Event Day

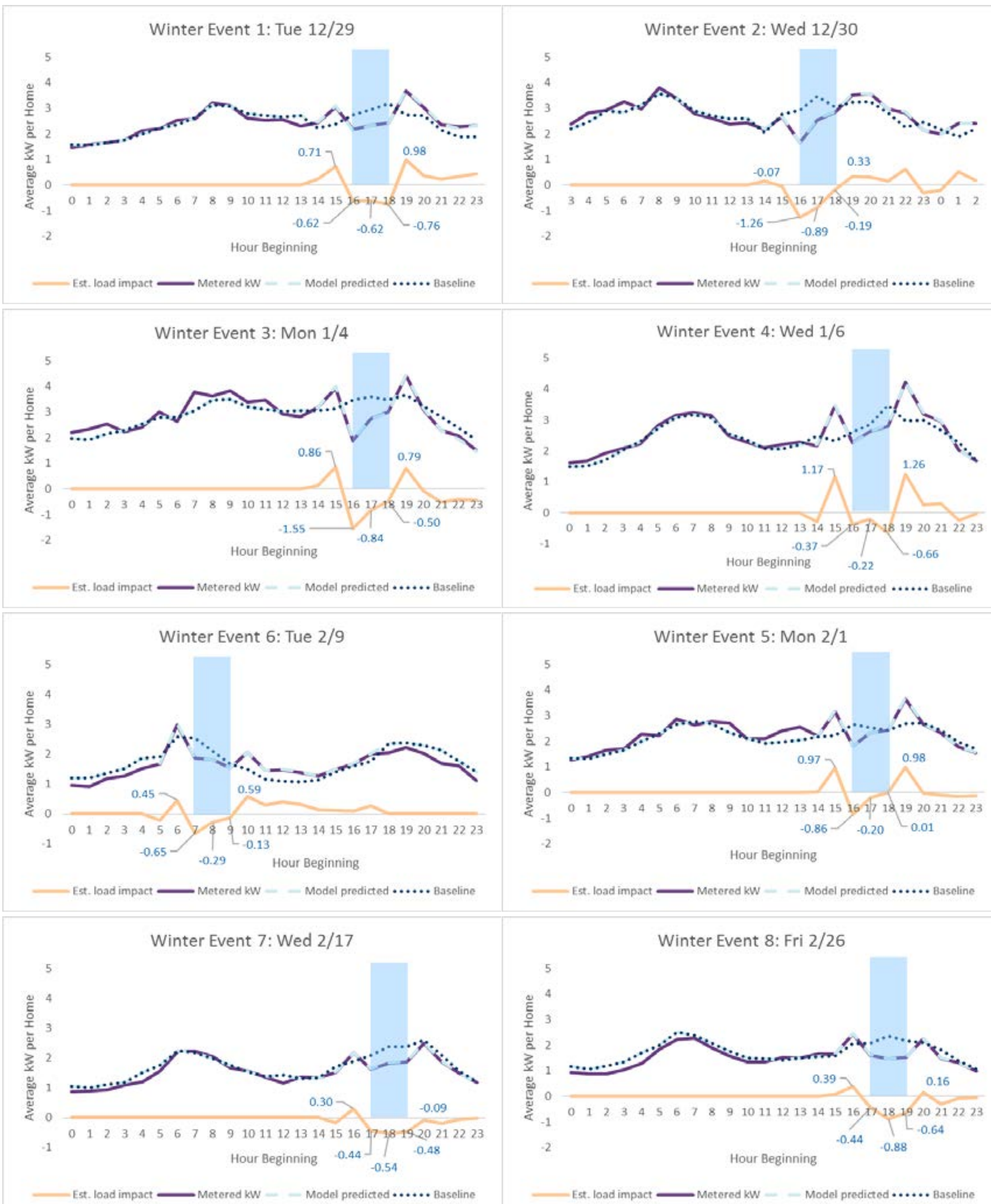


Figure 32 Summer Season Demand Reduction by Event Day

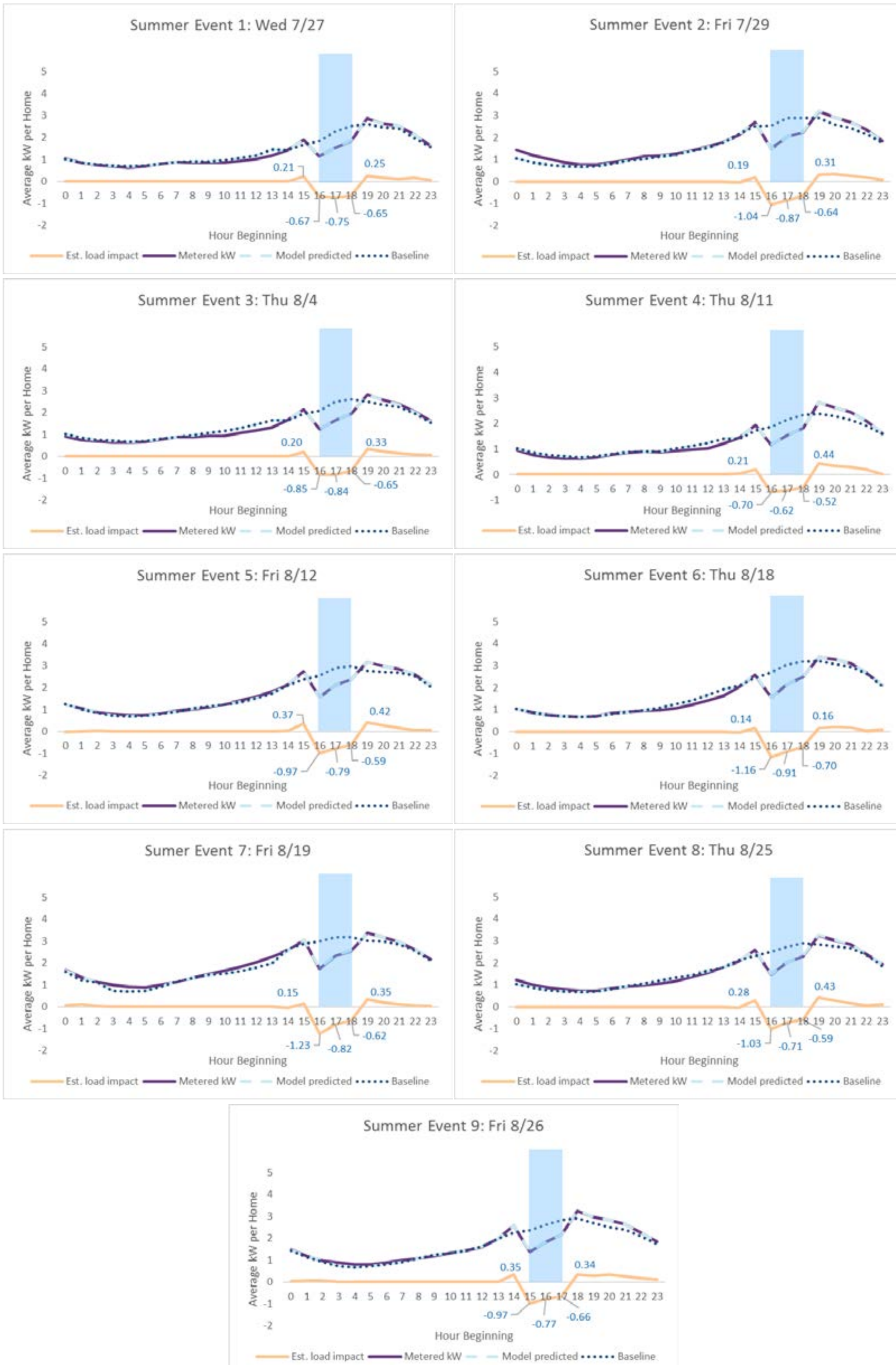


Table 49 provides additional model details regarding hourly demand impacts occurring on summer event days. As noted, the more extreme weather days (events 6 and 7) saw larger demand reductions during the first hours (over 1 kW) but decreased by nearly half by the third hour. Largely due to the increase in sample size, all event hour estimates for the summer season were statistically significant at 10%.

Table 49 Summer Hourly Impacts by Event

Event	Date	Hour	Hour Type	Outside Temp. (°F)	Estimated Impact (kW)	SE Estimated Impact (kW)	Significant at 10%	Metered (kW)	Predicted (kW)	Baseline (kW)
1	27-Jul-16	15	Pre-Hr 1	89	0.209	0.066	Yes	1.88	1.88	1.67
1	**27-Jul-16**	**16**	**Event Hr 1**	**88**	**-0.67**	**0.06**	**Yes**	**1.15**	**1.16**	**1.83**
1	**27-Jul-16**	**17**	**Event Hr 2**	**87**	**-0.75**	**0.07**	**Yes**	**1.53**	**1.53**	**2.28**
1	**27-Jul-16**	**18**	**Event Hr 3**	**84**	**-0.65**	**0.07**	**Yes**	**1.85**	**1.85**	**2.51**
1	27-Jul-16	19	Post-Hr 1	78	0.251	0.071	Yes	2.86	2.86	2.61
1	27-Jul-16	20	Post-Hr 2	75	0.156	0.067	Yes	2.63	2.63	2.47
1	27-Jul-16	21	Post-Hr 3	72	0.101	0.066	No	2.51	2.51	2.41
1	27-Jul-16	22	Post-Hr 4	69	0.167	0.059	Yes	2.14	2.14	1.98
1	27-Jul-16	23	Post-Hr 5	67	0.048	0.050	No	1.61	1.62	1.57
1	28-Jul-16	0	Post-Hr 6	66	0.018	0.043	No	1.24	1.24	1.22
1	28-Jul-16	1	Post-Hr 7	63	0.015	0.034	No	0.98	0.98	0.96
1	28-Jul-16	2	Post-Hr 8	61	0.001	0.029	No	0.88	0.88	0.88
2	29-Jul-16	15	Pre-Hr 1	94	0.188	0.080	Yes	2.69	2.69	2.51
2	**29-Jul-16**	**16**	**Event Hr 1**	**93**	**-1.04**	**0.07**	**Yes**	**1.49**	**1.49**	**2.54**
2	**29-Jul-16**	**17**	**Event Hr 2**	**89**	**-0.87**	**0.08**	**Yes**	**2.03**	**2.04**	**2.90**
2	**29-Jul-16**	**18**	**Event Hr 3**	**84**	**-0.64**	**0.08**	**Yes**	**2.25**	**2.25**	**2.90**
2	29-Jul-16	19	Post-Hr 1	78	0.312	0.076	Yes	3.20	3.21	2.89
2	29-Jul-16	20	Post-Hr 2	73	0.335	0.073	Yes	2.93	2.93	2.59
2	29-Jul-16	21	Post-Hr 3	70	0.264	0.068	Yes	2.69	2.68	2.42
2	29-Jul-16	22	Post-Hr 4	67	0.171	0.064	Yes	2.33	2.33	2.15
2	29-Jul-16	23	Post-Hr 5	65	0.082	0.058	No	1.84	1.84	1.76
2	30-Jul-16	0	Post-Hr 6	63	0.091	0.048	Yes	1.41	1.42	1.33
2	30-Jul-16	1	Post-Hr 7	60	0.067	0.041	Yes	1.12	1.12	1.06
2	30-Jul-16	2	Post-Hr 8	60	0.019	0.036	No	0.94	0.94	0.92
3	4-Aug-16	15	Pre-Hr 1	91	0.201	0.076	Yes	2.14	2.14	1.94
3	**4-Aug-16**	**16**	**Event Hr 1**	**90**	**-0.85**	**0.07**	**Yes**	**1.24**	**1.24**	**2.09**
3	**4-Aug-16**	**17**	**Event Hr 2**	**87**	**-0.84**	**0.07**	**Yes**	**1.64**	**1.64**	**2.49**
3	**4-Aug-16**	**18**	**Event Hr 3**	**83**	**-0.65**	**0.07**	**Yes**	**1.94**	**1.95**	**2.60**
3	4-Aug-16	19	Post-Hr 1	78	0.333	0.073	Yes	2.82	2.82	2.49
3	4-Aug-16	20	Post-Hr 2	75	0.228	0.068	Yes	2.59	2.59	2.36
3	4-Aug-16	21	Post-Hr 3	71	0.132	0.069	Yes	2.38	2.37	2.24
3	4-Aug-16	22	Post-Hr 4	69	0.077	0.059	No	2.03	2.02	1.94
3	4-Aug-16	23	Post-Hr 5	67	0.052	0.052	No	1.62	1.61	1.55

Event	Date	Hour	Hour Type	Outside Temp. (ºF)	Estimated Impact (kW)	SE Estimated Impact (kW)	Significant at 10%	Metered (kW)	Predicted (kW)	Baseline (kW)
3	4-Aug-16	0	Post-Hr 6	64	0.000	0.042	No	0.92	1.02	1.02
3	5-Aug-16	1	Post-Hr 7	63	0.030	0.036	No	0.98	0.98	0.95
3	5-Aug-16	2	Post-Hr 8	61	0.019	0.029	No	0.83	0.83	0.81
4	11-Aug-16	15	Pre-Hr 1	89	0.209	0.068	Yes	1.93	1.93	1.72
4	**11-Aug-16**	**16**	**Event Hr 1**	**89**	**-0.70**	**0.06**	**Yes**	**1.16**	**1.16**	**1.86**
4	**11-Aug-16**	**17**	**Event Hr 2**	**88**	**-0.62**	**0.07**	**Yes**	**1.53**	**1.53**	**2.15**
4	**11-Aug-16**	**18**	**Event Hr 3**	**84**	**-0.52**	**0.07**	**Yes**	**1.81**	**1.82**	**2.33**
4	11-Aug-16	19	Post-Hr 1	78	0.443	0.072	Yes	2.82	2.82	2.38
4	11-Aug-16	20	Post-Hr 2	75	0.331	0.067	Yes	2.61	2.61	2.28
4	11-Aug-16	21	Post-Hr 3	73	0.303	0.064	Yes	2.45	2.45	2.14
4	11-Aug-16	22	Post-Hr 4	71	0.197	0.058	Yes	2.11	2.11	1.91
4	11-Aug-16	23	Post-Hr 5	68	0.005	0.050	No	1.60	1.60	1.59
4	12-Aug-16	0	Post-Hr 6	67	-0.031	0.045	No	1.23	1.23	1.26
4	12-Aug-16	1	Post-Hr 7	66	0.010	0.038	No	1.03	1.03	1.02
4	12-Aug-16	2	Post-Hr 8	63	0.041	0.031	No	0.88	0.89	0.84
5	12-Aug-16	15	Pre-Hr 1	96	0.365	0.085	Yes	2.73	2.74	2.37
5	**12-Aug-16**	**16**	**Event Hr 1**	**97**	**-0.97**	**0.08**	**Yes**	**1.57**	**1.57**	**2.54**
5	**12-Aug-16**	**17**	**Event Hr 2**	**94**	**-0.79**	**0.08**	**Yes**	**2.10**	**2.10**	**2.90**
5	**12-Aug-16**	**18**	**Event Hr 3**	**89**	**-0.59**	**0.08**	**Yes**	**2.38**	**2.38**	**2.97**
5	12-Aug-16	19	Post-Hr 1	83	0.416	0.082	Yes	3.18	3.18	2.76
5	12-Aug-16	20	Post-Hr 2	81	0.266	0.083	Yes	2.99	2.99	2.72
5	12-Aug-16	21	Post-Hr 3	79	0.159	0.083	Yes	2.84	2.84	2.68
5	12-Aug-16	22	Post-Hr 4	75	0.053	0.082	No	2.60	2.60	2.54
5	12-Aug-16	23	Post-Hr 5	72	0.069	0.079	No	2.13	2.13	2.06
5	13-Aug-16	0	Post-Hr 6	69	0.043	0.071	No	1.70	1.70	1.65
5	13-Aug-16	1	Post-Hr 7	68	0.088	0.049	Yes	1.34	1.34	1.25
5	13-Aug-16	2	Post-Hr 8	66	0.105	0.040	Yes	1.17	1.17	1.06
6	18-Aug-16	15	Pre-Hr 1	100	0.145	0.085	Yes	2.60	2.61	2.46
6	**18-Aug-16**	**16**	**Event Hr 1**	**98**	**-1.16**	**0.08**	**Yes**	**1.55**	**1.55**	**2.71**
6	**18-Aug-16**	**17**	**Event Hr 2**	**94**	**-0.91**	**0.08**	**Yes**	**2.14**	**2.14**	**3.05**
6	**18-Aug-16**	**18**	**Event Hr 3**	**89**	**-0.70**	**0.08**	**Yes**	**2.49**	**2.49**	**3.19**
6	18-Aug-16	19	Post-Hr 1	85	0.163	0.080	Yes	3.38	3.38	3.22
6	18-Aug-16	20	Post-Hr 2	82	0.203	0.080	Yes	3.29	3.29	3.08
6	18-Aug-16	21	Post-Hr 3	79	0.168	0.076	Yes	3.10	3.10	2.94
6	18-Aug-16	22	Post-Hr 4	75	0.026	0.071	No	2.67	2.67	2.65
6	18-Aug-16	23	Post-Hr 5	71	0.073	0.062	No	2.13	2.13	2.06
6	19-Aug-16	0	Post-Hr 6	71	0.066	0.055	No	1.67	1.66	1.60
6	19-Aug-16	1	Post-Hr 7	68	0.127	0.041	Yes	1.34	1.34	1.21
6	19-Aug-16	2	Post-Hr 8	66	0.044	0.037	No	1.14	1.14	1.09

Event	Date	Hour	Hour Type	Outside Temp. (ºF)	Estimated Impact (kW)	SE Estimated Impact (kW)	Significant at 10%	Metered (kW)	Predicted (kW)	Baseline (kW)
7	19-Aug-16	15	Pre-Hr 1	99	0.149	0.085	Yes	3.04	3.04	2.89
7	**19-Aug-16**	**16**	**Event Hr 1**	**98**	**-1.23**	**0.08**	**Yes**	**1.74**	**1.75**	**2.98**
7	**19-Aug-16**	**17**	**Event Hr 2**	**96**	**-0.82**	**0.08**	**Yes**	**2.35**	**2.36**	**3.18**
7	**19-Aug-16**	**18**	**Event Hr 3**	**91**	**-0.62**	**0.08**	**Yes**	**2.56**	**2.57**	**3.19**
7	19-Aug-16	19	Post-Hr 1	84	0.350	0.078	Yes	3.37	3.38	3.03
7	19-Aug-16	20	Post-Hr 2	80	0.198	0.078	Yes	3.17	3.18	2.98
7	19-Aug-16	21	Post-Hr 3	76	0.114	0.071	No	2.96	2.96	2.85
7	19-Aug-16	22	Post-Hr 4	74	0.061	0.069	No	2.62	2.61	2.55
7	19-Aug-16	23	Post-Hr 5	72	0.047	0.065	No	2.17	2.16	2.11
7	20-Aug-16	0	Post-Hr 6	69	0.052	0.057	No	1.76	1.75	1.70
7	20-Aug-16	1	Post-Hr 7	67	0.054	0.048	No	1.41	1.40	1.35
7	20-Aug-16	2	Post-Hr 8	67	0.059	0.046	No	1.22	1.22	1.16
8	25-Aug-16	15	Pre-Hr 1	94	0.278	0.078	Yes	2.58	2.59	2.31
8	**25-Aug-16**	**16**	**Event Hr 1**	**93**	**-1.03**	**0.07**	**Yes**	**1.48**	**1.48**	**2.51**
8	**25-Aug-16**	**17**	**Event Hr 2**	**92**	**-0.71**	**0.08**	**Yes**	**2.01**	**2.02**	**2.73**
8	**25-Aug-16**	**18**	**Event Hr 3**	**87**	**-0.59**	**0.07**	**Yes**	**2.29**	**2.31**	**2.90**
8	25-Aug-16	19	Post-Hr 1	81	0.432	0.073	Yes	3.24	3.26	2.83
8	25-Aug-16	20	Post-Hr 2	77	0.297	0.075	Yes	3.04	3.05	2.75
8	25-Aug-16	21	Post-Hr 3	76	0.149	0.072	Yes	2.82	2.83	2.68
8	25-Aug-16	22	Post-Hr 4	73	0.030	0.067	No	2.39	2.39	2.36
8	25-Aug-16	23	Post-Hr 5	69	0.084	0.053	No	1.93	1.93	1.84
8	26-Aug-16	0	Post-Hr 6	67	0.029	0.046	No	1.47	1.47	1.44
8	26-Aug-16	1	Post-Hr 7	64	0.066	0.037	Yes	1.20	1.20	1.13
8	26-Aug-16	2	Post-Hr 8	62	0.054	0.029	Yes	0.97	0.97	0.92
9	26-Aug-16	14	Pre-Hr 1	95	0.347	0.080	Yes	2.59	2.59	2.25
9	**26-Aug-16**	**15**	**Event Hr 1**	**95**	**-0.97**	**0.08**	**Yes**	**1.39**	**1.40**	**2.37**
9	**26-Aug-16**	**16**	**Event Hr 2**	**95**	**-0.77**	**0.08**	**Yes**	**1.82**	**1.82**	**2.60**
9	**26-Aug-16**	**17**	**Event Hr 3**	**93**	**-0.66**	**0.08**	**Yes**	**2.17**	**2.18**	**2.84**
9	26-Aug-16	18	Post-Hr 1	86	0.344	0.076	Yes	3.25	3.26	2.91
9	26-Aug-16	19	Post-Hr 2	81	0.294	0.076	Yes	2.97	2.97	2.68
9	26-Aug-16	20	Post-Hr 3	79	0.335	0.075	Yes	2.84	2.84	2.50
9	26-Aug-16	21	Post-Hr 4	77	0.262	0.075	Yes	2.64	2.64	2.38
9	26-Aug-16	22	Post-Hr 5	73	0.166	0.065	Yes	2.26	2.26	2.09
9	26-Aug-16	23	Post-Hr 6	69	0.126	0.055	Yes	1.85	1.86	1.73
9	27-Aug-16	0	Post-Hr 7	66	0.119	0.046	Yes	1.46	1.47	1.35
9	27-Aug-16	1	Post-Hr 8	63	0.034	0.041	No	1.17	1.17	1.13

Table 50 provides additional model details regarding hourly demand impacts during winter event days. As noted, more extreme weather days (events 2 and 3) saw larger demand reductions in the first hours (over 1 kW), which then decreased significantly in the subsequent hours.

Table 50 Winter Hourly Impacts by Event

Event	Date	Hour	Hour Type	Outside Temp. (^{0}F)	Estimated Impact (kW)	SE Estimated Impact (kW)	Significant at 10%	Metered (kW)	Predicted (kW)	Baseline (kW)
1	29-Dec-15	15	Pre-Hr 1	39	0.713	0.355	Yes	3.07	3.09	2.38
1	**29-Dec-15**	**16**	**Event Hr 1**	**39**	**-0.62**	**0.32**	**Yes**	**2.18**	**2.12**	**2.74**
1	**29-Dec-15**	**17**	**Event Hr 2**	**38**	**-0.62**	**0.36**	**Yes**	**2.33**	**2.34**	**2.95**
1	**29-Dec-15**	**18**	**Event Hr 3**	**38**	**-0.76**	**0.38**	**Yes**	**2.42**	**2.43**	**3.19**
1	29-Dec-15	19	Post-Hr 1	38	0.977	0.411	Yes	3.68	3.71	2.73
1	29-Dec-15	20	Post-Hr 2	38	0.349	0.394	No	3.03	3.07	2.72
1	29-Dec-15	21	Post-Hr 3	37	0.243	0.314	No	2.36	2.38	2.14
1	29-Dec-15	22	Post-Hr 4	36	0.327	0.307	No	2.27	2.21	1.88
1	29-Dec-15	23	Post-Hr 5	34	0.430	0.402	No	2.33	2.33	1.90
1	30-Dec-15	0	Post-Hr 6	33	0.206	0.294	No	1.94	1.94	1.74
1	30-Dec-15	1	Post-Hr 7	32	0.311	0.309	No	1.98	1.98	1.67
1	30-Dec-15	2	Post-Hr 8	32	0.478	0.330	No	2.23	2.23	1.76
2	30-Dec-15	15	Pre-Hr 1	40	-0.065	0.485	No	2.65	2.69	2.76
2	**30-Dec-15**	**16**	**Event Hr 1**	**38**	**-1.26**	**0.29**	**Yes**	**1.64**	**1.66**	**2.92**
2	**30-Dec-15**	**17**	**Event Hr 2**	**36**	**-0.89**	**0.44**	**Yes**	**2.55**	**2.58**	**3.47**
2	**30-Dec-15**	**18**	**Event Hr 3**	**35**	**-0.19**	**0.44**	**No**	**2.84**	**2.88**	**3.06**
2	30-Dec-15	19	Post-Hr 1	35	0.335	0.518	No	3.53	3.58	3.24
2	30-Dec-15	20	Post-Hr 2	35	0.300	0.499	No	3.56	3.56	3.26
2	30-Dec-15	21	Post-Hr 3	35	0.157	0.366	No	2.97	2.97	2.82
2	30-Dec-15	22	Post-Hr 4	34	0.621	0.399	No	2.82	2.86	2.24
2	30-Dec-15	23	Post-Hr 5	34	-0.308	0.392	No	2.14	2.16	2.46
2	31-Dec-15	0	Post-Hr 6	34	-0.196	0.342	No	1.99	1.98	2.18
2	31-Dec-15	1	Post-Hr 7	33	0.508	0.353	No	2.39	2.40	1.89
2	31-Dec-15	2	Post-Hr 8	33	0.184	0.362	No	2.39	2.40	2.21
3	4-Jan-16	15	Pre-Hr 1	35	0.862	0.492	Yes	3.94	4.00	3.14
3	**4-Jan-16**	**16**	**Event Hr 1**	**34**	**-1.55**	**0.35**	**Yes**	**1.90**	**1.92**	**3.47**
3	**4-Jan-16**	**17**	**Event Hr 2**	**34**	**-0.84**	**0.41**	**Yes**	**2.73**	**2.75**	**3.59**
3	**4-Jan-16**	**18**	**Event Hr 3**	**34**	**-0.50**	**0.42**	**No**	**2.99**	**2.98**	**3.48**
3	4-Jan-16	19	Post-Hr 1	33	0.790	0.513	No	4.41	4.45	3.66
3	4-Jan-16	20	Post-Hr 2	33	-0.076	0.415	No	3.11	3.15	3.23
3	4-Jan-16	21	Post-Hr 3	33	-0.532	0.319	Yes	2.28	2.28	2.81
3	4-Jan-16	22	Post-Hr 4	32	-0.418	0.334	No	2.08	1.95	2.37
3	4-Jan-16	23	Post-Hr 5	32	-0.453	0.241	Yes	1.51	1.46	1.92
3	5-Jan-16	0	Post-Hr 6	33	-0.130	0.280	No	1.58	1.60	1.73

Event	Date	Hour	Hour Type	Outside Temp. (°F)	Estimated Impact (kW)	SE Estimated Impact (kW)	Significant at 10%	Metered (kW)	Predicted (kW)	Baseline (kW)
3	5-Jan-16	1	Post-Hr 7	33	0.099	0.308	No	1.71	1.73	1.63
3	5-Jan-16	2	Post-Hr 8	33	0.180	0.307	No	2.23	2.25	2.07
4	6-Jan-16	15	Pre-Hr 1	41	1.166	0.483	Yes	3.46	3.48	2.31
4	**6-Jan-16**	**16**	**Event Hr 1**	**39**	**-0.37**	**0.30**	**No**	**2.26**	**2.25**	**2.61**
4	**6-Jan-16**	**17**	**Event Hr 2**	**39**	**-0.22**	**0.32**	**No**	**2.63**	**2.63**	**2.85**
4	**6-Jan-16**	**18**	**Event Hr 3**	**38**	**-0.66**	**0.38**	**Yes**	**2.79**	**2.82**	**3.48**
4	6-Jan-16	19	Post-Hr 1	38	1.256	0.493	Yes	4.23	4.23	2.97
4	6-Jan-16	20	Post-Hr 2	38	0.248	0.390	No	3.19	3.23	2.99
4	6-Jan-16	21	Post-Hr 3	38	0.300	0.381	No	2.95	2.97	2.67
4	6-Jan-16	22	Post-Hr 4	37	-0.248	0.361	No	2.03	2.02	2.27
4	6-Jan-16	23	Post-Hr 5	37	-0.030	0.287	No	1.67	1.66	1.69
4	7-Jan-16	0	Post-Hr 6	35	-0.088	0.264	No	1.56	1.56	1.64
4	7-Jan-16	1	Post-Hr 7	36	0.403	0.287	No	1.94	1.95	1.54
4	7-Jan-16	2	Post-Hr 8	36	0.171	0.261	No	1.93	1.93	1.76
5	1-Feb-16	15	Pre-Hr 1	45	0.966	0.472	Yes	3.16	3.20	2.24
5	**1-Feb-16**	**16**	**Event Hr 1**	**45**	**-0.86**	**0.38**	**Yes**	**1.81**	**1.81**	**2.68**
5	**1-Feb-16**	**17**	**Event Hr 2**	**44**	**-0.20**	**0.33**	**No**	**2.33**	**2.34**	**2.53**
5	**1-Feb-16**	**18**	**Event Hr 3**	**43**	**0.01**	**0.33**	**No**	**2.43**	**2.43**	**2.42**
5	1-Feb-16	19	Post-Hr 1	42	0.985	0.398	Yes	3.65	3.69	2.70
5	1-Feb-16	20	Post-Hr 2	42	-0.023	0.340	No	2.67	2.70	2.72
5	1-Feb-16	21	Post-Hr 3	41	-0.100	0.277	No	2.34	2.33	2.43
5	1-Feb-16	22	Post-Hr 4	41	-0.169	0.257	No	1.78	1.79	1.96
5	1-Feb-16	23	Post-Hr 5	40	-0.136	0.299	No	1.56	1.58	1.72
5	2-Feb-16	0	Post-Hr 6	38	0.161	0.217	No	1.47	1.50	1.34
5	2-Feb-16	1	Post-Hr 7	37	0.037	0.243	No	1.45	1.46	1.42
5	2-Feb-16	2	Post-Hr 8	36	-0.213	0.230	No	1.48	1.50	1.72
6	9-Feb-16	6	Pre-Hr 1	40	0.449	0.368	No	2.98	3.02	2.57
6	**9-Feb-16**	**7**	**Event Hr 1**	**40**	**-0.65**	**0.29**	**Yes**	**1.86**	**1.88**	**2.53**
6	**9-Feb-16**	**8**	**Event Hr 2**	**45**	**-0.29**	**0.26**	**No**	**1.82**	**1.82**	**2.12**
6	**9-Feb-16**	**9**	**Event Hr 3**	**51**	**-0.13**	**0.26**	**No**	**1.53**	**1.53**	**1.66**
6	9-Feb-16	10	Post-Hr 1	55	0.588	0.271	Yes	2.08	2.08	1.49
6	9-Feb-16	11	Post-Hr 2	57	0.287	0.202	No	1.45	1.45	1.16
6	9-Feb-16	12	Post-Hr 3	58	0.395	0.188	Yes	1.47	1.48	1.09
6	9-Feb-16	13	Post-Hr 4	59	0.311	0.206	No	1.37	1.39	1.08
6	9-Feb-16	14	Post-Hr 5	60	0.130	0.179	No	1.26	1.26	1.13
6	9-Feb-16	15	Post-Hr 6	58	0.104	0.190	No	1.49	1.49	1.39
6	9-Feb-16	16	Post-Hr 7	57	0.084	0.243	No	1.67	1.68	1.60
6	9-Feb-16	17	Post-Hr 8	54	0.267	0.223	No	2.00	2.02	1.75
7	17-Feb-16	16	Pre-Hr 1	53	0.297	0.247	No	2.18	2.19	1.89

Event	Date	Hour	Hour Type	Outside Temp. (^{o}F)	Estimated Impact (kW)	SE Estimated Impact (kW)	Significant at 10%	Metered (kW)	Predicted (kW)	Baseline (kW)
7	**17-Feb-16**	**17**	**Event Hr 1**	**52**	**-0.44**	**0.21**	**Yes**	**1.63**	**1.64**	**2.09**
7	**17-Feb-16**	**18**	**Event Hr 2**	**49**	**-0.54**	**0.24**	**Yes**	**1.83**	**1.84**	**2.38**
7	**17-Feb-16**	**19**	**Event Hr 3**	**48**	**-0.48**	**0.25**	**Yes**	**1.88**	**1.89**	**2.37**
7	17-Feb-16	20	Post-Hr 1	48	-0.089	0.283	No	2.49	2.51	2.60
7	17-Feb-16	21	Post-Hr 2	47	-0.203	0.220	No	1.87	1.89	2.09
7	17-Feb-16	22	Post-Hr 3	47	-0.065	0.183	No	1.49	1.49	1.56
7	17-Feb-16	23	Post-Hr 4	46	-0.028	0.142	No	1.19	1.17	1.20
7	18-Feb-16	0	Post-Hr 5	45	-0.193	0.145	No	0.98	0.99	1.18
7	18-Feb-16	1	Post-Hr 6	44	0.124	0.136	No	1.03	1.03	0.90
7	18-Feb-16	2	Post-Hr 7	44	-0.110	0.150	No	1.08	1.09	1.20
7	18-Feb-16	3	Post-Hr 8	45	0.127	0.152	No	1.41	1.44	1.31
8	26-Feb-16	16	Pre-Hr 1	51	0.387	0.319	No	2.44	2.46	2.08
8	**26-Feb-16**	**17**	**Event Hr 1**	**50**	**-0.44**	**0.20**	**Yes**	**1.61**	**1.62**	**2.07**
8	**26-Feb-16**	**18**	**Event Hr 2**	**50**	**-0.88**	**0.28**	**Yes**	**1.47**	**1.48**	**2.36**
8	**26-Feb-16**	**19**	**Event Hr 3**	**50**	**-0.64**	**0.24**	**Yes**	**1.53**	**1.53**	**2.17**
8	26-Feb-16	20	Post-Hr 1	50	0.156	0.248	No	2.26	2.25	2.10
8	26-Feb-16	21	Post-Hr 2	49	-0.310	0.187	Yes	1.48	1.49	1.80
8	26-Feb-16	22	Post-Hr 3	50	-0.070	0.159	No	1.32	1.33	1.39
8	26-Feb-16	23	Post-Hr 4	50	-0.053	0.135	No	0.99	1.00	1.05
8	27-Feb-16	0	Post-Hr 5	50	-0.060	0.138	No	0.94	0.94	1.00
8	27-Feb-16	1	Post-Hr 6	52	0.063	0.153	No	0.92	0.94	0.88
8	27-Feb-16	2	Post-Hr 7	52	0.093	0.150	No	0.93	0.93	0.83
8	27-Feb-16	3	Post-Hr 8	52	-0.065	0.143	No	0.92	0.93	0.99

Appendix D - Cadmus Evaluation of PGE’s Rush Hour Rewards 2016-2017

CADMUS

PGE

RHR Pilot Evaluation Interim Findings

Winter 2016/2017 & Summer 2017

February 8, 2018

Agenda

- Overview
- Evaluation Approach and Methods
- Impact Findings
- Take-Aways and Next Steps
- Appendix

Evaluation Approach and Methods

Evaluation Overview

Evaluation of load impacts and customer satisfaction for two RHR seasons

Winter 2016/2017

- Eight events
- Quasi-experimental design for Winter 2016/2017
  - Nest did not utilize the random assignments in Winter 2016/2017
- 512 enrolled customers
  - Primarily heat pumps customers

Summer 2017

- RCT design for Summer 2017
- 3,551 enrolled customers
  - Heat pump and CAC customers

Previous RHR evaluations

- Event demand savings for two previous seasons
  - Winter 2015/2016: 0.6 kW per home
  - Summer 2016: 0.8 kW per home

Event Schedules

Table 51 Event Schedule for Rush Hour Rewards

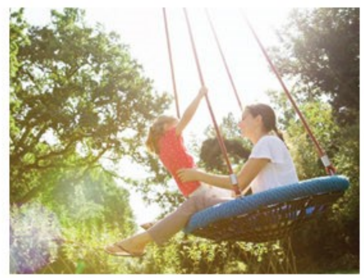
Event	Date	Time	Temperature	Snow
Winter 2016/2017				
1	12/6/2016	5:00 p.m. - 8:00 p.m.	34°F	
2	12/8/2016	4:00 p.m. - 7:00 p.m.	32°F	❄
3	12/14/2016	5:00 p.m. - 8:00 p.m.	28°F	
4	12/15/2016	5:00 p.m. - 8:00 p.m.	31°F	❄
5	1/3/2017	5:00 p.m. - 8:00 p.m.	29°F	
6	1/4/2017	5:00 p.m. - 8:00 p.m.	29°F	
7	1/6/2017	7:00 a.m. - 10:00 a.m.	20°F	
8	1/11/2017	7:00 a.m. - 10:00 a.m.	29°F	❄
Summer 2017				
1	7/25/2017	5:00 p.m. - 8:00 p.m.	83°F	
2	7/31/2017	5:00 p.m. - 8:00 p.m.	85°F	
3	8/2/2017	5:00 p.m. - 8:00 p.m.	93°F	
4	8/3/2017	5:00 p.m. - 8:00 p.m.	94°F	
5	8/8/2017	5:00 p.m. - 8:00 p.m.	86°F	
6	8/10/2017	4:00 p.m. - 7:00 p.m.	88°F	
7	8/28/2017	4:00 p.m. - 7:00 p.m.	92°F	

Impact Summary

Table 52 Impact Summary for Rush Hour Rewards

Winter 2016/2017				
Average Event Hour Savings	Maximum Event Hour Savings	Minimum Event Hour Savings	High Load Day Savings (A.M.)	High Load Day Savings (P.M.)
0.93 kW (27%)	1.62 kW (47%)	0.38 kW (11%)	0.78 kW (23%)	1.17 kW (34%)
Summer 2017				
Average Event Hour Savings	Maximum Event Hour Savings	Minimum Event Hour Savings	High Load Day Savings (P.M.)	
1.01 kW (38%)	1.52 kW (59%)	0.57 kW (21%)	1.00 kW (37%)	

Evaluation Objectives & Methods



Evaluation Objectives

Evaluation Objectives & Methods

Evaluation Objectives

- Estimate average savings per treated customer for each RHR event
- Estimate total program load impacts for each event
- Estimate load impacts during hours before and after for each event (i.e., any pre-heating/cooling, snapback effects)
- Update planning estimate of RHR demand savings per participant customer
- Assess customer satisfaction with RHR and PGE
- Identify any implementation challenges and recommend solutions

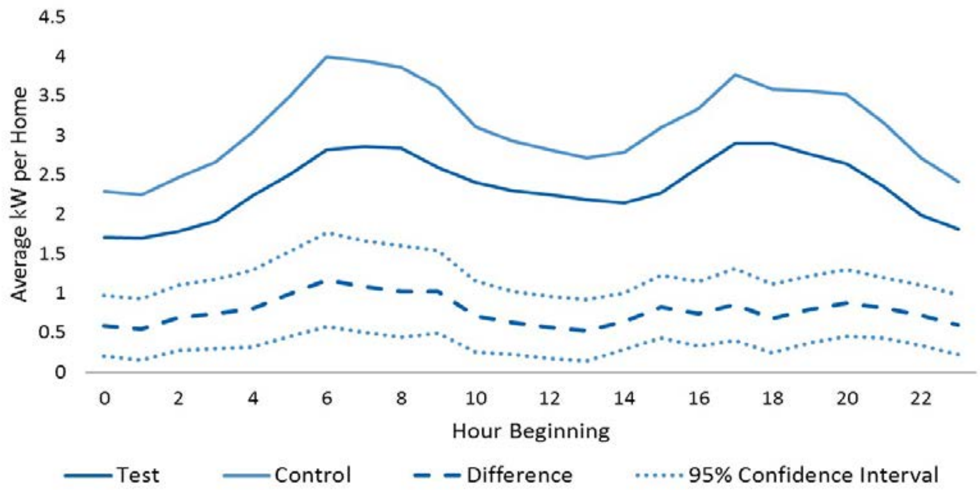
Impact Methodology

- Collect AMI meter data for Nest RHR participant customers
- Test for equivalence of test and control groups and develop strategy for addressing imbalances
  - Nest did not use PGE random assignments for winter 16/17
- Estimate panel regression models by OLS
  - Difference-in-differences specification
  - Dependent variable was kWh/hour for customer *i* in hour *t*
  - Controls for non-event day consumption, day, hour, and weather, assignment to treatment
  - Clustered standard errors
- Test robustness of savings estimates

Winter 2016/2017

Comparison of evaluation test and control groups

Figure 33 Similar non-event days[122]



[122] Similar non-event days are 10 non-event days (weekdays & non-holidays) with coldest average temperatures.

Strategy for addressing imbalances and non-random assignment

Issues

- **Significant imbalances between test and control groups due to Nest non-implementation of randomized design**
- **Assignment to test and control groups changes between events**

Solutions

- **Employ difference-in-difference estimation strategy**
  - **Parallel trend assumption**
- **Limit days used in estimation of baseline to 10 nonevent days with lowest average temperature**
- **Estimate a separate model for each event**

Table 53 Analysis Sample

Homes	Test	Control	Total
Participant Population[123]	165	316	481
Analysis Sample by Event (Number of homes)[124]			
Event 1	151	277	428
Event 2	151	277	428
Event 3	153	278	431
Event 4	155	281	436
Event 5	158	283	441
Event 6	158	282	440
Event 7	158	282	440
Event 8	161	286	447

[123] Number of RHR homes on February 28, 2017 for which Cadmus received AMI data before any filters were applied.
[124] Total number of RHR homes in analysis sample used in estimation of RHR impacts.

Comparison of evaluation randomized test and control groups

Figure 34 All non-event days

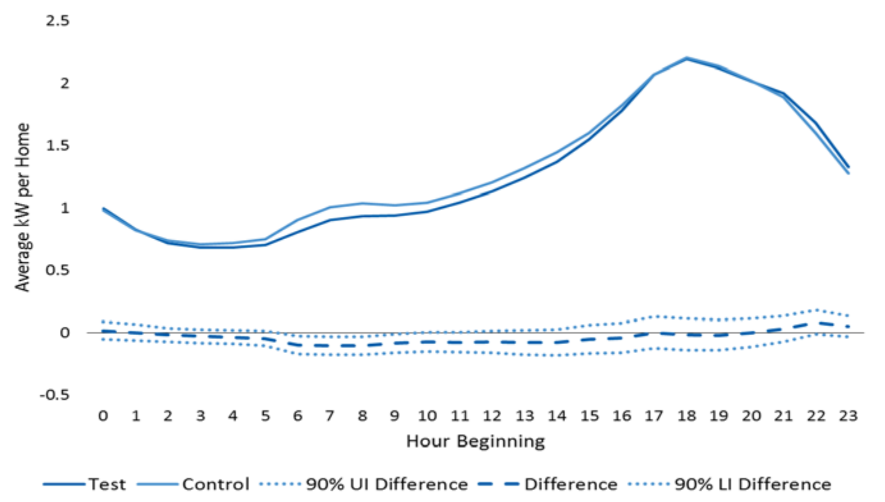
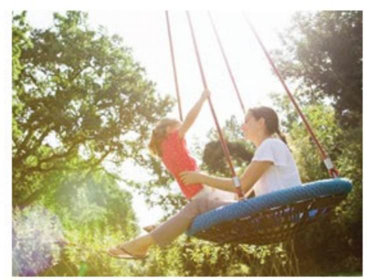


Table 54 Analysis Sample

Homes	Test	Control	Total
Participant Population[125]	2,848	428	3,276
Analysis Sample by Event (Number of homes)[126]			
Event 1	2,829	422	3,251
Event 2	2,829	422	3,251
Event 3	2,830	421	3,251
Event 4	2,829	421	3,250
Event 5	2,828	422	3,250
Event 6	2,827	421	3,248
Event 7	2,830	421	3,251

[125] Number of RHR homes on August 31, 2017 for which Cadmus received AMI data before any filters were applied.
[126] Total number of RHR homes in analysis sample used in estimation of RHR impacts.

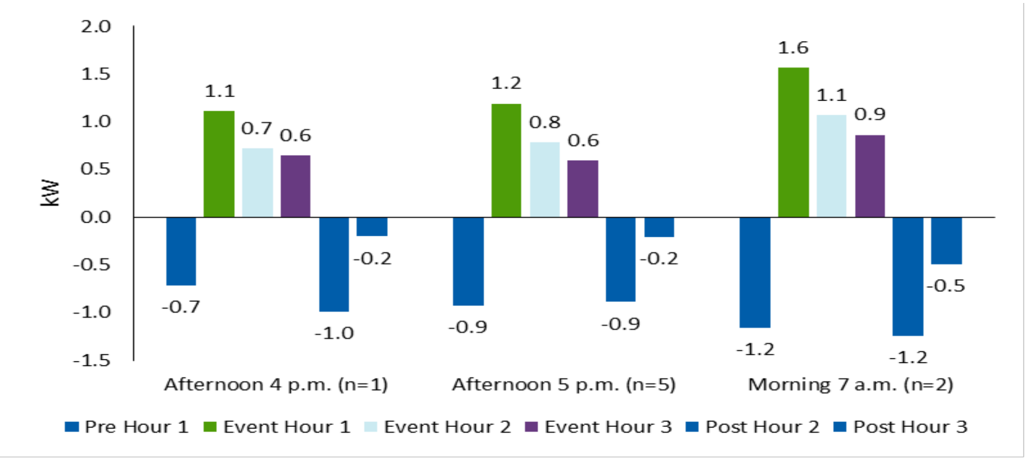
Impact Findings



Impact Findings

Winter 2016/2017

Average Demand Savings Per RHR Participant (kW) by Event Starting Time[127]



[127] n in parentheses indicates the number of events that started at the given time.

Table 55 Average Demand Impact per RHR Participant

Event Hour		Winter (kW per customer)		
		5:00 p.m. – 8:00 p.m. (5 events)	4:00 p.m. – 7:00 p.m. (1 event)	7:00 a.m. – 10:00 a.m. (2 event)
Avg. demand impact per event hour (kW)		-0.85	-0.82	-1.17
Max demand impact per event hour (kW)		-1.40	-1.11	-1.62
Min demand impact per event hour (kW)		-0.38	-0.64	-0.72
Avg. energy impact per event (kWh)		-0.35	-0.48	-0.20
PGE high load day[128]	Avg. demand impact per event hour (kW)	-0.78		-1.17
PGE planning estimate		-1.00		
Winter 2015/2016		-0.57	-0.64	-0.36

[128] Winter high load days – Dec. 14 (p.m.), Jan. 4 (p.m.), and Jan. 6 (a.m.).

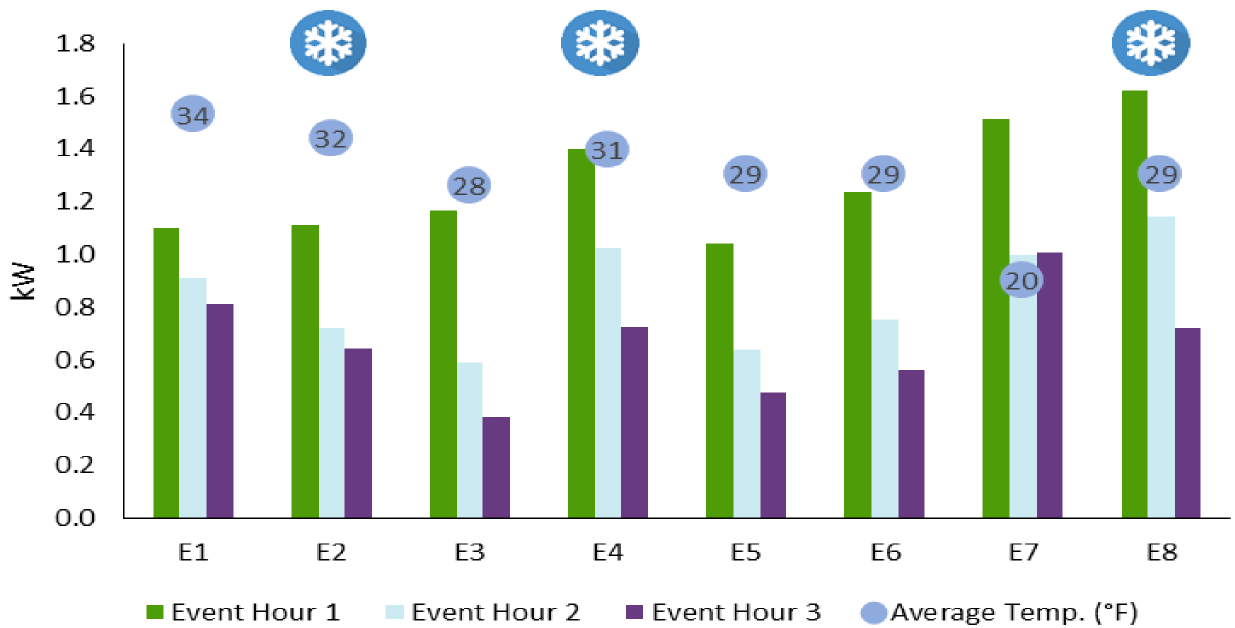
Winter 2016/2017

Table 56 Percentage Demand Impacts per RHR Participant[129]

Event Hour		Winter 5:00 p.m. – 8:00 p.m. (5 events)	Winter 4:00 p.m. – 7:00 p.m. (1 event)	Winter 7:00 a.m. – 10:00 a.m. (2 event)
Avg. demand impact per event hour (%)		-25%	-24%	-34%
Max demand impact per event hour (%)		-41%	-32%	-47%
Min demand impact per event hour (%)		-11%	-18%	-20%
Avg. energy impact per event (%)		-2%	-8%	7%
PGE high load day[130]	Avg. demand impact per event hour (%)	-23%		-34%
PGE planning estimate	Avg. demand impact per event hour (%)	-54%		
Winter 2015/2016	Avg. demand impact per event hour (%)	-25%	-21%	-16%

[129] Percentage impacts estimated by dividing average kW load impact estimate by average treatment customer demand on similar days.
[130] Winter high load days – Dec. 14 (p.m.), Jan. 4 (p.m.), and Jan. 6 (a.m.).

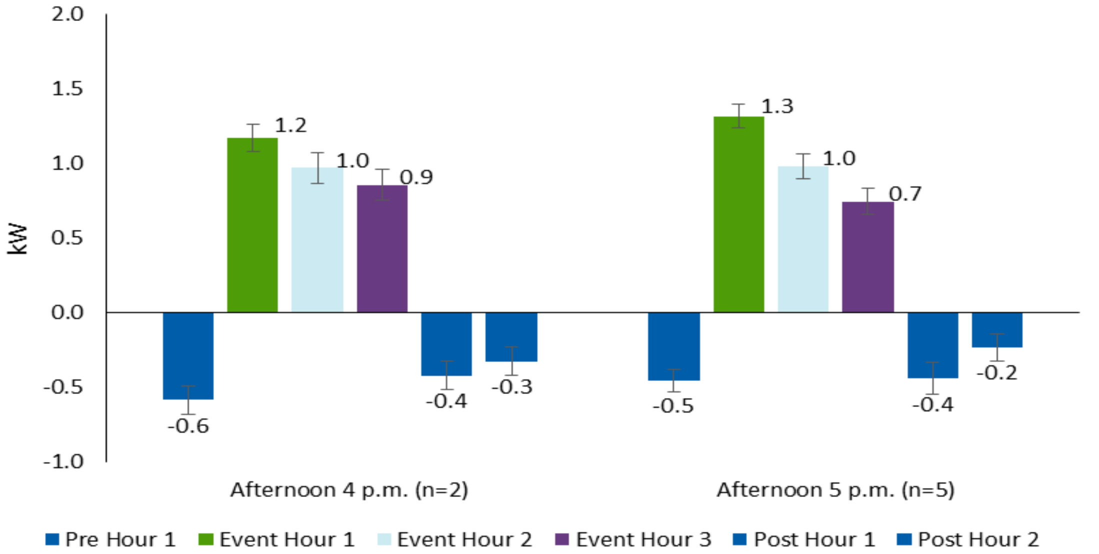
Figure 35 Average Demand Savings Per RHR Participant by Event[131]



[131] E1 – E8 denotes events 1 to 8 during Winter 2016/17. Snow days were days when the Portland metropolitan area received snowfall that shut down local schools and many businesses.

Summer 2017

Figure 36 Average Demand Savings Per Treated Customer[132]



[132] n in parentheses indicates the number of events that started at the given time.

Table 57 Average Demand Impact per RHR Participant Home

Event Hour		Summer (kW per customer)	
		5:00 p.m. – 8:00 p.m. (5 events)	4:00 p.m. – 7:00 p.m. (2 events)
Avg. demand impact per event hour (kW)		-1.02	-1.00
Max demand impact per event hour (kW)		-1.52	-1.24
Min demand impact per event hour (kW)		-0.57	-0.80
Avg. energy impact per event (kWh)		-1.34	-1.08
PGE high load day[133]	Avg. demand impact per event hour (kW)	-1.00	
PGE planning estimate		-0.80	
Summer 2016		-	-0.79

[133] Summer critical peak days: Aug. 2 (p.m.) and Aug. 3 (p.m.).

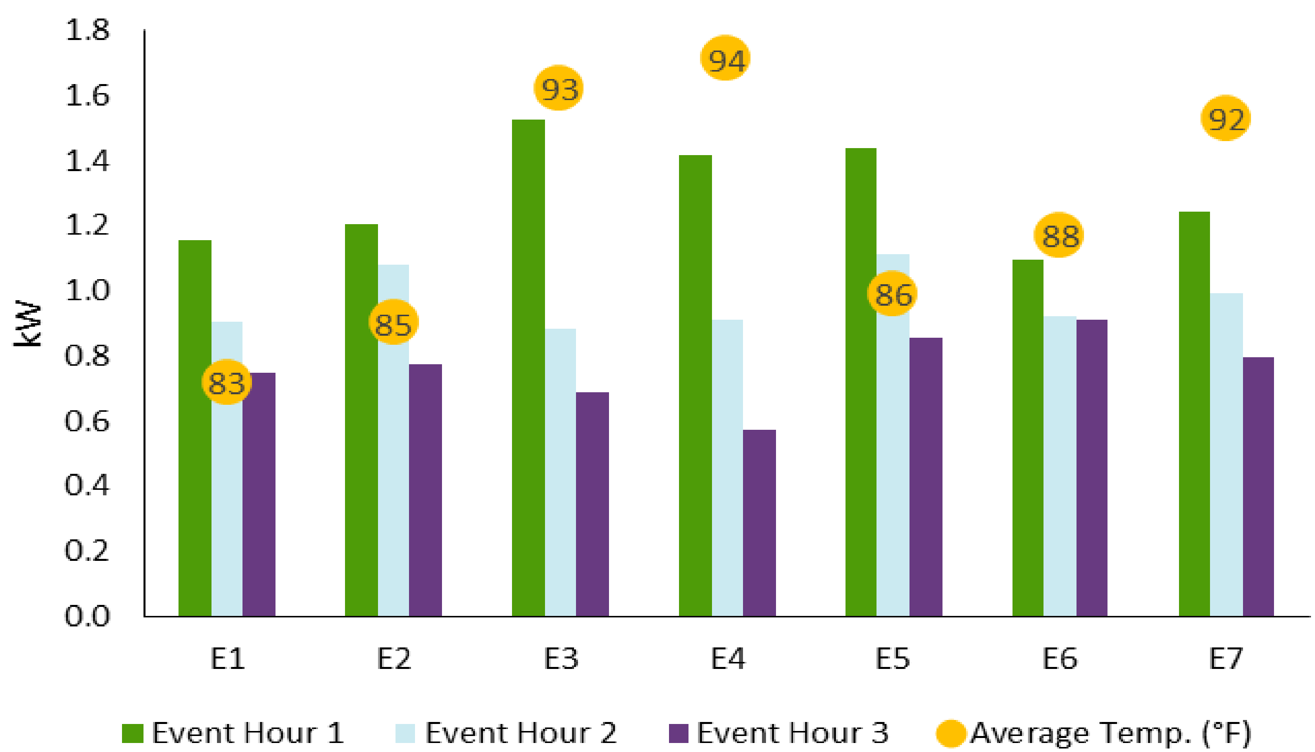
Summer 2017

Table 58 Percentage Demand Impact per RHR Participant

<table>
<tr><th colspan="2" rowspan="3">Event Hour</th><th colspan="2">Summer</th></tr>
<tr><th>5:00 p.m. – 8:00 p.m.</th><th>4:00 p.m. – 7:00 p.m.</th></tr>
<tr><th>(5 events)</th><th>(2 events)</th></tr>
<tr><td colspan="2">Avg. demand impact per event hour (%)</td><td>-33%</td><td>-33%</td></tr>
<tr><td colspan="2">Max demand impact per event hour (%)</td><td>-59%</td><td>-48%</td></tr>
<tr><td colspan="2">Min demand impact per event hour (%)</td><td>-21%</td><td>-29%</td></tr>
<tr><td colspan="2">Avg. energy impact per event (%)</td><td>-42%</td><td>-36%</td></tr>
<tr><td>PGE high load day[134]</td><td rowspan="3">Avg. demand impact per event hour (%)</td><td colspan="2">-37%</td></tr>
<tr><td>PGE planning estimate</td><td colspan="2">-43%</td></tr>
<tr><td>Summer 2016</td><td>-</td><td>-30%</td></tr>
</table>

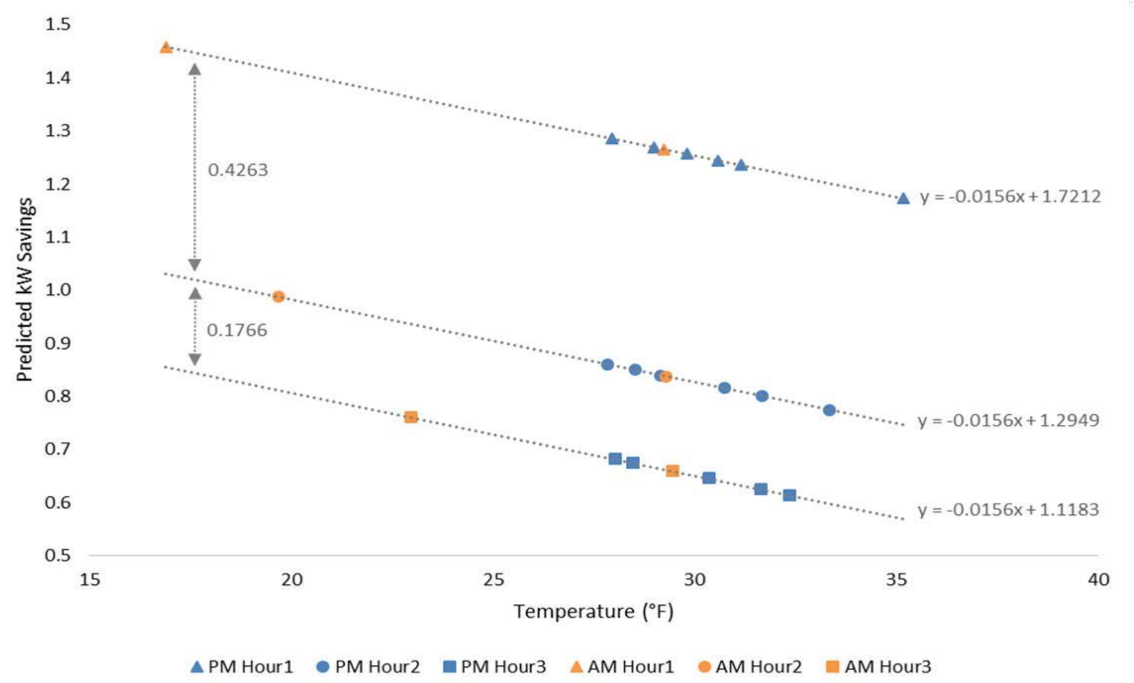
[134] Ibid.

Figure 37 Average Demand Savings Per RHR Participant by Event



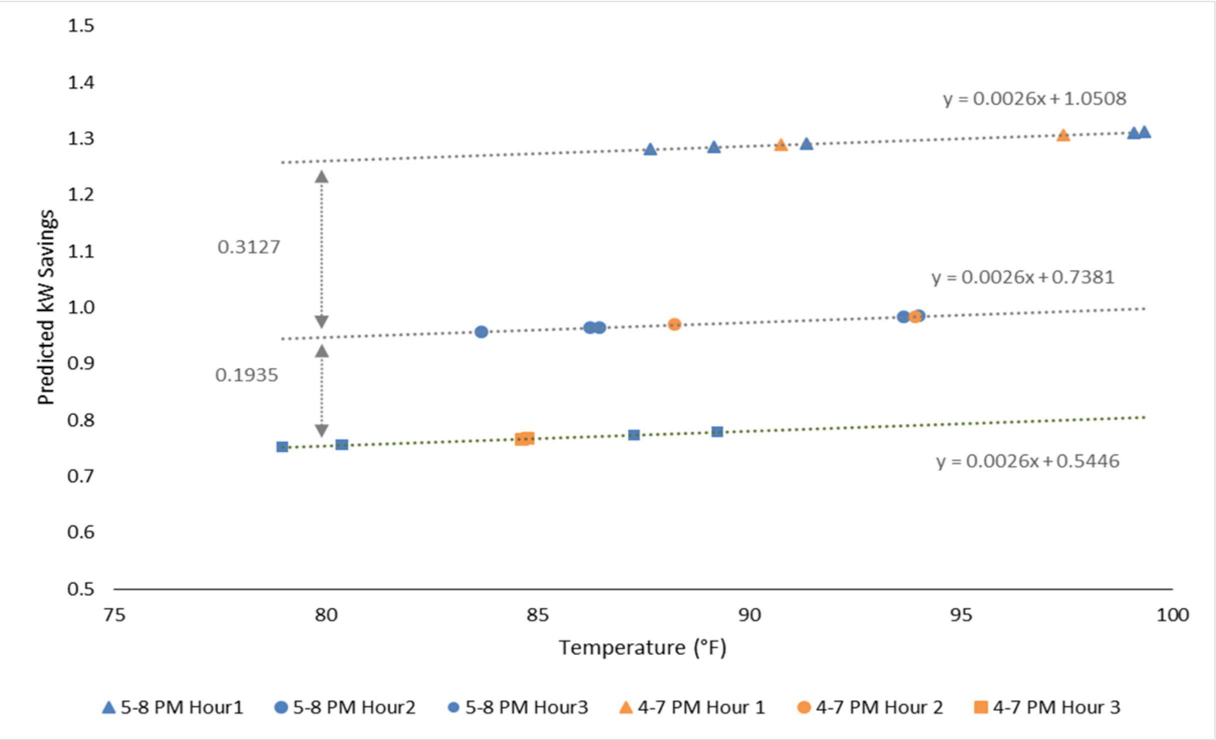
Winter 16/17

Figure 38 Winter 2016/2017 Predicted Event Hour Impacts

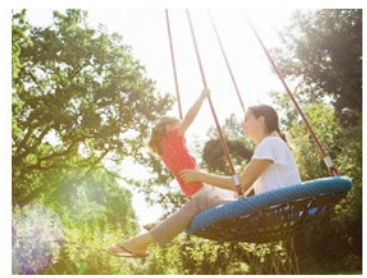


Summer 17

Figure 39 Summer 2017 Predicted Event Hour Impacts



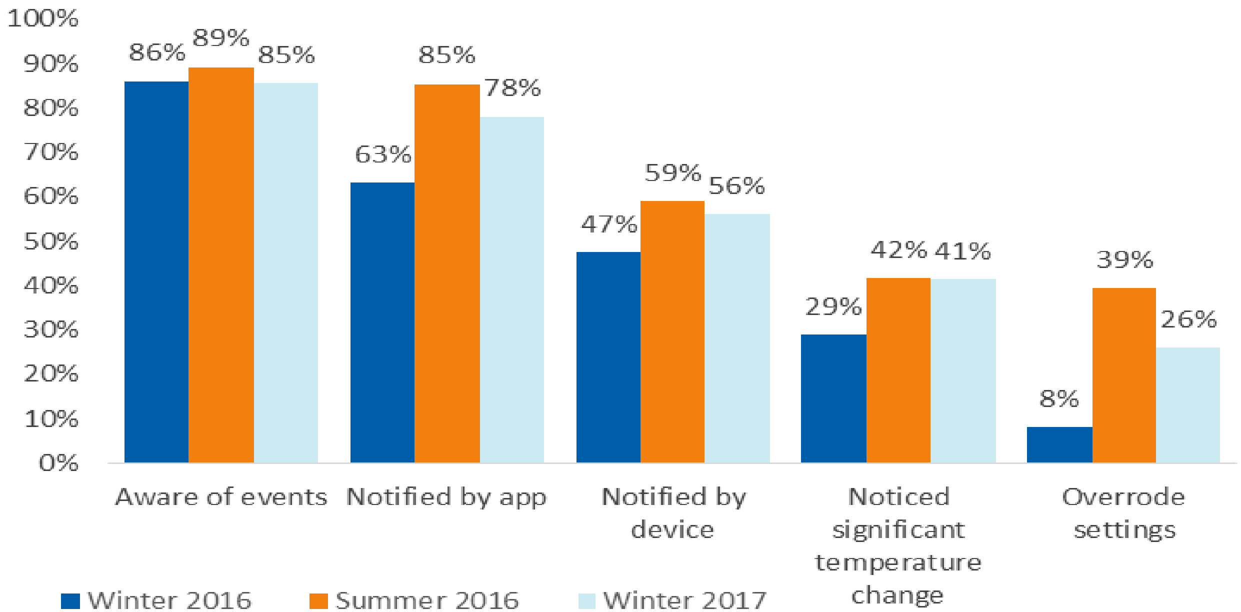
Process Findings



Process Findings

Participant Surveys

Figure 40 Awareness and Response to Events



Winter 2016/2017: Participant Surveys

Winter 16/17: Participant Surveys

Figure 41 Program Satisfaction

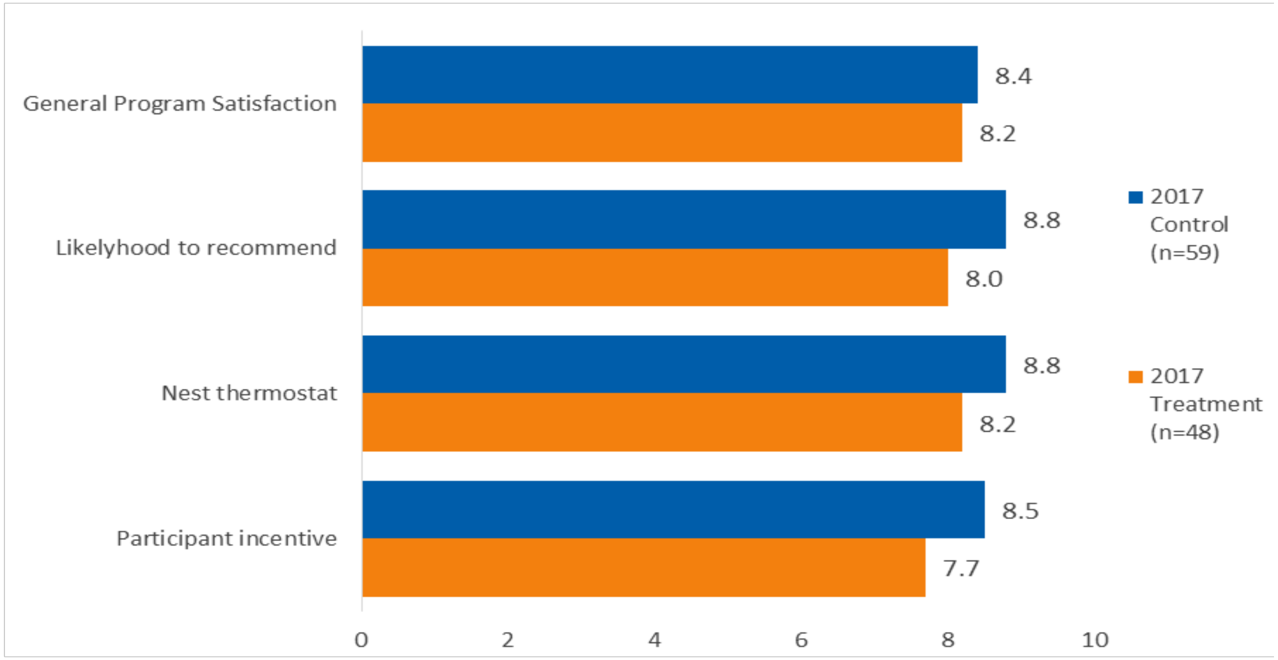


Figure 42 Satisfaction with PGE

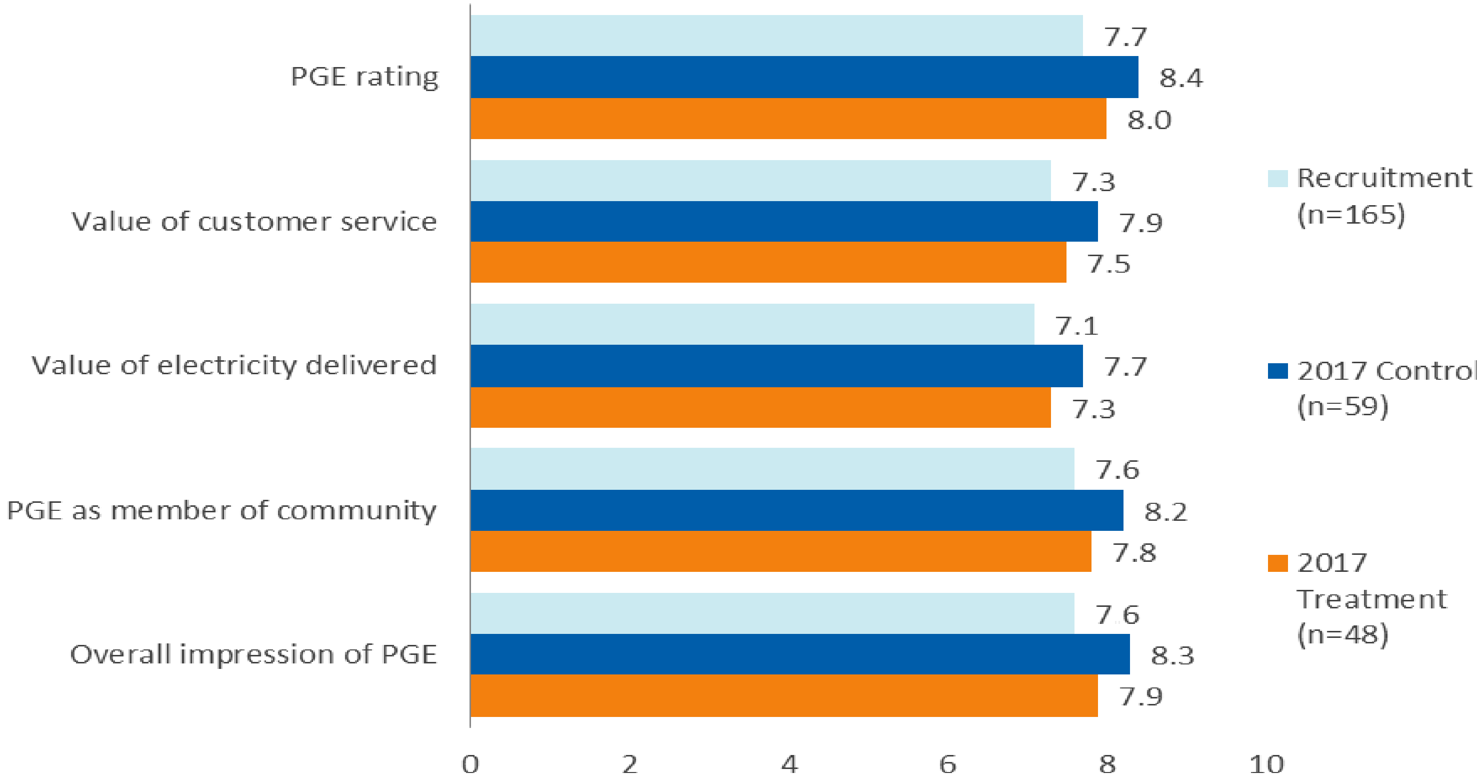
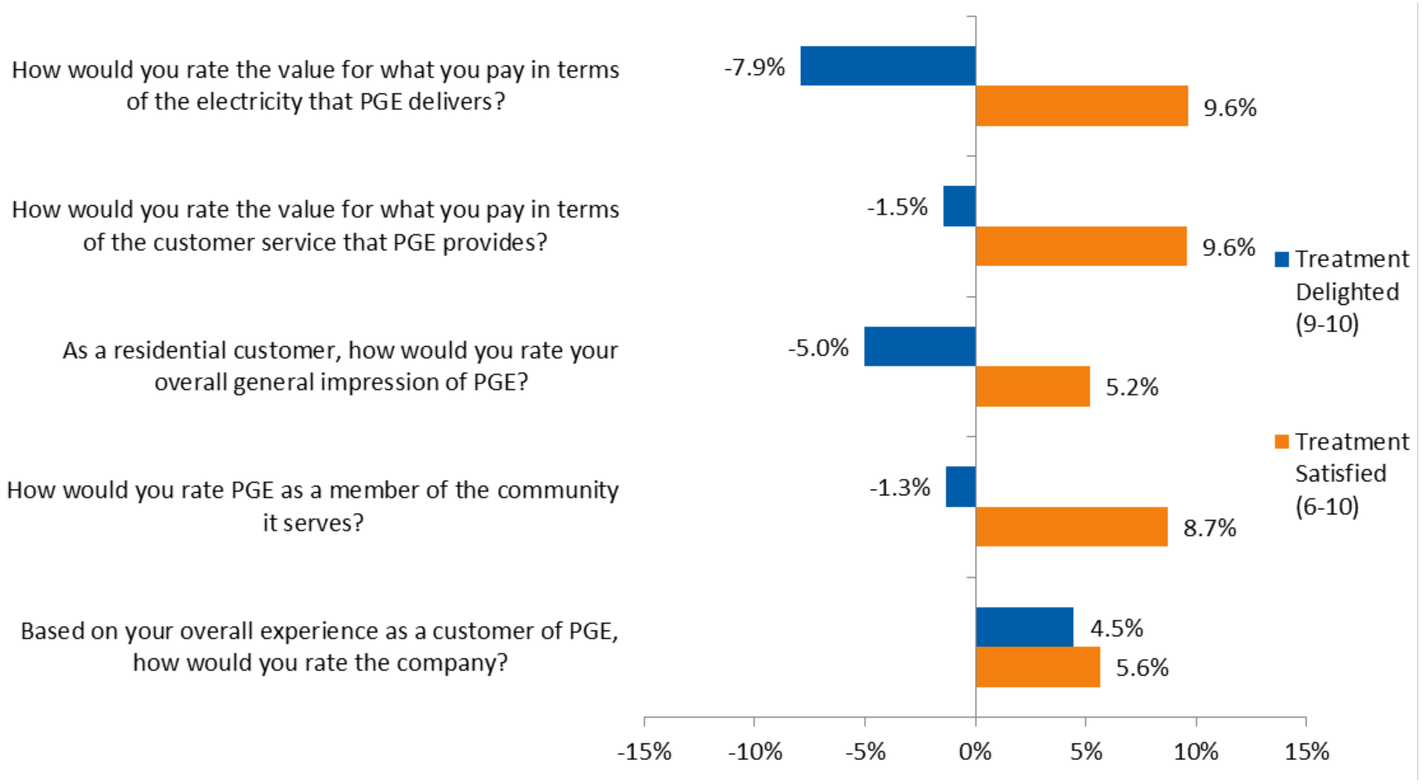
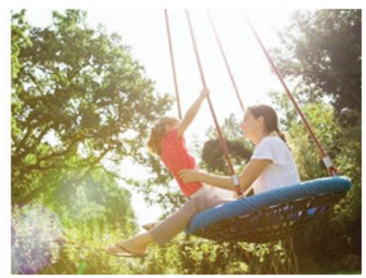


Figure 43 Change in PGE Ratings from Recruitment to Winter 16/17



Take-Aways and Next Steps



Take-Aways

Take Aways and Next Steps

Take Aways

- RHR pilot delivered expected capacity
  - ~0.9 kW per home in winter 2016/2017
  - ~1 kW per home in summer 2017
- Increased impact compared to previous seasons
- Largest load reduction occurs in winter mornings
  - >1.5 kW in first hour
- Pre/post snapback – important to account in utility operations
  - In winter, ~ 1 kW per home
  - In summer, ~0.5 kW per home

Next Steps

Next Steps

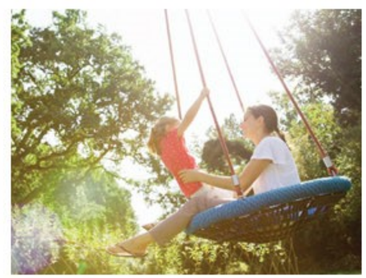
Winter 2017/2018

- Evaluate current season impacts

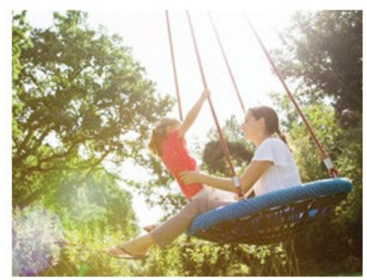
Reporting – Q4 2018

- Includes W 16/17, S17, W17/18, and S18

Appendix



Load Impacts by Winter Event



Appendix

Load Impacts by Winter Event

Winter 2016/2017

Figure 44 Event 1 (12/6/2016, 4:00 p.m. – 7:00 p.m., Avg. Temp. 34°F)

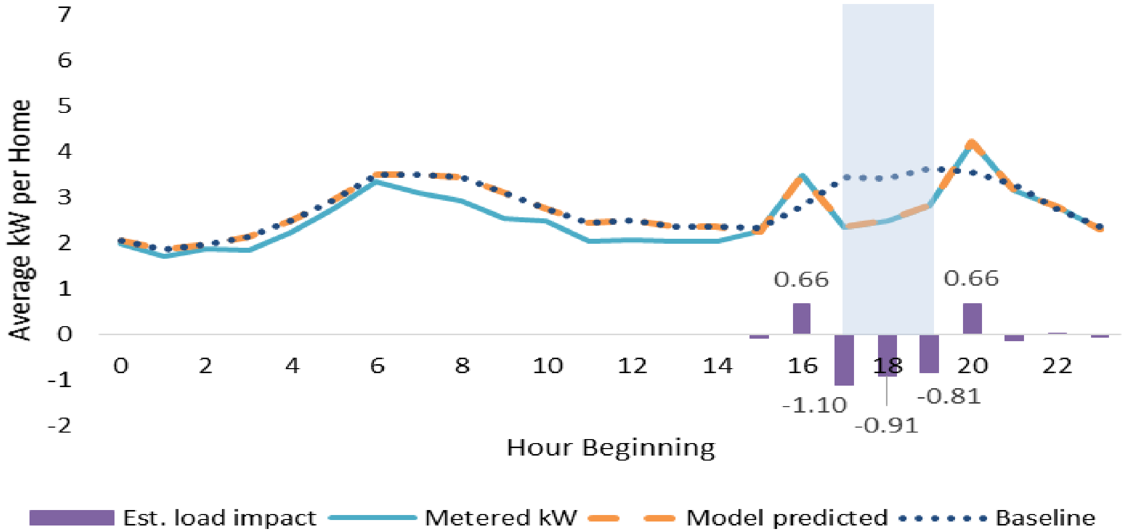


Figure 45 Event 2 (12/8/2016, 4:00 p.m. – 7:00 p.m., Avg. Temp. 32°F)

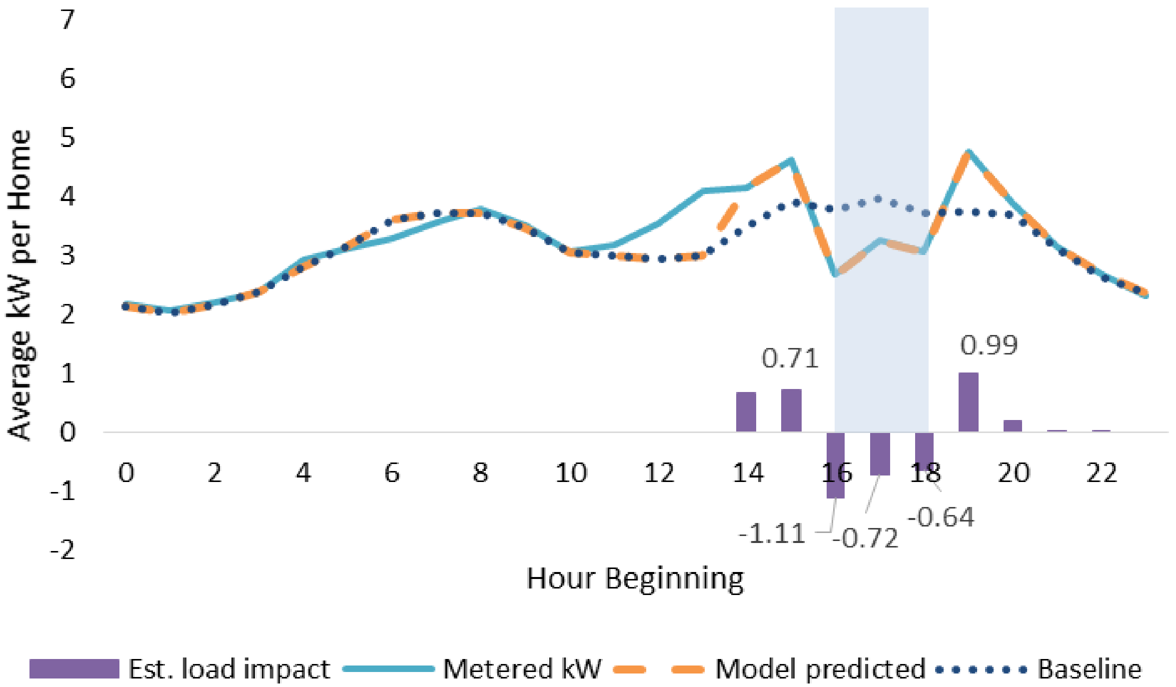


Figure 46 Event 3 (12/14/2016, 5:00 p.m. – 8:00 p.m., Avg. Temp. 28°F)

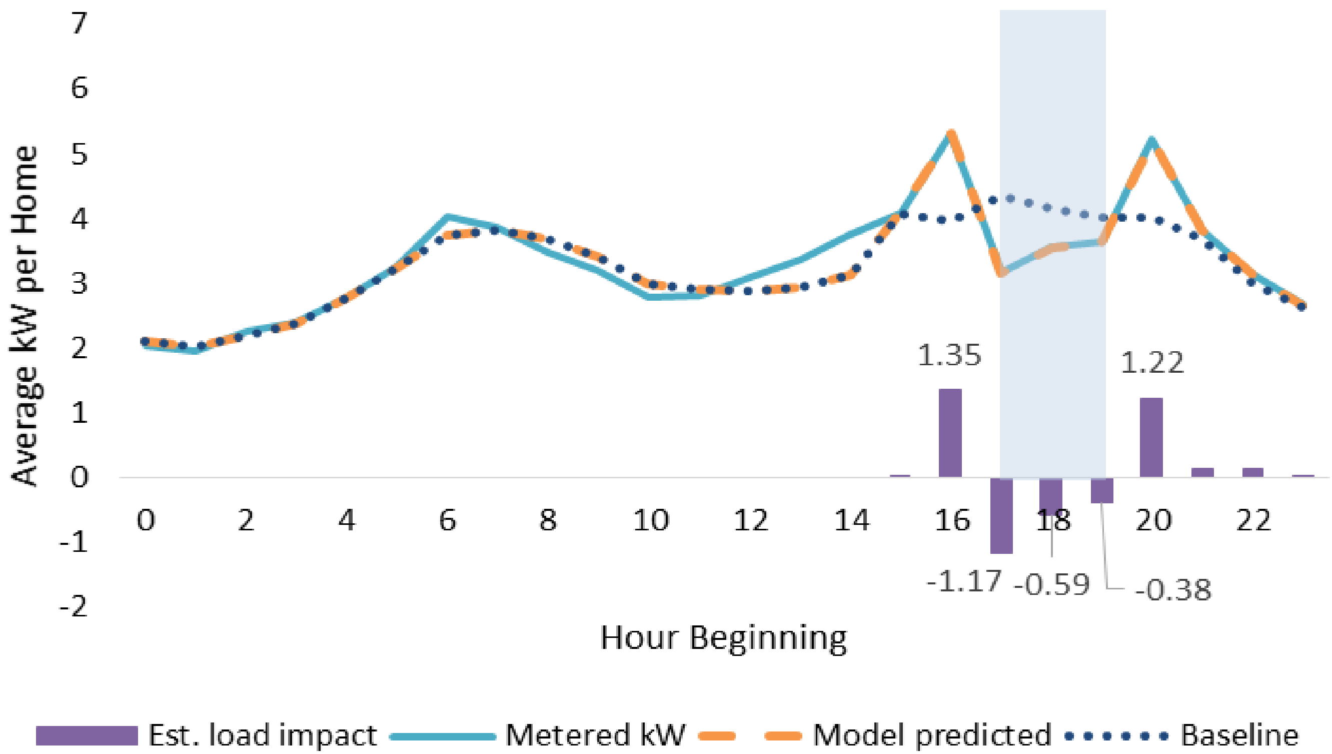


Figure 47 Event 4 (12/15/2016, 5:00 p.m. – 8:00 p.m., Avg. Temp. 31°F)

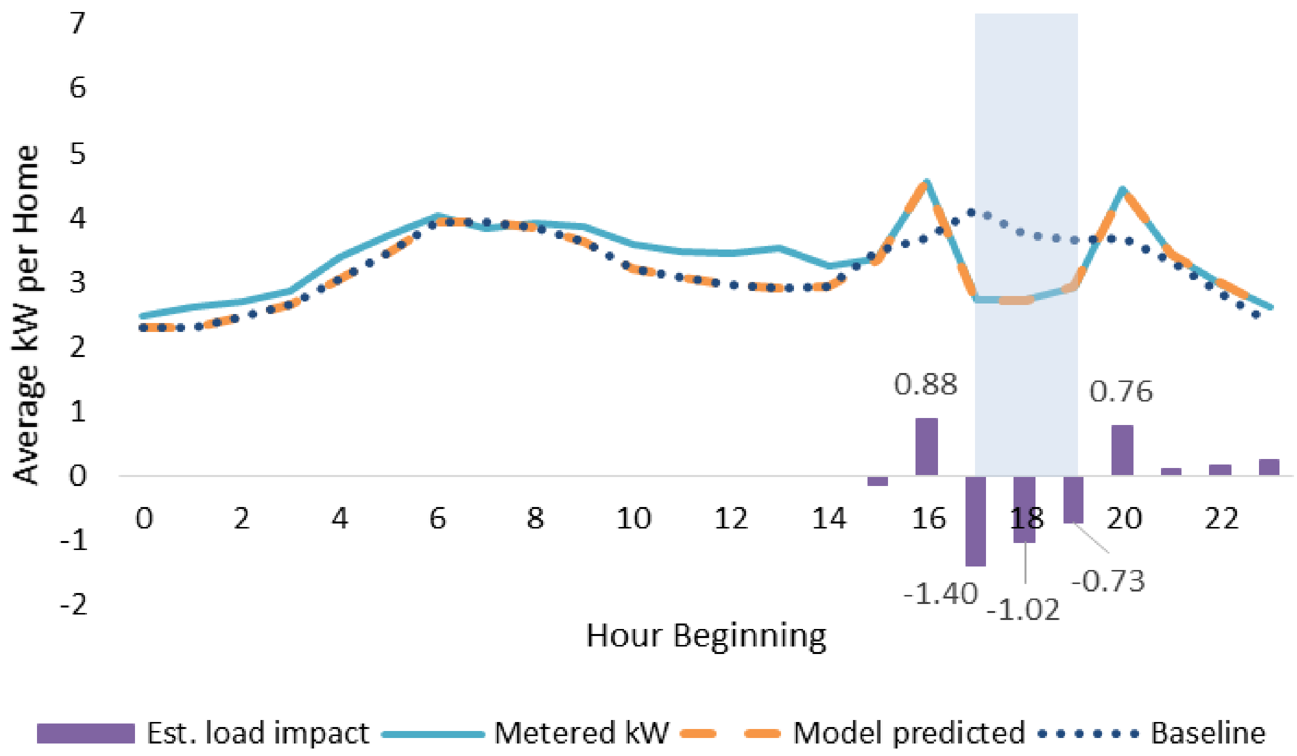
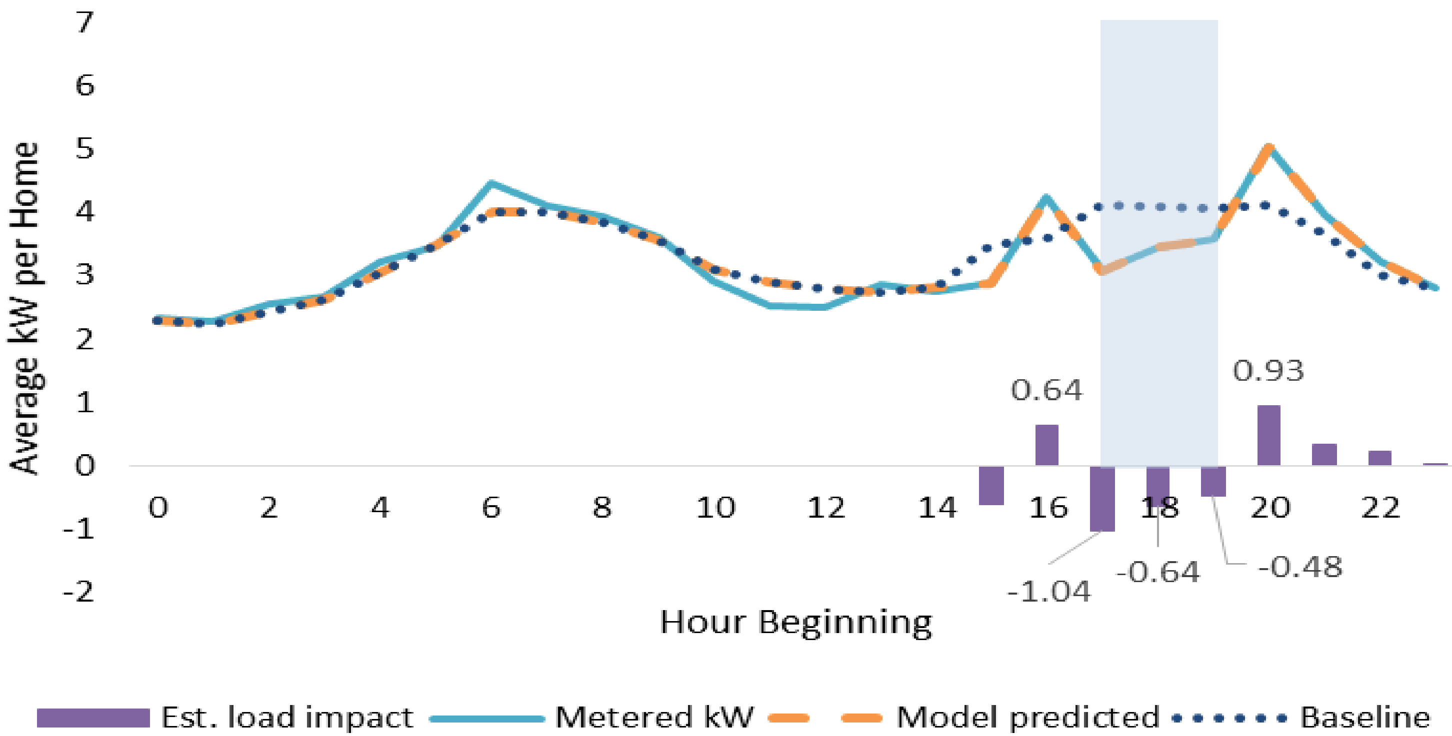
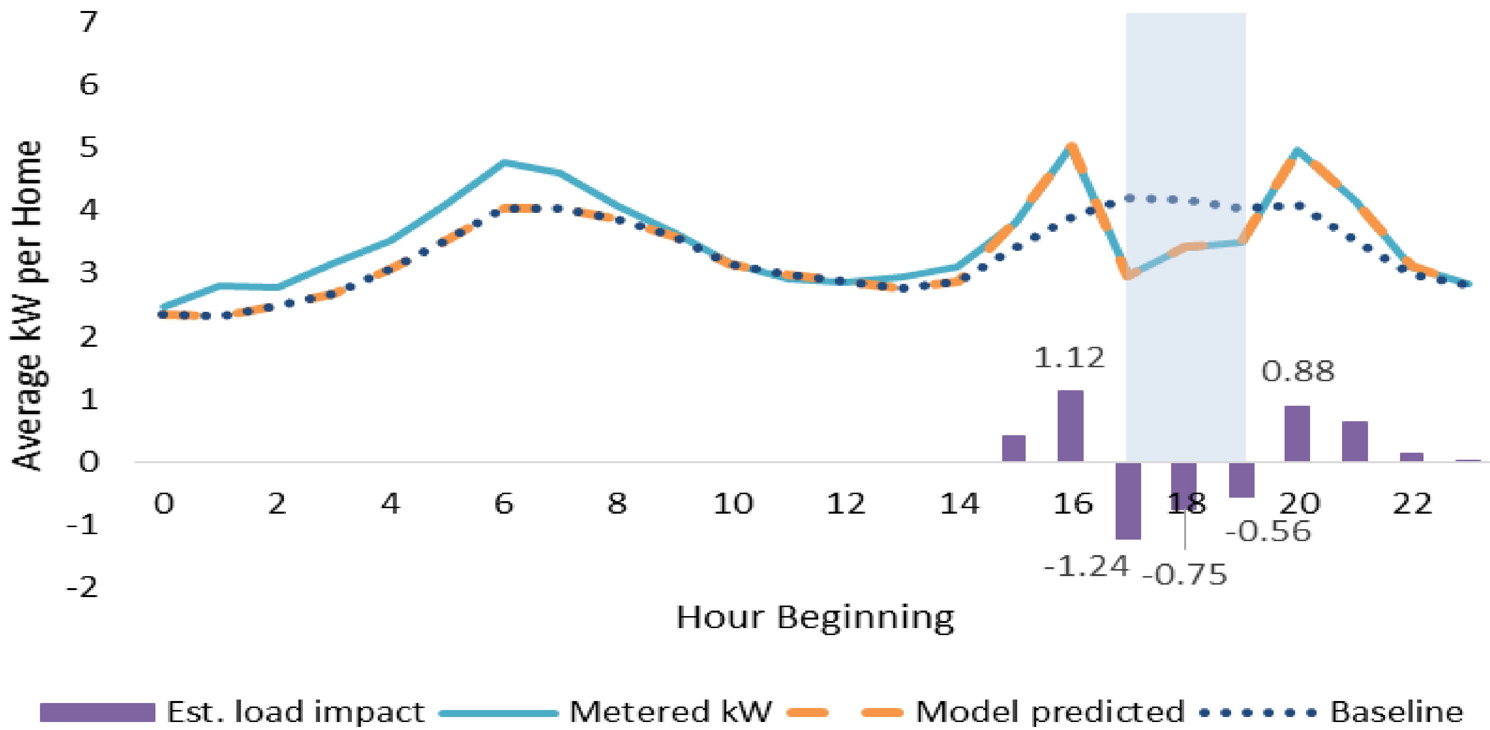


Figure 48 Event 5 (1/3/2017, 5:00 p.m. – 8:00 p.m., Avg. Temp. 29°F)



Opt-Out: Summer Events

Figure 49 Event 6 (1/4/2017, 5:00 p.m. – 8:00 p.m., Avg. Temp. 29°F)



Winter 2016/2017

Figure 50 Event 7 (1/6/2017, 7:00 p.m. – 10:00 p.m., Avg. Temp. 20°F)

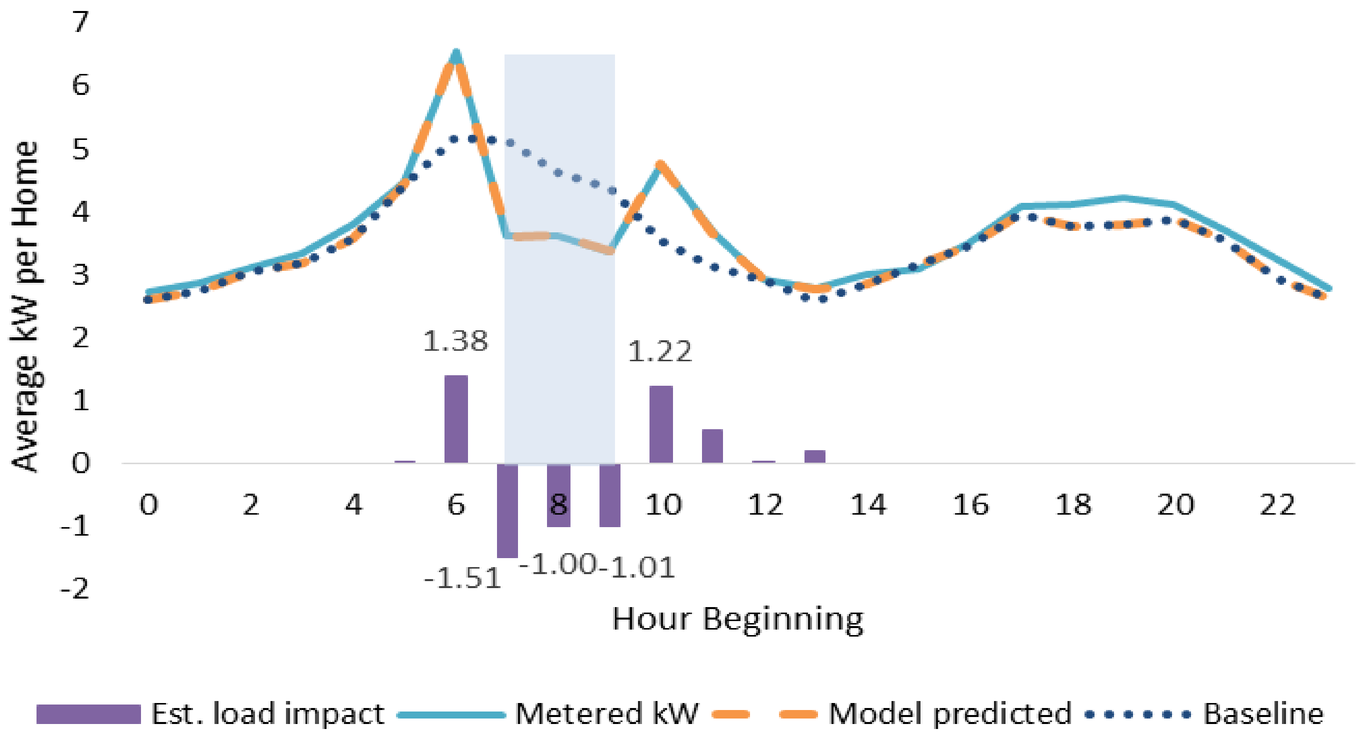
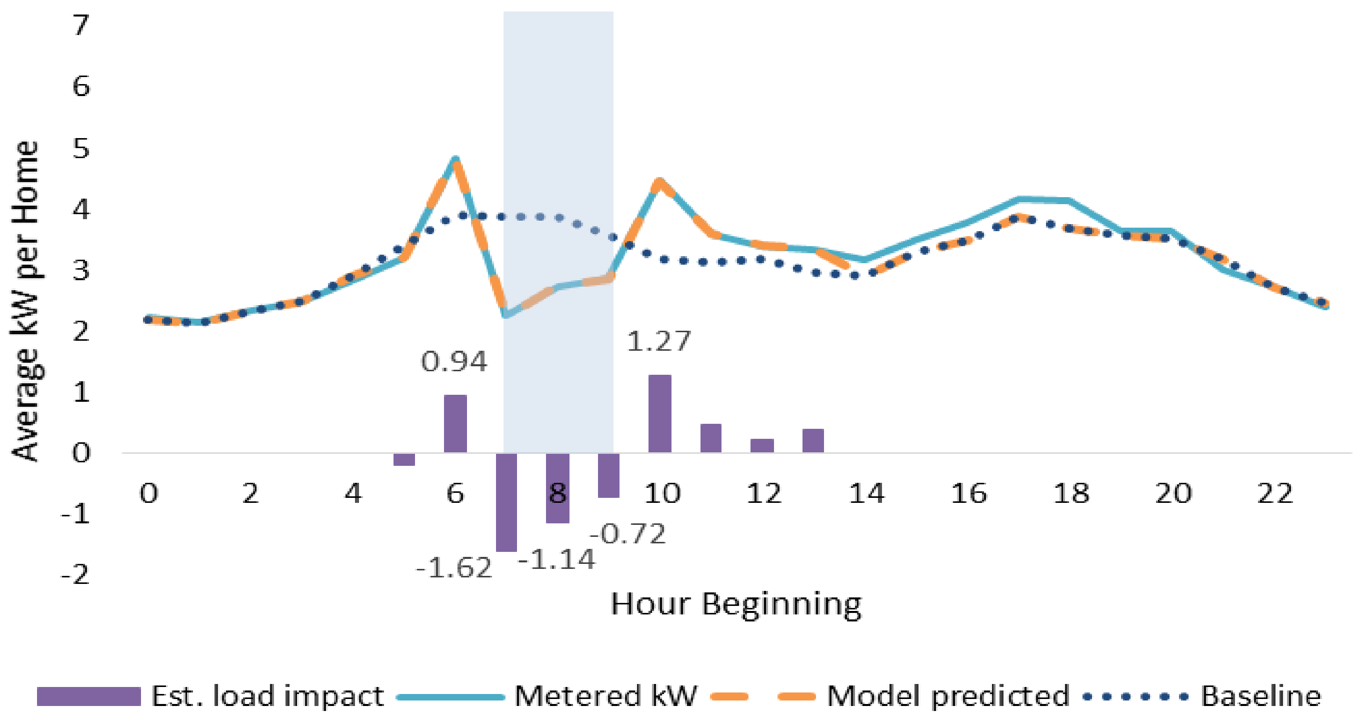
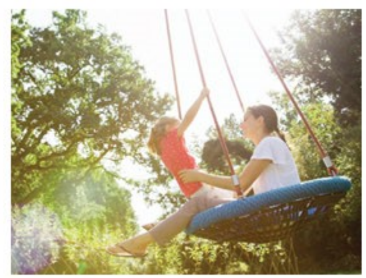


Figure 51 Event 8 (1/11/2017, 7:00 p.m. – 10:00 a.m., Avg. Temp. 29°F)



Load Impacts by Summer Event



Load Impacts by Summer Event

Figure 52 Event 1 (7/25/2017, 5:00 p.m. – 8:00 p.m., Avg. Temp. 83°F)

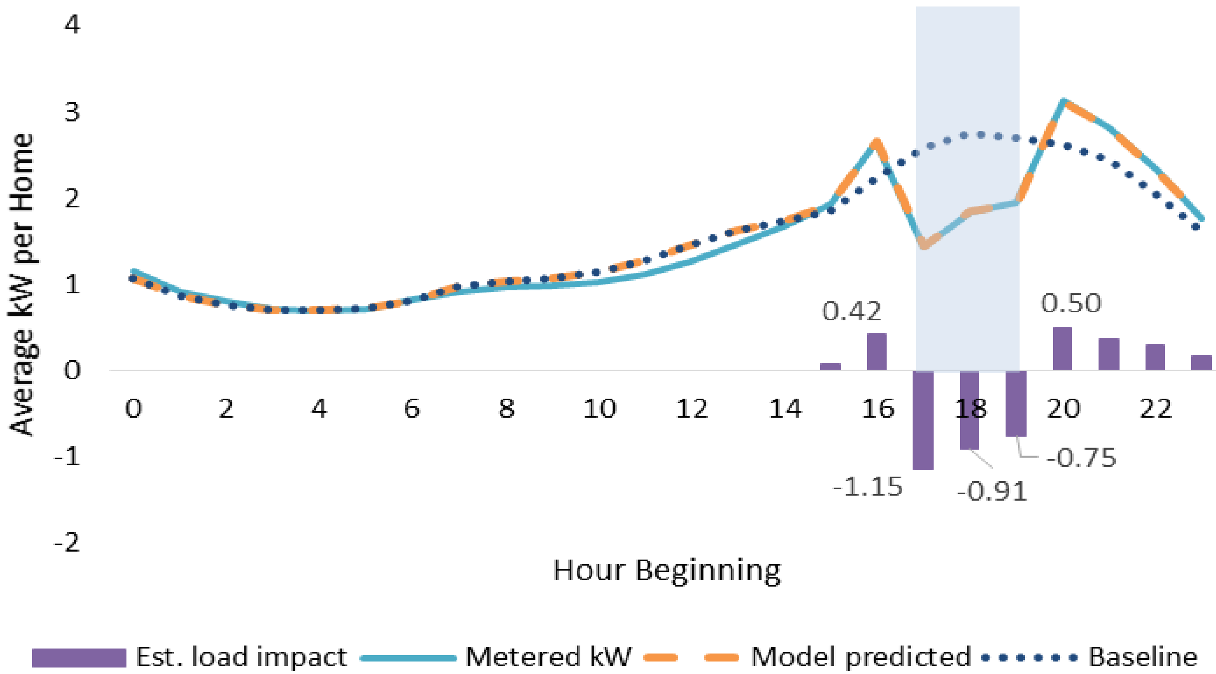


Figure 53 Event 2 (7/31/2017, 5:00 p.m. – 8:00 p.m., Avg. Temp. 85°F)

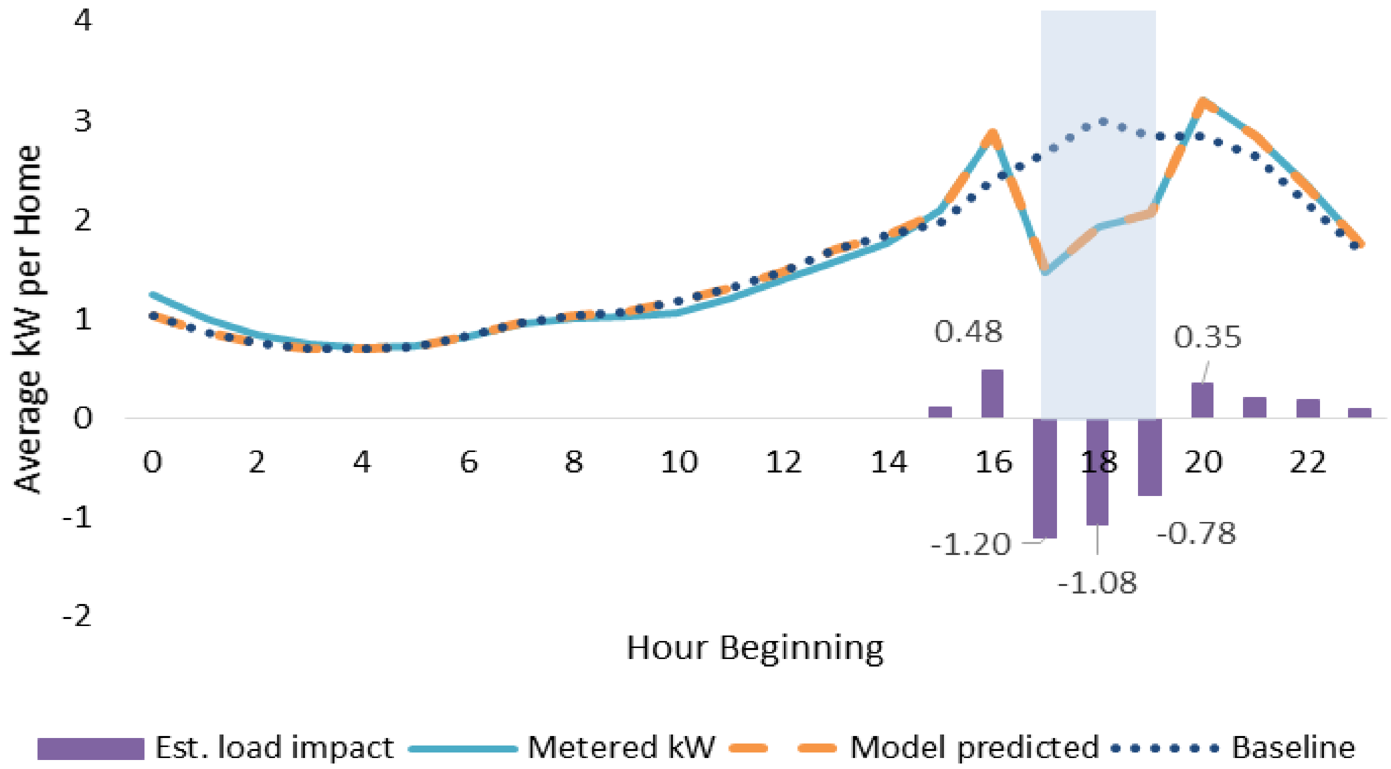


Figure 54 Event 3 (8/2/2017, 5:00 p.m. – 8:00 p.m., Avg. Temp. 93°F)

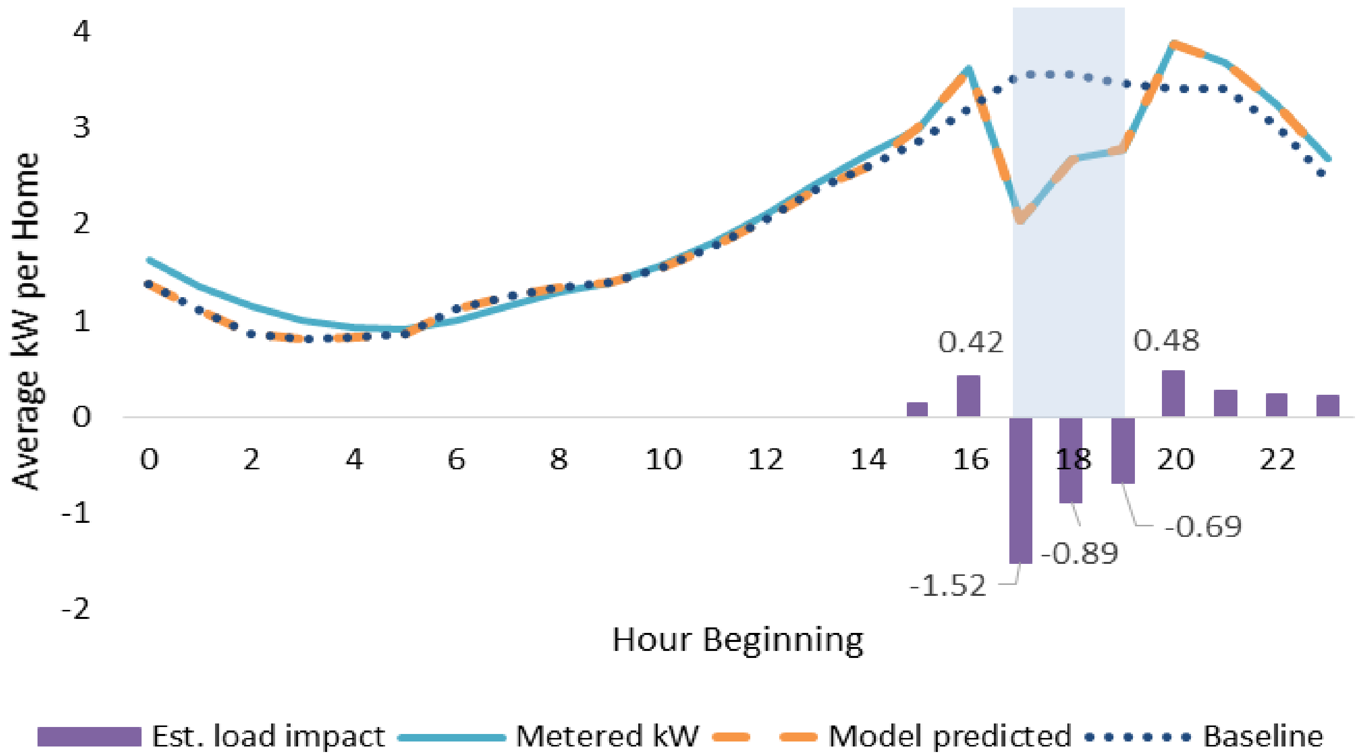


Figure 55 Event 4 (8/3/2017, 5:00 p.m. – 8:00 p.m., Avg. Temp. 94°F)

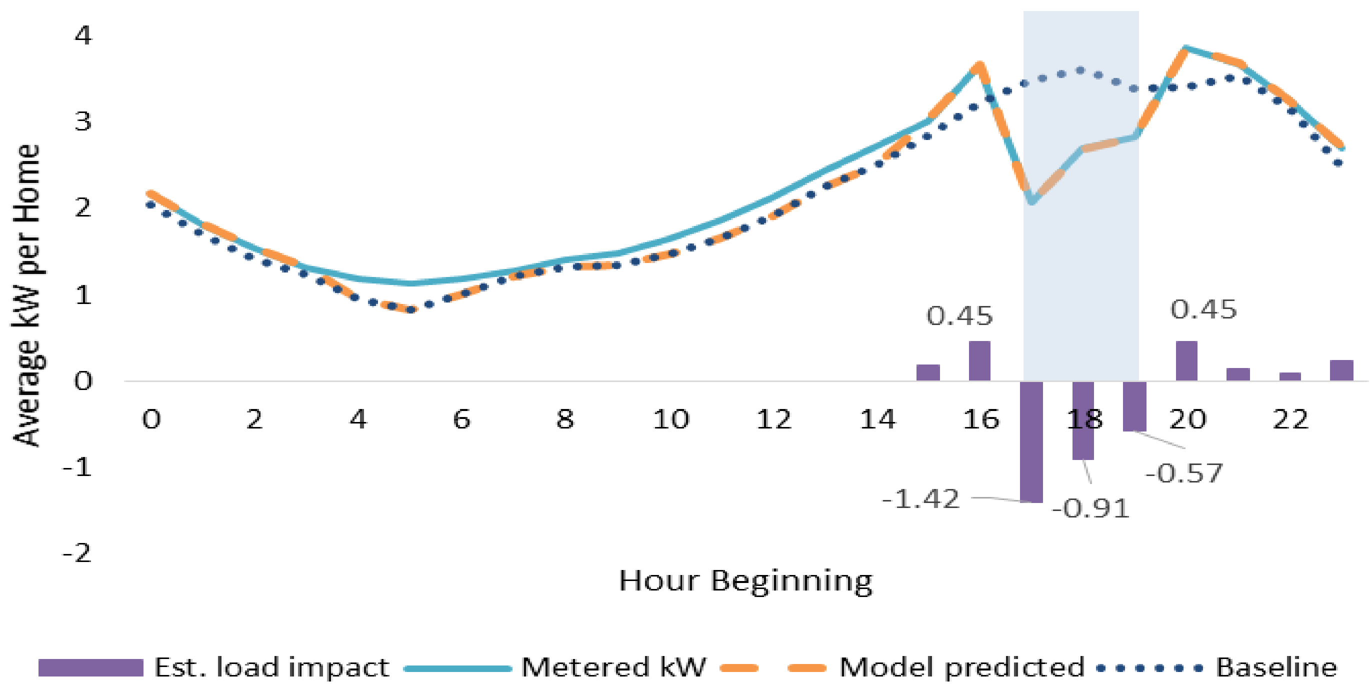


Figure 56 Event 5 (8/8/2017, 5:00 p.m. – 8:00 p.m., Avg. Temp. 86°F)

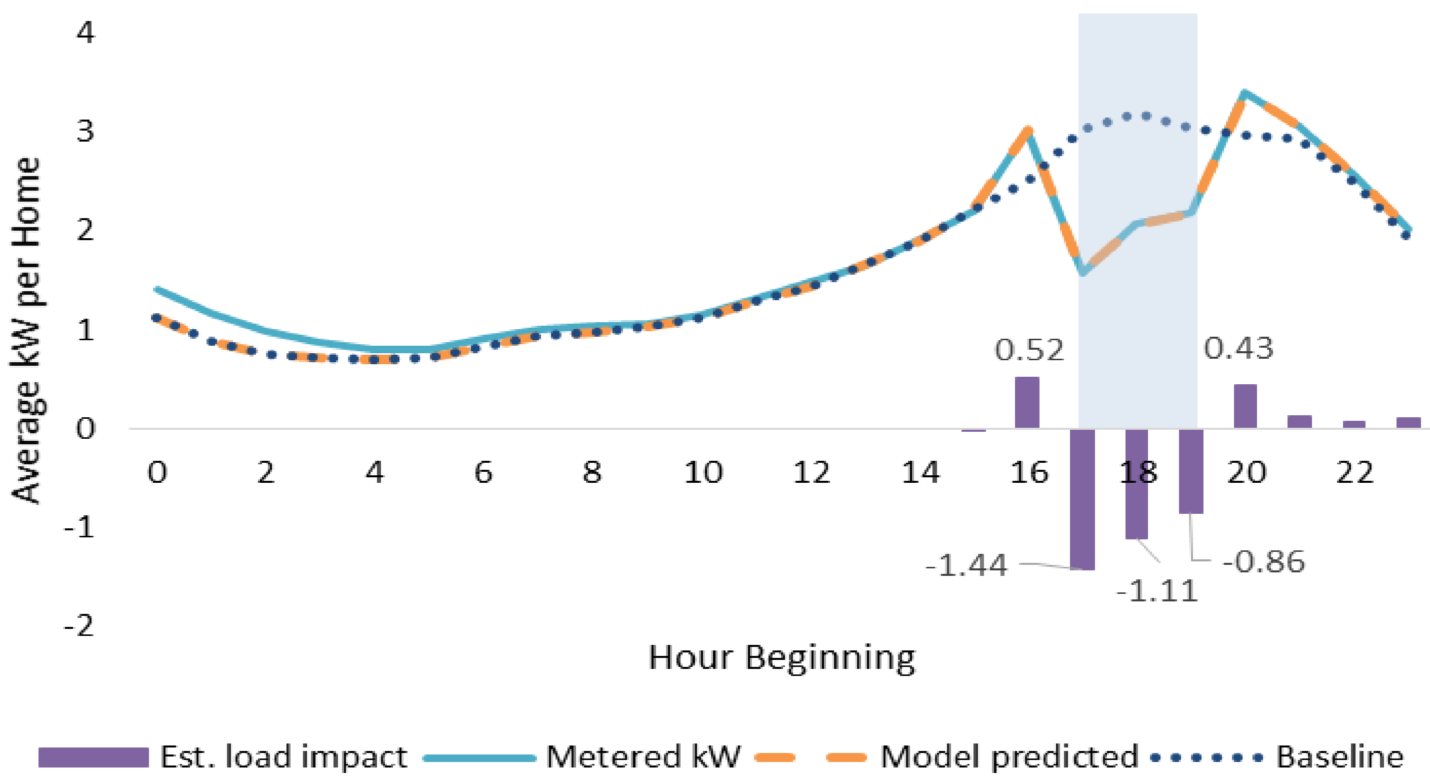
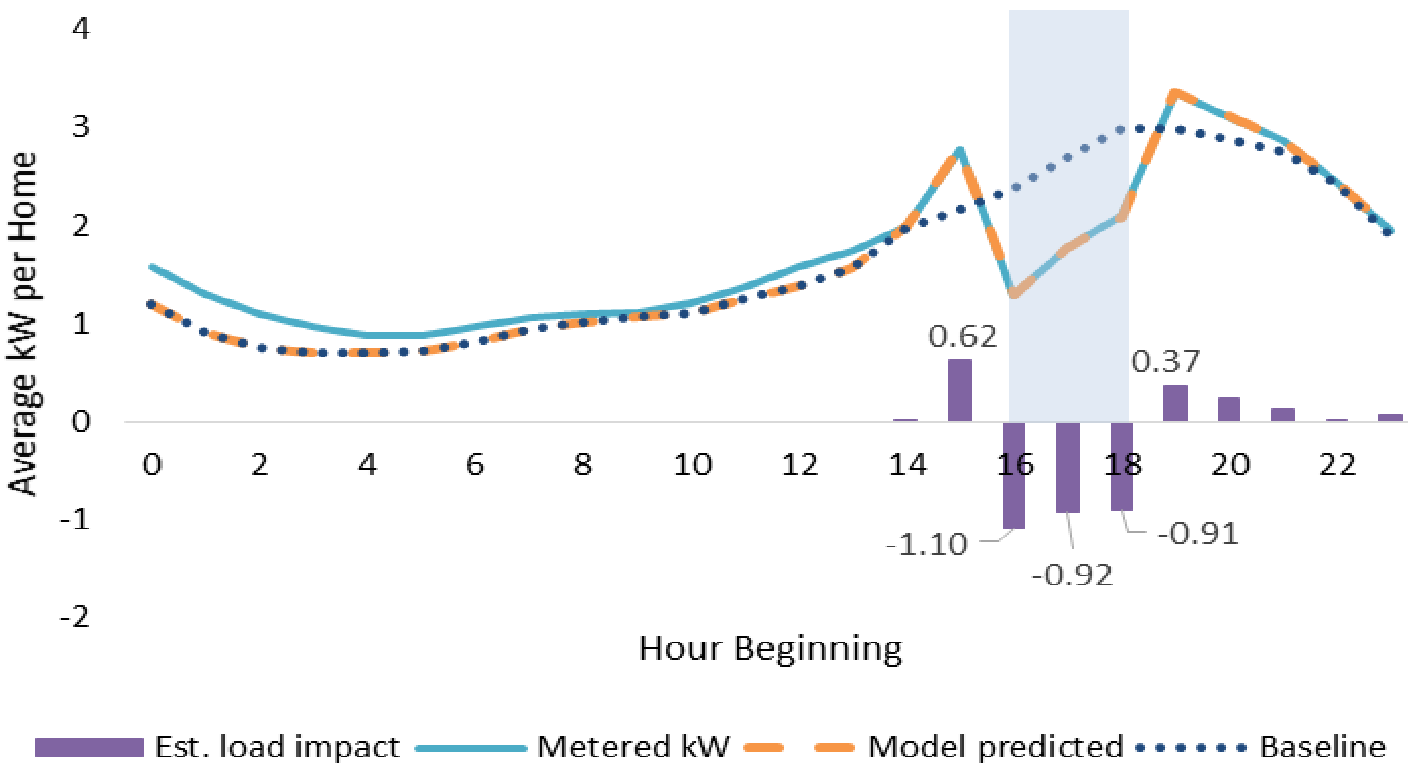
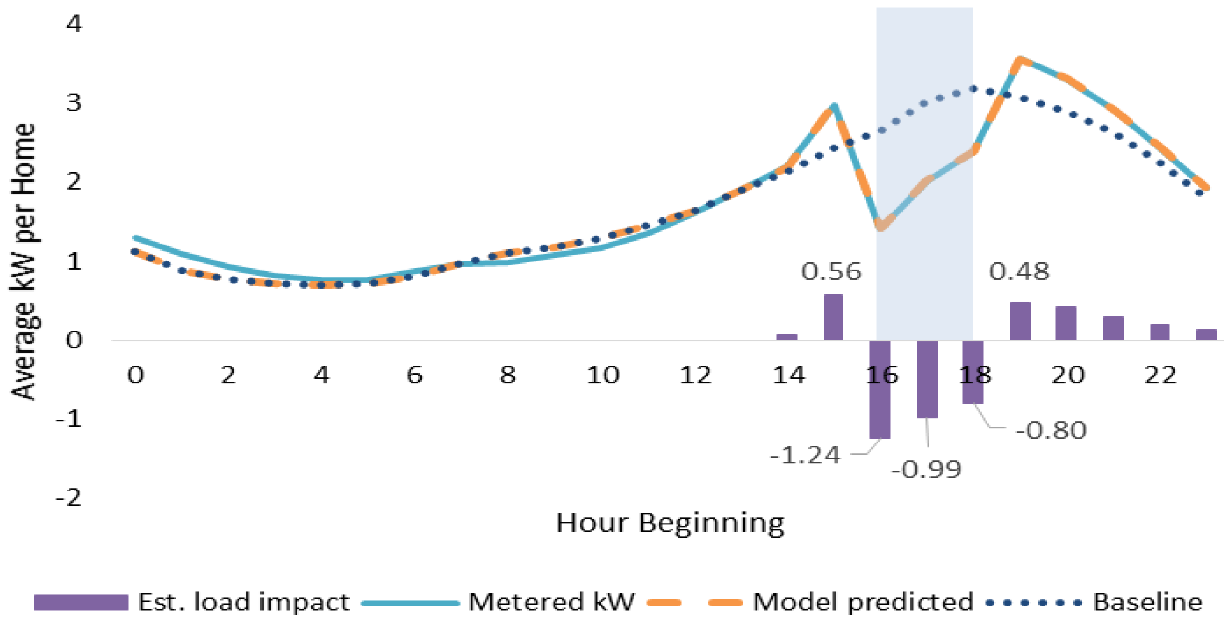


Figure 57 Event 6 (8/10/2017, 4:00 p.m. – 7:00 p.m., Avg. Temp. 88°F)



Summer 2017

Figure 58 Event 7 (8/28/2017, 4:00 p.m. – 7:00 p.m., Avg. Temp. 92°F)



Winter 2016/2017

Table 59 Customer Level Event Impacts (kW)

Event Hour	Winter 2016/2017							
	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8
	5:00 p.m. – 8:00 p.m.	4:00 p.m. – 7:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	7:00 a.m. – 10:00 a.m.	7:00 a.m. – 10:00 a.m.
Pre-Hour 1	0.66	0.71	1.35	0.88	0.64	1.12	1.38	0.94
Event Hour 1	**-1.10**	**-1.11**	**-1.17**	**-1.40**	**-1.04**	**-1.24**	**-1.51**	**-1.62**
Event Hour 2	**-0.91**	**-0.72**	**-0.59**	**-1.02**	**-0.64**	**-0.75**	**-1.00**	**-1.14**
Event Hour 3	**-0.81**	**-0.64**	**-0.38**	**-0.73**	**-0.48**	**-0.56**	**-1.01**	**-0.72**
Post Hour 1	0.66	0.99	1.22	0.76	0.93	0.88	1.22	1.27
Post Hour 2	-0.13	0.20	0.12	0.11	0.32	0.62	0.52	0.46
Post Hour 3	0.04	0.04	0.15	0.17	0.21	0.13	0.01	0.22
Post Hour 4	-0.06	0.05	0.03	0.24	0.01	0.01	0.20	0.38
Event avg. demand impact (kW)	**-0.94**	**-0.82**	**-0.71**	**-1.05**	**-0.72**	**-0.85**	**-1.17**	**-1.16**
Event max hourly demand impact (kW)	**-1.10**	**-1.11**	**-1.17**	**-1.40**	**-1.04**	**-1.24**	**-1.51**	**-1.62**
Event min hourly demand impact (kW)	**-0.81**	**-0.64**	**-0.38**	**-0.73**	**-0.48**	**-0.56**	**-1.00**	**-0.72**
Avg. energy impact per event (kWh)	**-1.65**	**-0.48**	**0.72**	**-0.98**	**-0.04**	**0.22**	**-0.18**	**-0.22**

Table 60 Event Impacts (% kW)

Event Hour	Winter 2016/2017							
	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8
	5:00 p.m. – 8:00 p.m.	4:00 p.m. – 7:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	7:00 a.m. – 10:00 a.m.	7:00 a.m. – 10:00 a.m.
Pre-Hour 1	23%	25%	48%	31%	23%	40%	49%	33%
Event Hour 1	**-32%**	**-32%**	**-34%**	**-41%**	**-30%**	**-36%**	**-44%**	**-47%**
Event Hour 2	**-27%**	**-21%**	**-17%**	**-30%**	**-19%**	**-22%**	**-29%**	**-34%**
Event Hour 3	**-22%**	**-18%**	**-11%**	**-20%**	**-13%**	**-15%**	**-28%**	**-20%**
Post Hour 1	19%	28%	34%	22%	26%	25%	34%	36%
Post Hour 2	-4%	6%	4%	3%	10%	19%	16%	14%
Post Hour 3	1%	1%	5%	6%	8%	5%	0%	8%
Post Hour 4	-2%	2%	1%	10%	0%	1%	9%	16%
Event avg. demand impact (%)	**-27%**	**-24%**	**-21%**	**-30%**	**-21%**	**-24%**	**-34%**	**-33%**
Event max hourly demand impact (%)	**-32%**	**-32%**	**-34%**	**-41%**	**-30%**	**-36%**	**-44%**	**-47%**
Event min hourly demand impact (%)	**-22%**	**-18%**	**-11%**	**-20%**	**-13%**	**-15%**	**-28%**	**-20%**
Avg. energy impact per event (%)	**-44%**	**-8%**	**31%**	**-18%**	**5%**	**16%**	**8%**	**7%**

Table 61 Program-Level Event Impacts (kW)

Event Hour	Winter 2016/2017							
	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8
	5:00 p.m. – 8:00 p.m.	4:00 p.m. – 7:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	7:00 a.m. – 10:00 a.m.	7:00 a.m. – 10:00 a.m.
Pre-Hour 1	113.84	123.52	238.44	155.28	114.72	201.71	248.68	172.90
Event Hour 1	**-190.69**	**-191.98**	**-206.40**	**-247.64**	**-187.16**	**-222.73**	**-272.07**	**-298.20**
Event Hour 2	**-157.31**	**-124.39**	**-104.65**	**-180.85**	**-114.43**	**-134.95**	**-179.26**	**-210.64**
Event Hour 3	**-140.72**	**-111.31**	**-68.03**	**-128.70**	**-85.59**	**-101.12**	**-181.30**	**-132.09**
Post Hour 1	114.85	171.43	215.28	135.05	166.95	158.00	219.31	233.90
Post Hour 2	-22.65	34.68	21.84	20.19	57.80	112.15	94.28	84.63
Post Hour 3	6.35	6.80	25.79	30.81	38.48	23.58	2.23	39.60
Post Hour 4	-9.61	7.86	4.60	42.16	1.76	2.69	36.53	69.06
Event avg. demand impact (kW)	**-162.91**	**-142.56**	**-126.36**	**-185.73**	**-129.06**	**-152.93**	**-210.88**	**-213.64**
Event max hourly demand impact (kW)	**-190.69**	**-191.98**	**-206.40**	**-247.64**	**-187.16**	**-222.73**	**-272.07**	**-298.20**
Event min hourly demand impact (kW)	**-140.72**	**-111.31**	**-68.03**	**-128.70**	**-85.59**	**-101.12**	**-179.26**	**-132.09**
Avg. energy impact per event (kWh)	**-285.95**	**-83.38**	**126.87**	**-173.70**	**-7.45**	**39.33**	**-31.60**	**-40.83**

Summer 2017

Table 62 Customer-Level Event Impacts (kW)

Event Hour	Summer 2017						
	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7
	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	4:00 p.m. – 7:00 p.m.	4:00 p.m. – 7:00 p.m.
Pre-Hour 1	0.42	0.48	0.42	0.45	0.52	0.62	0.56
Event Hour 1	**-1.15**	**-1.20**	**-1.52**	**-1.42**	**-1.44**	**-1.10**	**-1.24**
Event Hour 2	**-0.91**	**-1.08**	**-0.89**	**-0.91**	**-1.11**	**-0.92**	**-0.99**
Event Hour 3	**-0.75**	**-0.78**	**-0.69**	**-0.57**	**-0.86**	**-0.91**	**-0.80**
Post Hour 1	0.50	0.35	0.48	0.45	0.43	0.37	0.48
Post Hour 2	0.37	0.21	0.27	0.14	0.12	0.24	0.41
Post Hour 3	0.29	0.18	0.23	0.08	0.07	0.12	0.29
Post Hour 4	0.16	0.09	0.21	0.24	0.10	0.01	0.20
Post Hour 5	0.13	0.15	0.12	0.12	0.07	0.07	0.11
Post Hour 6	0.10	0.06	0.12	0.18	0.08	0.10	0.12
Event avg. demand impact (kW)	**-0.94**	**-1.02**	**-1.03**	**-0.97**	**-1.13**	**-0.98**	**-1.01**
Event max hourly demand impact (kW)	**-1.15**	**-1.20**	**-1.52**	**-1.42**	**-1.44**	**-1.10**	**-1.24**
Event min hourly demand impact (kW)	**-0.75**	**-0.78**	**-0.69**	**-0.57**	**-0.86**	**-0.91**	**-0.80**
Avg. energy impact per event (kWh)	**-1.08**	**-1.75**	**-1.50**	**-1.54**	**-2.16**	**-1.57**	**-1.09**

Table 63 Event Impacts (% kW)

Event Hour	Summer 2017						
	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7
	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	4:00 p.m. – 7:00 p.m.	4:00 p.m. – 7:00 p.m.
Pre-Hour 1	18%	21%	18%	20%	23%	27%	24%
Event Hour 1	**-44%**	**-46%**	**-59%**	**-55%**	**-55%**	**-42%**	**-48%**
Event Hour 2	**-33%**	**-39%**	**-32%**	**-33%**	**-40%**	**-33%**	**-36%**
Event Hour 3	**-28%**	**-29%**	**-25%**	**-21%**	**-31%**	**-33%**	**-29%**
Post Hour 1	19%	14%	18%	17%	16%	14%	18%
Post Hour 2	16%	9%	11%	6%	5%	10%	17%
Post Hour 3	15%	9%	12%	4%	4%	6%	15%
Post Hour 4	10%	6%	14%	16%	7%	1%	13%
Post Hour 5	11%	12%	10%	10%	6%	6%	9%
Post Hour 6	11%	6%	13%	19%	8%	11%	12%
Event avg. demand impact (%)	**-35%**	**-38%**	**-39%**	**-36%**	**-42%**	**-36%**	**-38%**
Event max hourly demand impact (%)	**-44%**	**-46%**	**-59%**	**-55%**	**-55%**	**-42%**	**-48%**
Event min hourly demand impact (%)	**-28%**	**-29%**	**-25%**	**-21%**	**-31%**	**-33%**	**-29%**
Avg. energy impact per event (%)	**-27%**	**-56%**	**-43%**	**-46%**	**-73%**	**-51%**	**-25%**

Table 64 Program-level Event Impacts (kW)

Event Hour	Summer 2017						
	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7
	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	5:00 p.m. – 8:00 p.m.	4:00 p.m. – 7:00 p.m.	4:00 p.m. – 7:00 p.m.
Pre-Hour 1	1,291.48	1,479.85	1,295.47	1,386.23	1,597.12	1,912.68	1,727.05
Event Hour 1	**-3,565.14**	**-3,722.46**	**-4,713.16**	**-4,376.34**	**-4,436.54**	**-3,389.61**	**-3,844.04**
Event Hour 2	**-2,805.37**	**-3,335.06**	**-2,737.43**	**-2,809.51**	**-3,435.22**	**-2,854.44**	**-3,070.45**
Event Hour 3	**-2,317.93**	**-2,399.71**	**-2,124.68**	**-1,768.07**	**-2,643.50**	**-2,811.95**	**-2,467.60**
Post Hour 1	1,540.42	1,097.28	1,472.57	1,389.72	1,318.76	1,144.51	1,486.43
Post Hour 2	1,145.38	642.07	819.73	434.81	370.22	729.17	1,273.80
Post Hour 3	888.66	542.89	705.59	255.93	226.04	376.30	909.59
Post Hour 4	487.32	271.03	656.13	742.44	320.19	45.50	616.75
Post Hour 5	396.28	456.58	371.80	367.04	229.63	210.18	352.49
Post Hour 6	322.52	171.68	385.02	558.27	247.75	321.59	361.73
Event avg. demand impact (kW)	**-2,896.15**	**-3,152.41**	**-3,191.76**	**-2,984.64**	**-3,505.09**	**-3,018.67**	**-3,127.36**
Event max hourly demand impact (kW)	**-3,565.14**	**-3,722.46**	**-4,713.16**	**-4,376.34**	**-4,436.54**	**-3,389.61**	**-3,844.04**
Event min hourly demand impact (kW)	**-2,317.93**	**-2,399.71**	**-2,124.68**	**-1,768.07**	**-2,643.50**	**-2,811.95**	**-2,467.60**
Avg. energy impact per event (kWh)	**-3,335.18**	**-5,424.11**	**-4,625.78**	**-4,744.80**	**-6,682.93**	**-4,847.84**	**-3,368.47**

Data Collection

Cadmus collected the following data

- For each RHR customer:
  - AMI 15- or 60-minute interval consumption (pre- and post-treatment)
  - Enrollment date
  - Assignment to test or control group
- Event dates and hours • Hourly weather data for PGE service area:

  https://www.ncdc.noaa.gov/qclcd/QCLCD?prior=N

Appendix E - Cadmus Evaluation of PGE's Rush Hour Rewards 2017-201

EVALUATION REPORT

April 24, 2019

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Executive Summary

As presented in its *2016 Integrated Resource Plan*,[135] PGE expects to face a shortfall in generating capacity in the next several years because of the planned closure of its Boardman facility in 2020 and the expiration of wholesale power contracts. At the same time, PGE plans to increase its production of electricity from intermittent renewable energy resources to comply with the requirements of Oregon Senate Bill 1547. In consideration of these developments, PGE's *2016 Integrated Resource Plan* calls for the use of DR to help manage system peak loads and integrate renewable energy resources. The plan sets a goal of adding DR capacity of 77 MW in winter and 69 MW in summer.

PGE designed the Smart Thermostat Demand Response program to help it manage residential summer and winter peak energy demand. Through the program, PGE can control cooling and heating loads of participating customers through set-point adjustments to their smart thermostats. Customers who own a smart thermostat can participate in the program through the bring-your-own thermostat (BYOT) component, while customers who do not already have a smart thermostat can participate through a Direct Install component.

In 2015, PGE launched Rush Hour Rewards, a BYOT smart thermostat demand response pilot program implemented by Nest, to test peak demand savings and customer acceptance of DR and to increase engagement with customers who already owned smart thermostats. In 2017, PGE expanded its BYOT offerings to include Ecobee and Honeywell smart thermostats through its Connected Savings program, which is delivered by Whisker Labs. As of November 2018, the BYOT Rush Hour Rewards and Connected Savings programs had enrolled approximately 10,881 customers and tested load control events over eight seasons.

This evaluation focuses on the Rush Hour Rewards program. PGE initiated eight load control events in winter 2017/2018 and eight events during summer 2018. In general, PGE called events on extreme weather days when residential electricity demand for air conditioning or space heating was higher than normal. Through meter data analysis, interviews with PGE and Nest program managers, and on-line customer surveys, the evaluation assessed the load impacts, program implementation, and customer experience.

[135] Portland General Electric. November 15, 2016. *2016 Integrated Resource Plan*. https://www.portlandgeneral.com/our-company/energy-strategy/resource-planning/integrated-resource-planning/2016-irp

Conclusions and Recommendations

Based on the evaluation findings, Cadmus came to several conclusions and recommendations, described below.

Load Impacts

Rush Hour Rewards reduced peak electricity demand from residential air conditioning and space heating.

The program achieved average demand savings of 0.93 kW and 0.62 kW per participant for summer and winter, respectively. These savings represented 32% of summer event hour demand and 23% of winter event hour demand. Evaluated savings surpassed the PGE planning value for BYOT smart thermostat DR of 0.8 kW per participant, though winter savings were less than the 1.0 kW planning estimate.

Demand savings significantly degraded across event hours.

During summer events, savings decreased by approximately 0.2 kW and 0.3 kW (22-27%) between the first and second event hours; three-hour events saw a further degradation of 0.4 kW (39%) between the first and last event hour. Winter savings followed a similar trend, showing average degradation of 24% for morning events and 8% for afternoon events between the first and second hour, and 51% and 37% between the first and third hours, respectively. Because of degradation of demand savings over the hours of events, the average savings understates the available capacity during the first event hour and overstates available capacity during the last event hour. By working with its DR service providers to implement Intelligent Demand Response (IDR) strategies, PGE may be able to avoid savings degradation and better meet its capacity needs.

Rush Hour Rewards load control events increased customer loads before and after events but did not result in a negative conservation effect.

In summer, loads increased by about 14% before events because of pre-cooling and by about 13% after events because of snapback. In winter, loads increased by 20-30% before events and about 20%-30% after events. However, the pre-conditioning and snapback did not lead to an increase in energy consumption on event days.

Rush Hour Rewards moved PGE closer to reaching its goal of 25 MW of DR capacity from residential smart thermostats by 2021.

In summer 2018, Rush Hour Rewards had 8,471 participants and realized averaged demand savings of 6.9 MW per event hour. In winter 2017, Rush Hour Rewards had 785 participants and realized average demand savings of 0.32 MW per event hour. In combination with Connected Savings, PGE's residential smart thermostat program yielded an average demand savings of 7.6 MW per event hour for the summer 2018 event season. PGE's DR capacity from Rush Hour Rewards, which includes potential savings from control group customers, is 7.7 MW in summer and 0.6 MW in winter on average.

In summer, PGE can expect the same demand savings per customer from Connected Savings and Rush Hour Rewards participants.

There were no statistically significant differences in savings between thermostat brands (Ecobee, Honeywell, and Nest). In summer 2018, the average savings of 0.93 kW for Rush Hour Rewards customers was slightly higher than but statistically indistinguishable from the average savings for Connected Savings participants (0.84 kW).

Load Impact Recommendations

- PGE should continue recruiting customers for BYOT Rush Hour Rewards, provided it represents a cost-effective resource.
- PGE should continue to test IDR control algorithms to maintain a constant level of demand savings and to avoid degradation of savings across event hours.
- PGE should coordinate internally to ensure well-defined objectives, design, and key metrics of event dispatch that align goals of program delivery and capacity planning teams.

Customer Experience

Rush Hour Rewards delivered a positive customer experience and achieved high customer satisfaction.

Most test group respondents were satisfied with the program (91%). In the open-end comments, test group respondents most often mentioned that the program is helpful to the customer (25%), works well (23%), and saves money (21%). As suggestions for program improvement, they mentioned increasing the incentive amount (30%), sending earlier pre-event notifications (14%), and providing a different incentive structure (13%).

The load control events did not adversely affect comfort for most customers.

Sixty-two percent of test group respondents said they noticed the summer events. Most noticed the events because of the event message display on the Nest thermostat (72%) and the event notification from the smartphone app (65%) rather than because of a change in temperature (36%). Moreover, before the events, 95% of respondents said their home's interior temperature was comfortable. During the events, 82% said they were comfortable, a significant decrease compared to the comfort level before the events; nevertheless, a majority reported feeling comfortable during the events.

Sending a pre-event notification makes the events significantly more noticeable for customers.

On average, test group respondents perceived 6.3 events out of the eight events called during the summer. Respondents likely perceived close to the actual number of events called because Nest sent pre-event notifications to customers via the Nest thermostat screen and app. This hypothesis is supported by the fact that Ecobee and Honeywell did not send out pre-event notifications to its test group customers for Connected Savings, and these respondents perceived 4.8 events, significantly fewer than did Rush

Hour Rewards' respondents. Furthermore, Nest allows Rush Hour Rewards participants to adjust their notification settings and opt out of receiving any event notifications. Most Rush Hour Rewards respondents (85%) said they were notified of the events prior to their occurrence, suggesting that either (1) most participants preferred to receive pre-event notifications, (2) many were not aware they could change their event notification settings, or (3) participants tend to not opt out the default option. While notifications increase event awareness, it is ambiguous whether awareness enhances or detracts from customer welfare and satisfaction.

A wider-range temperature setback instead of a one-size-fits-all temperature setback may make for a more comfortable event experience.

Rush Hour Rewards and Connected Savings achieved similar program satisfaction results but differed in perceived comfort during events. Rush Hour Rewards' test group respondents were significantly more comfortable during events (82%) than Connected Savings' test group respondents (74%). This difference may be explained by the temperature setback strategy used by Nest versus Whisker Labs. Nest deployed a one- to five-degree setback specifically to each customer's comfort preferences and home thermal properties. Whisker Labs calibrated a three-degree one-size-fits-all setback that did not accommodate customer preferences.

PGE incurs a small decrement to customer satisfaction when smart thermostats are controlled.

Most test and control group respondents were satisfied with the program, but a significantly higher proportion of control group respondents (96%) than test group respondents (91%) were satisfied. Most test and control group respondents were also satisfied with the $25 incentive, but significantly more control group respondents were satisfied (96%) than test group respondents (87%). These differences between groups can be explained by the fact that control group participants did not experience any events (that is, their thermostats were not controlled), yet they still received the $25 incentive. There was no decrement to customer satisfaction with PGE; the same proportion of test group (97%) and control group (97%) respondents were satisfied with PGE.

Customer Experience Recommendation

- PGE should work with Nest to send Rush Hour Rewards participants reminders about the ability to adjust the event notification settings. This recommendation speaks to the notion that some customers may benefit from event awareness while others may not. Reminding customers that they can customize their event notifications may further enhance customer satisfaction. PGE can send out the reminder via email, and Nest can send the reminder through the smartphone app. The program has been running for three years, and a reminder may be helpful in getting long-time participants to review their notification settings while introducing newer participants to the notifications feature.

Implementation

The program's maturity has minimized implementation challenges.

Now in its third year, Rush Hour Rewards did not encounter any major implementation challenges. Program marketing, recruitment, and event management worked well. The only challenge, though minor, that PGE encountered was about using Nest's trademark for online marketing. PGE developed and tested an online awareness campaign for the program using online ads, Google key word searches, and social media. PGE found that "Nest" was the best word to use for the online campaign, but it was not permitted to use "Nest" as a key word because of trademark legalities. As a result, PGE had to place its online campaign idea on hold. This minor online marketing challenge did not appear to impede program enrollment.

Nest's strong market presence and more frequent marketing likely enabled Rush Hour Rewards to increase enrollments.

By the end of summer 2018, 8,471 customers had enrolled in Rush Hour Rewards, an average of 3,068 customers per year. The high enrollment rate for Rush Hour Rewards may be attributed to Nest's large share of the smart thermostat market. Another possible reason is Nest's frequent marketing. Nest sends program promotions to eligible customers on a seasonal basis and employs search engine marketing and targeted social media ads to drive the sales of its thermostats. In contrast, Connected Savings only enrolled 1,662 customers in its first year. Ecobee and Honeywell, manufacturers of the thermostats used for Connected Savings, send marketing once a year.

Targeted marketing was possible for Rush Hour Rewards because the smart thermostat manufacturer and the DR service provider were the same party.

Nest is both the smart thermostat manufacturer and the DR service provider for Rush Hour Rewards. Therefore, Nest can collect run-time data from its own thermostats to determine the customer's HVAC system type and use these data to find eligible customers and conduct targeted marketing. This was a major advantage over Whisker Labs, the DR service provider for Connected Savings, which could not collect such data from Ecobee and Honeywell thermostats until the customer enrolled in the program.

Implementation Recommendation

- PGE should consider having Nest take the lead on marketing the program to customers, using its large market reach and frequent, targeted marketing approach. Having Nest take the lead on Rush Hour Rewards' marketing would allow PGE to take the lead on marketing Connected Savings.

Introduction

In the next several years, PGE will face a shortfall in generating capacity from the planned closure of its Boardman facility in 2020 and the expiration of wholesale power contracts. At the same time, PGE plans to increase its production of electricity from intermittent renewable energy resources to comply with the requirements of Oregon Senate Bill 1547. In consideration of these developments, PGE's *2016 Integrated Resource Plan* calls for the use of dispatchable resources including DR to help manage system peak loads and integrate renewable energy resources. The plan sets a goal of adding DR capacity of 77 MW in winter and 69 MW in summer.

Residential customers participating in DR programs will provide an important source of PGE's future DR capacity. These programs use price signals, load control, behavior-based treatments, or combinations of these to encourage customers to reduce demand during periods when it is costly for the utility to supply or distribute electricity.

DR represents a fundamental shift in a utility's relationship with its customers. Customers participating in DR programs do not simply consume utility-supplied electricity: they also provide peak capacity to utilities. To take full advantage of this evolving "prosumer" role, PGE will need to offer its customers new retail electricity rates or other incentives as well as compelling education, marketing, and program experience to encourage customers to participate.

In 2015, PGE launched Rush Hour Rewards, a BYOT smart thermostat DR pilot program implemented by Nest, to test peak demand savings and customer acceptance of DR and to increase engagement with customers who already owned smart thermostats. PGE seeks to understand aspects of program delivery, customer acceptance and satisfaction, and load impacts and to lay the groundwork for a future where most of its residential customers participate in DR programs.

For this evaluation, Cadmus assessed the design and delivery, load impacts, and customer experiences of Rush Hour Rewards across winter and summer event seasons. PGE tested the DR treatments as randomized controlled trials (RCTs), providing highly credible evidence about the program treatment effects. This evaluation gives PGE feedback about the program's performance and presents insights that can be used to optimize PGE's future DR program offerings.

Program Description

PGE designed the Smart Thermostat Demand Response program to help manage residential summer and winter loads during hours of peak electricity demand. Through the program, PGE can enable load control of cooling and heating through participating customers' smart thermostats.

Bring-Your-Own Thermostat

The Smart Thermostat Demand Response program has two approaches to enroll customers: BYOT for customers who already own a smart thermostat and Direct Install for customers who do not own one (Figure 58). PGE launched the program in 2015, first as BYOT, recruiting customers who already owned a Nest thermostat to enroll in Rush Hour Rewards, the name that the DR service provider Nest uses to market its program. PGE launched Rush Hour Rewards first because of Nest's dominant share of the smart thermostat market. In 2017, PGE extended the program and began recruiting customers with Ecobee, Honeywell Lyric, and other Honeywell Wi-Fi-enabled thermostats to enroll in Connected Savings, which is marketed by the DR service provider Whisker Labs. Connected Savings aimed to increase PGE's DR capacity further by leveraging the growing number of customers with a non-Nest thermostat.

Rush Hour Rewards

Figure 58 summarizes the BYOT Rush Hour Rewards Smart Thermostat Demand Response program design (in yellow) and shows how it differs from Connected Savings and Direct Install.

Figure 59 BYOT Rush Hour Rewards Smart Thermostat Demand Response Program Design

Bring-Your-Own Thermostat		Direct Install
Launched in Fall 2015	Launched in Fall 2017	Launched in Summer 2018
Customer already owns or purchases/installs their own… Nest	Customer already owns or purchases/installs their own… Ecobee, Honeywell Lyric, Honeywell other	Customer receives free or discounted… Nest, Ecobee …and free installation
Customer self-enrolls in **Rush Hour Rewards** and receives $25 for enrolling	Customer self-enrolls in **Connected Savings** and receives $25 for enrolling	Installation technician enrolls the customer in **Rush Hour Rewards or Connected Savings**
Customer receives $25 incentive per demand response season for event participation	Customer receives $25 incentive per demand response season for event participation	No incentives for event participation; customer agrees to a five-year commitment

Rush Hour Rewards operates similarly to Connected Savings but differs from Direct Install in which customers are eligible to participate and the incentives participants receive.

Goals and Objectives

PGE established several goals and objectives for the Smart Thermostat Demand Response program:

- Implement the program over winter and summer seasons by calling six to 10 peak demand events per season
- Enroll 24,000 customers by 2019
- Obtain customer participation in at least 50% of event hours per season
- Achieve positive customer experiences and high customer satisfaction
- Realize a demand reduction goal of 25 MW by 2021

Implementation

This section describes the implementation of BYOT Rush Hour Rewards.

Marketing and Recruitment

PGE and Nest began marketing Rush Hour Rewards to customers in fall 2015 and continue to work together to market it. The marketing channels and strategies differed based on the target audience:

- **Customers who already have a Nest smart thermostat.** Nest sent out Rush Hour Rewards promotions via email and app notifications several times a year to PGE customers who purchased or installed a Nest thermostat. Nest worked with PGE to cobrand the program promotions. PGE also helped recruit more participants by promoting Rush Hour Rewards on its website and sending out promotion emails and direct mail.
- **Customers who have yet to purchase a Nest smart thermostat.** Nest employed search engine marketing and targeted social media ads to drive the sales of its thermostats. PGE also promoted Nest on its website and sent out sales promotions via email. These sales promotions described Rush Hour Rewards and incentive offers, and marketing was ramped up during holiday periods such as Black Friday and Father's Day. PGE also collaborated with the Energy Trust of Oregon and promoted its $50 discount coupon toward the purchase of a Nest smart thermostat. PGE also marketed the sales of Nest and Rush Hour Rewards promotions on its social media channels and paid online ads.

To encourage customers to enroll in Rush Hours Rewards, PGE offered a one-time $25 enrollment incentive. Customers received a $25 check in the mail after PGE verified the customer's program eligibility.

Enrollment Process

The promotion emails, direct mail, and web content directed customers to their Nest online accounts to enroll in Rush Hour Rewards. The Rush Hour Rewards page provided program details. To enroll, customers logged in to their Nest account, entered their utility account information, and answered questions about their HVAC system to confirm program eligibility. Nest gave PGE the list of enrollees. PGE reviewed the list and approved the enrollees, then mailed the $25 enrollment incentive check a few weeks later.

Program Eligibility Requirements

To be eligible for Rush Hour Rewards, customers had to meet several 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 Nest smart thermostat installed that controls the HVAC system in the home
- Have a Wi-Fi network in the home

Participant Enrollments

Table 65 shows the participant enrollment counts for winter 2017/2018 and summer 2018, overall and by HVAC system. These participant counts reflect the approximate total enrollees as of the end of each event season (February 2018 and September 2018, respectively).

Table 65 Rush Hour Rewards Participant Enrollments

Category	Winter 2017/2018		Summer 2018	
	Count	Percentage of Total	Count	Percentage of Total
Central AC	N/A	0%	7,544	89%
Heat Pump	774	99%	927	11%
Electric Furnace	11	1%	N/A	0%
Overall	**785**	**100%**	**8,471**	**100%**

Event Management

PGE contracted with Nest to provide the DRMS and load data aggregation services. Nest set up an online management platform, on which PGE could review the enrollment counts, check load forecasts, schedule events, and download data. When PGE was ready to call an event, it used the online management platform to schedule the event one day ahead. Once Nest received the event dispatch, it sent out a notification to participants to customers on the day before the event and Wi-Fi signals to adjust the smart thermostat settings on the event day.

The OPUC requires PGE to call six to 10 events per season. Events lasted two to three consecutive hours and occurred on weekday (non-holiday) afternoons or mornings, when electricity demand for space conditioning was greatest (that is, on cold days during winter and hot days during summer). The winter 2017/2018 event season ran from December 1, 2017, through February 28, 2018. The summer 2018 event season ran from June 1, 2018, through September 30, 2018. As shown in Table 66, PGE called eight events in winter 2017/2018 and eight events in summer 2018.

Table 66 Rush Hour Rewards Load Control Events

Season	Event	Date	Avg. Outdoor Temp.[136]	Start Time	Duration (hours)
Winter 2017/2018	1	1/3/2018	39°F	5:00 p.m.	3
	2	1/9/2018	46°F	4:00 p.m.	3
	3	1/18/2018	43°F	5:00 p.m.	3
	4	1/25/2018	43°F	5:00 p.m.	3
	5	2/1/2018	44°F	7:00 a.m.	3
	6	2/9/2018	44°F	7:00 a.m.	3
	7 ❄	2/20/2018	35°F	5:00 p.m.	3
	8	2/23/2018	28°F	7:00 a.m.	3
Summer 2018	1	7/12/2018	93°F	4:00 p.m.	3
	2	7/13/2018	88°F	4:00 p.m.	3
	3	7/23/2018	90°F	4:00 p.m.	3
	4	7/26/2018	92°F	4:00 p.m.	3
	5	7/31/2018	82°F	5:00 p.m.	2
	6	8/8/2018	90°F	5:00 p.m.	2
	7 🔥	8/14/2018	88°F	5:00 p.m.	2
	8 🔥	8/22/2018	84°F	4:00 p.m. (IDR icon)	3

❄ = snow day

🔥 = fire day

(IDR icon) = IDR

During the August 22, 2018 event, PGE tested IDR for the first time for Rush Hour Rewards. IDR customizes the thermostat setback for individual customers based on historical heating or cooling demand and the thermal properties of the home to achieve more consistent and lasting load reductions across event hours. IDR also includes regulating the dispatch of load control signals to avoid big changes in aggregate

[136] Outdoor temperature is the average temperature during event hours.

loads due to simultaneous pre-conditioning before the event, the event initiation, or snapback after an event.

Test group participants received a pre-event notification from Nest on the thermostat screen and smartphone app. During the event, the thermostat and smartphone app displayed information that an event was in progress. Participants could adjust their notification settings and opt out of receiving any of notifications.

About an hour before the event, the thermostat pre-conditioned the home (by raising or lowering the interior temperature) to increase thermal comfort and to maximize the size and duration of the event demand savings. During the events, Nest employed a one- to five-degree setback specifically to each customer's comfort preferences and home thermal properties. Table 67 shows the event details for Rush Hour Rewards.

Table 67 Event Orchestration Details

Brand	Pre-Event Notification	Event In-Progress Notification	Pre-Conditioning before Event	Temperature Setback during Event
Nest	Displayed on thermostat screen and app	Displayed on thermostat screen and app	2°F pre-heating in winter; 2°F pre-cooling in summer	1°F to 5°F lower in winter; 1°F to 5°F higher in summer

Test group participants could override the load control during events by adjusting the thermostat settings or hitting the event cancel button. If customers participated in at least 50% of event hours during a season, they received a $25 incentive check. Control group participants also received a $25 incentive check per event season even though their thermostats were not controlled.

Only customers with a heat pump could participate in both winter and summer seasons and could earn up to $50 in incentives per year. Customers with an electric furnace (winter) or central air conditioner (summer) participate in only one season and could earn $25 in incentives per year. PGE mailed out incentive checks to participants six to eight weeks after the end of the season.

Evaluation Methodology

This section describes Cadmus' methodology for evaluating Rush Hour Rewards.

Evaluation Objectives

PGE specified five evaluation objectives for Rush Hour Rewards:

1. Estimate the average kilowatt impact per 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 load impacts, customer comfort, and satisfaction between Rush Hour Rewards Nest thermostat impacts and to Connected Savings thermostat brands

5. Identify opportunities for improving program marketing, customer recruitment, program performance, cost-effectiveness, and customer satisfaction

Evaluation Approach

Table 68 lists the Rush Hour Rewards evaluation activities and how they address the evaluation objectives. Each activity is described in greater detail in the subsequent sections.

Table 68 Rush Hour Rewards Evaluation Activities

Activity	Description	Corresponding Evaluation Objective(s)	Outcome
Research Design	Pre-season random assignment of participants into test or control group	1, 2, 3, 4	Accurate and precise estimates of impacts
Data Collection and Preparation	Collect and prepare analysis of individual-customer (AMI meter interval consumption data	1, 2, 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 program staff to understand program implementation processes, successes, and challenges	5	Thorough understanding and documentation of the program design and implementation
Logic Model	A graphic that outlines the relationships between program activities, outputs, and expected outcomes	5	Documentation of program activities, associated outputs, and short-term and intermediate outcomes
Customer Surveys	Recruitment, event, and seasonal experience surveys with participants	3, 4, 5	Findings on customer engagement, event awareness, comfort, and satisfaction

The Rush Hour Rewards evaluation presented in this report covers winter 2017/2018 and summer 2018 event seasons. PGE also asked Cadmus to evaluate Connected Savings for winter 2017/2018 and summer 2018, which is presented in a separate report. Note that this Rush Hour Rewards evaluation report will refer to results obtained from the Connected Savings evaluation for comparison purposes.

Evaluation Design

To estimate the impacts of thermostat controls, Cadmus worked with PGE to implement Rush Hour Rewards as a RCT, which involved randomly assigning program participants (residential customers with smart thermostats who met eligibility requirements) to a test group or control group. Test group customers experienced load control events, while control group customers did not. Customers were not informed about which group they had been assigned. Savings were estimated by comparing the test and control group demand during event hours. As the gold standard in program evaluation, this RCT is expected to produce unbiased estimates of the program savings.

Typically, at the beginning of each season, Cadmus randomly reassigned all program participants to either the test group or the control group and then used pretest monthly consumption data and post-test hourly consumption data on non-event days to verify that the test and control groups were balanced. Customers who enrolled after the initial assignments were randomly assigned on a rolling basis to the test or control group.[137]

Table 69 shows winter 2017/2018 and summer 2018 random assignments of customers overall, by brand, and by HVAC system.

Table 69 Rush Hour Rewards Participant Random Assignments

System	Winter 2017/2018		Summer 2018	
	Test	Control	Test	Control
Central AC	N/A	N/A	6,945	599
Heat Pump	522	252	632	295
Electric Furnace	7	4	N/A	N/A
Overall	**529**	**256**	**7,577**	**894**

Data Collection and Preparation

Cadmus collected and prepared several types of data for analysis:

- ***Participant enrollment data***, provided by PGE, tracked enrollment for test group and control group customers. These data included participant name, contact information (such as address), a unique customer 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-minute and 60-minute intervals, measured using AMI meters. For historical usage periods (prior to enrollment), only hourly data were available.
- ***Local weather data,*** including hourly average temperatures from December 2017 through September 2018 for five NOAA weather stations. The team used zip codes to identify weather stations nearest to each participant's home and merged the weather data with each participant's billing data.
- ***Event data,*** including dates and times of all load control events, by season, were provided by PGE.

The AMI meter data recorded a customer's electricity consumption at 15- or 60-minute intervals and covered every month in which an event occurred. Cadmus aggregated all 15-minute interval consumption data to the customer-hour level and performed standard data-cleaning steps (described in *Appendix A*) to address duplicate observations, extreme 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.

[137] Due to contractual delays, PGE performed the random assignment for the summer 2018 season. Cadmus tested the balance of test and control participant load profiles after the event season completion and found these groups to be sufficiently equivalent (see *Appendix C* for more detail).

Cadmus used the enrollment and program participation data to identify customers in the test and control groups, to develop survey sample frames, and to calculate test opt-out rates. Enrollment and participation data provided several key fields for each customer, including:

- Assignment to test or control group
- Dates for participant enrollment and un-enrollment date, when applicable
- Customer ID and address
- Service point active status (confirming meter activity)

Appendix A describes Cadmus' solutions to these issues. Robustness checks of the Rush Hour Rewards test savings estimates indicate that the estimates were not sensitive to the specific solutions Cadmus developed.

Analysis Samples

In cleaning and preparing the AMI meter data, Cadmus encountered several issues that had to be addressed before the data could be analyzed (see *Appendix A* for more detail on sample attrition):

- Some AMI datasets were recorded on Coordinated Universal Time instead of Pacific Time
- AMI data were not provided for all customers
- The Connected Savings winter 2017/2018 test groups were not balanced

Table 70 shows the initial and final analysis samples for the winter 2017/2018 and summer 2018 seasons. The initial analysis sample included all customers who were randomly assigned to a test or control group and whose billing account remained active at the beginning of each Rush Hour Rewards season. Customers who opted out of the program, moved, or discontinued electricity service before the season began were excluded from samples. The final analysis sample includes customers used in the impact estimation and excludes a small number of customers who had two thermostats assigned to different groups or who were missing AMI data.

Table 70 Rush Hour Rewards Program Final Analysis Sample Sizes

Sample	Winter 2017/2018	Summer 2018
Initial Analysis Sample (N)	785	8,471
Final Analysis Sample (n)	720	8,131
Analysis Sample Percentage	92%	96%

Cadmus verified that there were not statistically significant differences in consumption between test and control group customers in the final analysis sample on non-event days. *Appendix C* provides detailed balance test results.

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 test 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 eight hours after each event. In addition to assignment to test or control group, the panel regression controlled for the impacts of hour of the day, the day of the week, weather, and differences between customers in their average demand.

Cadmus estimated the models by OLS and clustered the standard errors on customers to account for correlations over time in customer demand. Cadmus estimated alternative model specifications to test the estimates' robustness to specification changes and found that the results were very robust. *Appendix B* provides a more detailed description of the savings estimation.

Staff Interviews

Cadmus conducted two interviews with PGE program staff to document program history, how the program operates, implementation challenges, and successes or lessons learned to date. The PGE staff members—the program manager, the program marketer, and the residential market manager—each gave a unique perspective of program process and objectives. Cadmus used information obtained from the interviews to design the logic model and customer surveys.

Logic Model

A logic model defines the program theory and outlines how a program should be expected to succeed, given its design. A program theory articulates and documents a program's primary objectives and its core assumptions, while the logic model graphically outlines the relationships between program activities, outputs, and expected outcomes. The logic model serves as a useful tool for program staff, implementers, and evaluators to determine whether a program is operating according to its stated goals, and whether the program's activities/outputs are producing the outcomes to support its theory. Cadmus developed a logic model for Rush Hours Rewards based using program materials and information obtained from the staff interviews. After developing the logic model, Cadmus reviewed it against the evaluation findings to determine whether Rush Hour Rewards operated as intended.

Customer Surveys

Cadmus designed and administered two online customer surveys:

- Event Survey –Summer 2018 (fielded in August 2018)

- Experience Survey – Summer 2018 (fielded in November 2018)[138]

Survey Design

To provide PGE with timely customer feedback, Cadmus administered the **event surveys** with test group participants during summer 2018, specifically, 24 hours after the August 22 event. The event surveys asked test group participants about their event awareness, thermal comfort, reasons for overriding the load control, and satisfaction.

Cadmus administered the **experience surveys** to test and control participants a few days after they received their incentive check. The experience surveys asked test group participants about their event awareness, thermal comfort, reasons for overriding the load control, and satisfaction. Control group customers were only asked questions about satisfaction.

Each survey took respondents less than seven minutes to complete. Respondents did not receive an incentive or reward for completing a survey.

Survey Sampling and Response Rates

Cadmus contacted a random sample of participants with an active PGE account who were enrolled in the program at the time of survey fielding. Table 71 and Table 72 show the number of participants contacted and the response rate for the two surveys. The summer event survey achieved a high response rate of 30%, while the summer experience survey had a 17% response rate. Response rates did not differ by HVAC system or by assignment.

Table 71 Customer Survey Samples and Response Rates: Event Survey – Summer 2018

	Original Sample[139]	Adjusted Sample (Successfully Emailed)	Number of Completes	Response Rate
By HVAC System (Test Group Only)				
Central Air Conditioner	400	395	117	30%
Heat Pump	400	398	121	30%
Overall	**800**	**793**	**238**	**30%**

[138] Cadmus did not administer an experience survey for winter 2017/2018 because evaluation activities did not commence until August 2018. Surveying customers about past winter events in the middle of summer would have confused them, and their recollection of the winter event season may not have been accurate or reliable.
[139] Cadmus selected a random sample of 800 records out of a population of 8,101 records for the survey.

Table 72 Customer Survey Samples and Response Rates: Experience Survey – Summer 2018

	Original Sample[140] (Number of Records)	Adjusted Sample (Successfully Emailed)	Number of Completes	Response Rate
By Assignment				
Test	1,344	1,336	232	17%
Control	599	596	106	18%
By HVAC System				
Central Air Conditioner	1,148	1,141	184	17%
Heat Pump	795	791	154	19%
Overall	**1,943**	**1,932**	**338**	**17%**

Survey Data Analysis

Cadmus compiled frequency outputs, coded open-end survey responses, and ran statistical tests to determine whether survey responses differed significantly by assignment and to Connected Savings. Findings are presented in the next section under Customer Experience.

Findings

This section provides detailed findings about Rush Hour Rewards demand savings, customer experience with the program, and program implementation challenges and lessons learned.

Load Impacts

Table 73 presents the average demand savings per customer during DR events. Across all event hours, the program reduced demand by an average 0.62 kW per participant (23% of baseline demand) in winter and 0.93 kW per participant (32%) in summer. The evaluated demand savings surpassed the PGE planning value for summer of 0.8 kW per participant, though was less than the planning estimate for winter of 1.0 kW per participant.

[140] Cadmus selected a random sample of test and control group records for the survey. A random sample of 1,344 test group records out of a population of 8,101 test group records were selected. A random sample of 599 control group records out of a population of 1,102 control group records were selected.

Table 73 Rush Hour Rewards Evaluated Demand Savings by Season

Season	Sample Size (n of participants)	Estimated Baseline Load (kW)[141]	Evaluated Demand Savings[142]			
			kW savings per participant	Absolute Precision	Relative Precision	Percentage
Winter 2017/2018	720	2.66	0.62	±0.26	±41%	**23%**
Summer 2018	8,131	2.90	0.93	±0.12	±12%	**32%**

Winter 2017/2018

During the Rush Hour winter 2017/2018 season, PGE launched three morning events starting at 7 a.m., and five afternoon events; one event started at 4 p.m. and four events started at 5 p.m. Each event lasted three hours.

Figure 60 and Figure 61 presents the average kilowatt impacts per customer for one hour prior to the event, each event hour, and two hours after the event ended for afternoon and morning events, respectively. Figure 61 and Figure 62 show the corresponding percentage savings. The program achieved average demand savings of 0.7 kW for morning events (starting at 7 a.m.) and 0.6 kW for afternoon events (including 0.4 kW for one 4 p.m. event and 0.6 kW for events starting at 5 p.m.). The average temperature during the 4 p.m. event was the warmest of all eight events, which may explain why it had low average savings.

For all events, savings peaked in the first hour, then diminished through the remaining hours. By the last hour of morning events, savings had decreased by 0.5 kW, approximately 51% less than the first hour savings; savings for events starting at 5 p.m. had decreased by 0.3 kW or 38% from the first hour; and savings for the 4 p.m. event decreased by 0.2 kW or 36% from the first hour. This pattern follows a similar one identified in previous evaluations of Rush Hour Reward seasons.

[141] Estimated baseline is average control group consumption across all event hours.

[142] Impacts were estimated using regression analysis of customer AMI meter data on indicator variable for assignment to the test group interacted with event hour and controls for hour of the day, weather, and event hour. Cadmus calculated the percentage demand reduction as the kilowatt demand reduction estimate divided by average control customer's demand per hour across all events. Impact estimates are the percentage demand reduction during load control events; blue indicates significance at 95%.

Figure 60 Average Kilowatt Demand Savings by Event Start Time: Winter 2017/2018 – Afternoon/Evening[143]

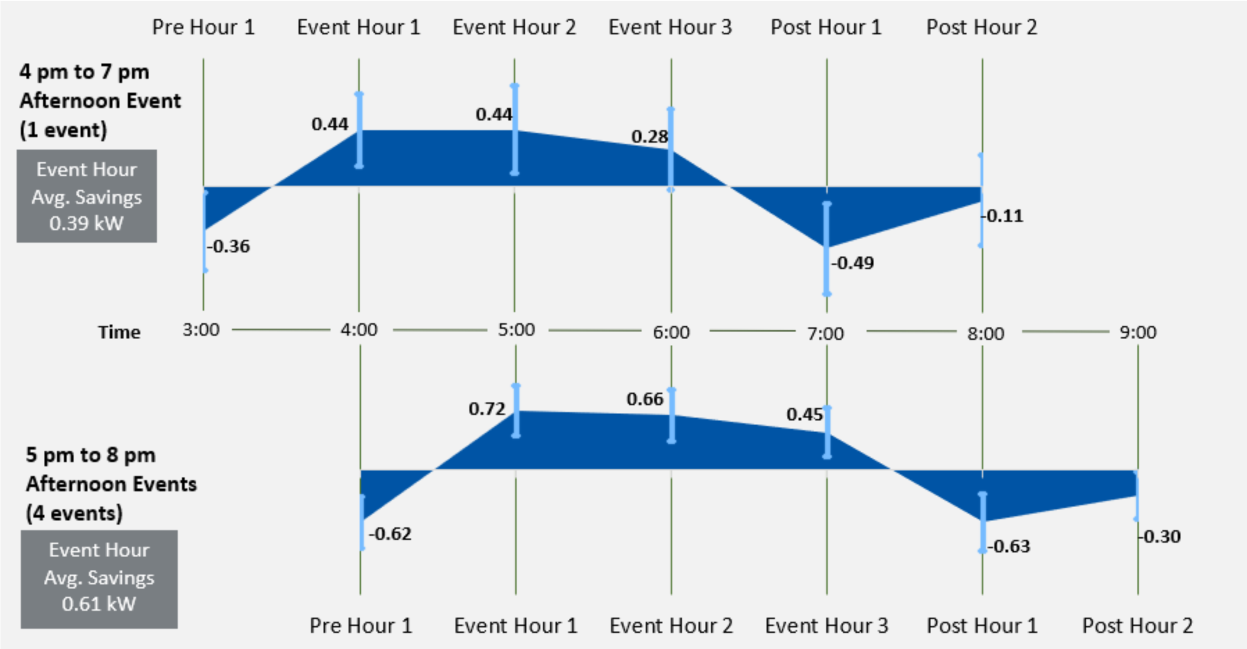
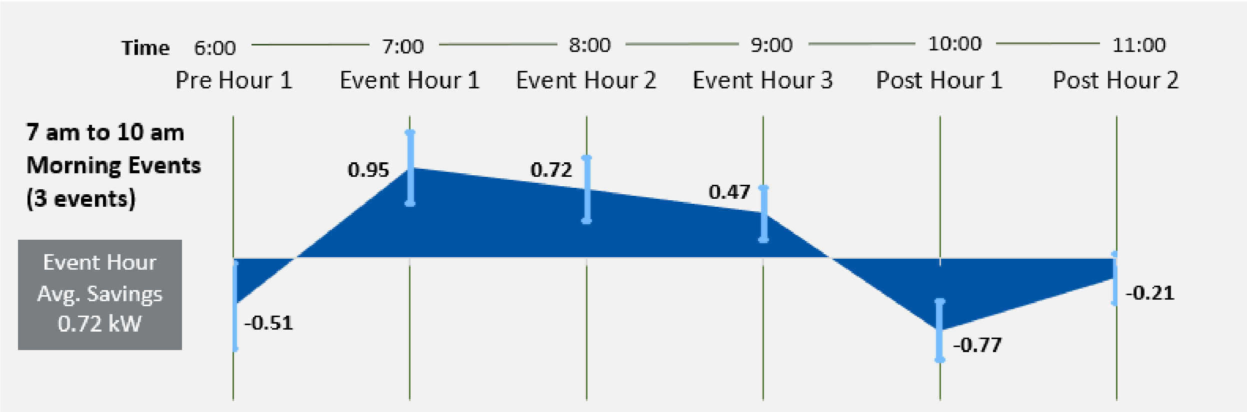


Figure 61. Average Kilowatt Demand Savings by Event Start Time: Winter 2017/2018 – Morning[144]



143 Impacts were estimated using regression analysis of customer AMI meter data. Errors bars show 95% confidence intervals estimated from standard errors clustered on customers. See Appendix B for details.
144 Ibid.

Figure 62. Average Percentage Demand Savings by Event Start Time: Winter 2017/2018 – Afternoon/Evening[145]

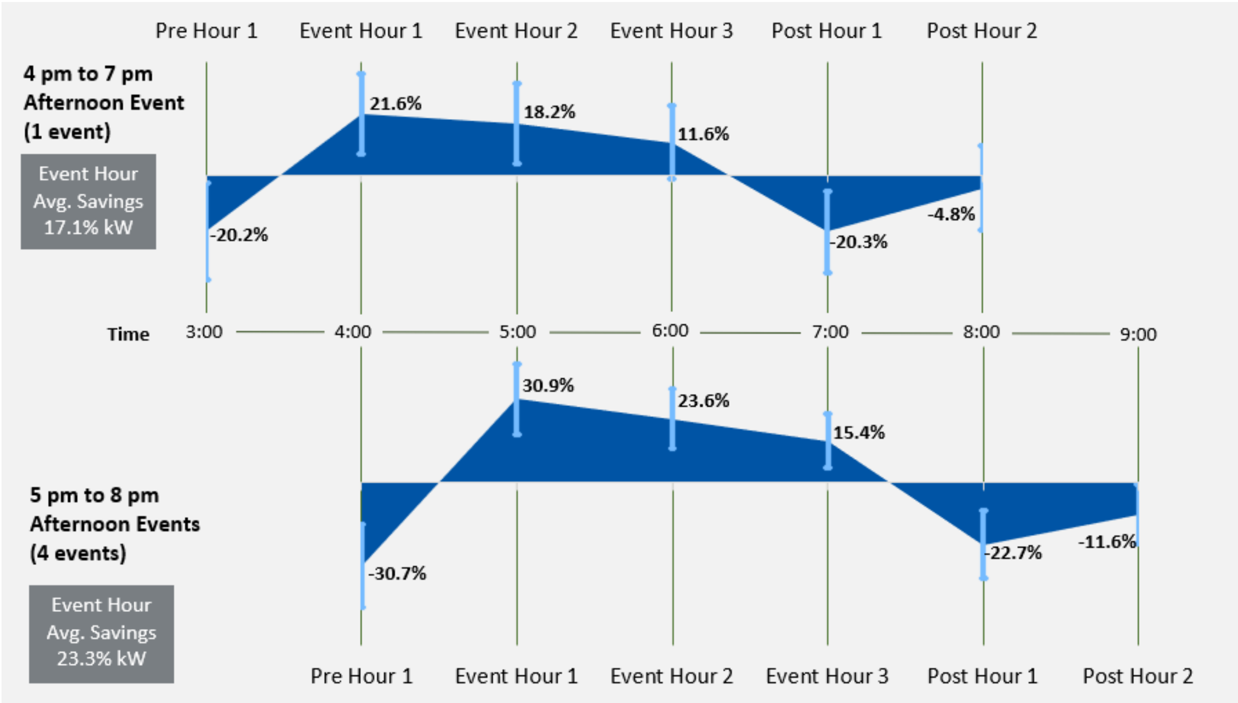
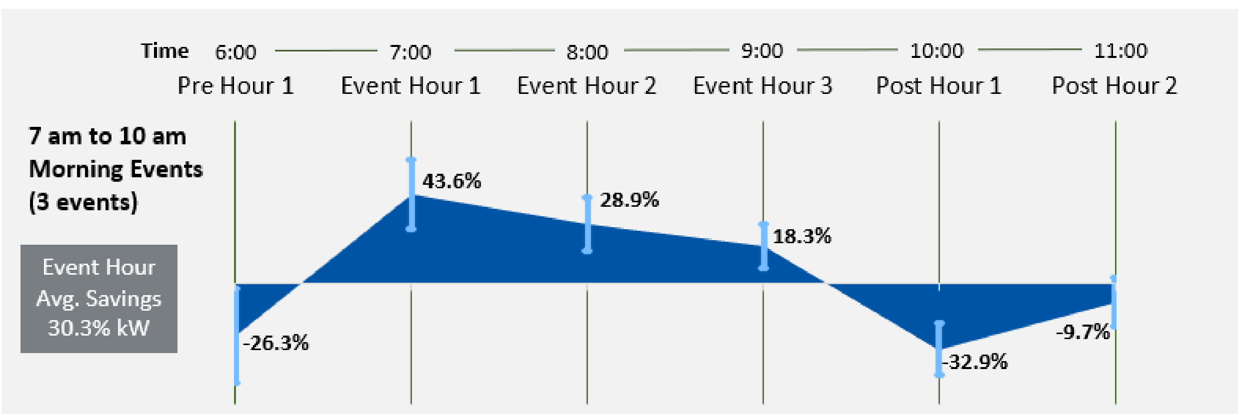


Figure 63. Average Percentage Demand Savings by Event Start Time: Winter 2017/2018 – Morning[146]



Pre-Heating and snapback increased participant loads before and after events. Pre-heating of participant homes increased electricity demand by 0.5 kW (26%) for morning events and between 0.4 kW and 0.6 kW (20-31%) for afternoon events. After events ended, demand increased above the usual levels, as thermostat settings returned to normal. After afternoon events, there was an increase in demand or snapback of between 0.5 kW and 0.6 kW (20-22%) per participant home. After morning events, demand

[145] Ibid.

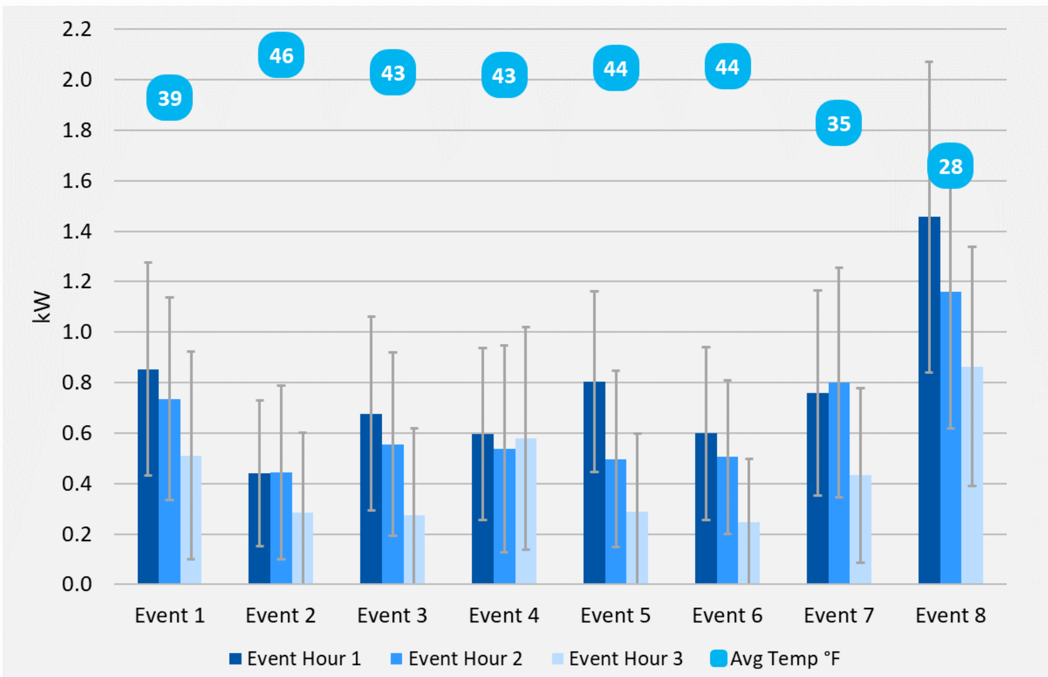
[146] Ibid.

increased by 0.8 kW (33%). Demand remained statistically greater than normal for approximately 1 to 2 hours after the events ended.

Demand Savings Estimates by Winter Event

Figure 64 shows the average demand savings per customer for each hour of the eight winter events. For most events, first hour savings per customer ranged 0.6 kW and 0.8 kW, while third hour savings per customer ranged between 0.2 kW and 0.6 kW. Event 8, which had the coldest outdoor temperatures, was the only event which generated savings higher than 1 kW, which occurred during the first and second hour of the event.

Figure 64 Average Demand Savings by Event – Winter 2017/2018[147]



In each event, savings degraded from the first event hour to the third, but Event 2 and Event 7 generated slightly larger savings during the second hour.

Appendix D contains point estimates of demand savings, pre-event and post-event demand impacts, and energy savings impacts. The energy savings for winter were estimated by summing load impacts across the pre-event hour, event hours, and the first two post-event hours. Load impacts for later post-event hours were not statistically significant and therefore not included in the energy savings calculations. On average, conservation was negative, ranging between -0.2 kWh and -0.6 kWh per customer, demonstrating that the program slightly decreased energy consumption.

[147] Ibid.

Program Demand Savings for Winter 2017/2018

Table 74 presents estimates of total Rush Hour Rewards program demand savings during winter 2017/2018 by event hour and on average for each event. The estimates were obtained by multiplying the evaluated per-customer average demand savings by the number of participants in each event.

Table 74 Total Rush Hour Rewards Program Demand Savings (MW) – Winter 2017/2018

Event	Beginning and Ending Times	Demand Savings (MW)			
		Hour 1	Hour 2	Hour 3	Event Average
Event 1	5 p.m. – 8 p.m.	0.42	0.36	0.25	0.34
Event 2	4 p.m. – 7 p.m.	0.22	0.22	0.14	0.19
Event 3	5 p.m. – 8 p.m.	0.34	0.28	0.14	0.25
Event 4	5 p.m. – 8 p.m.	0.30	0.27	0.29	0.29
Event 5	7 a.m.-10 a.m.	0.41	0.25	0.15	0.27
Event 6	7 a.m.-10 a.m.	0.31	0.26	0.13	0.23
Event 7	5 p.m. – 8 p.m.	0.40	0.42	0.23	0.35
Event 8	7 a.m. – 10 a.m.	0.76	0.61	0.45	0.61
Hour Average		0.39	0.33	0.22	0.32

Across events, demand savings averaged 0.3 MW. Note participants do not include control customers (n=256) who did not participate in events and would have contributed to PGE's winter demand response capacity. Event 8, which began at 7 a.m. and lasted three hours, had the largest average demand savings of 0.6 MW. Event 2, which began at 4 p.m. and lasted three hours had the smallest average demand savings of 0.2 MW.

Summer 2018

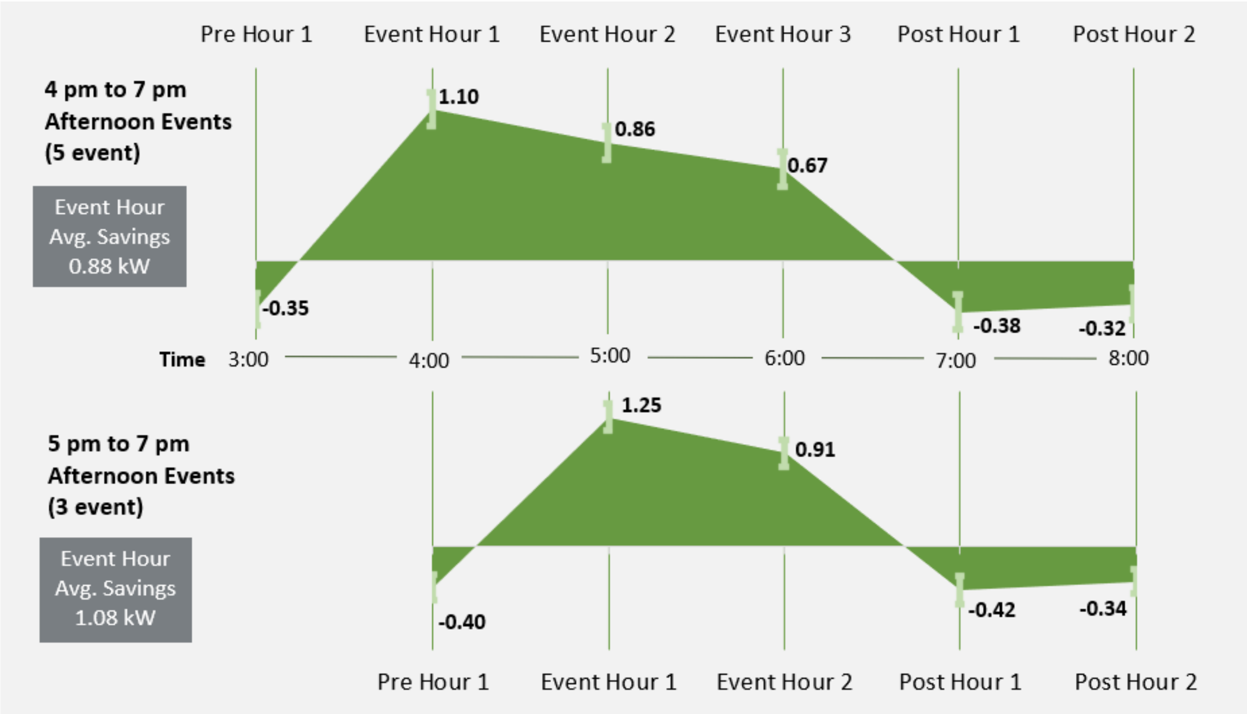
During summer 2018, five Rush Hour Rewards events started at 4 p.m. and lasted three hours and three events started at 5 p.m. and lasted two hours.

Figure 65 presents the kilowatt impacts for one hour prior to the event, each event hour, and two hours after the event ended. The program achieved average demand savings of 0.93 kW per customer on average, with 0.88 kW per customer for three-hour events (4 p.m. start time) and 1.08 kW for two-hour events per customer (5 p.m. start time). This difference in savings is primarily due to the third hour of the 4 p.m. events, which averaged 0.67 kW per participant and pulled down the overall average. The impact estimates across the first two event hours were similar for events starting at 4 p.m. and 5 p.m.

During summer events, savings peaked in the first hour, then diminished through the remaining hours, which follows a similar trend identified in previous evaluations of Rush Hour Rewards; however, this degradation was more extreme for the three-hour events (4 p.m.) than the two-hour events (5 p.m.). Between the first and second events hours, savings had decreased by 0.2 kW (22%) for three-hour events and 0.3 kW (27%) for two-hour events. For three-hour events, the difference in savings between the first and third event hour was 0.4 kW or approximately 39%.

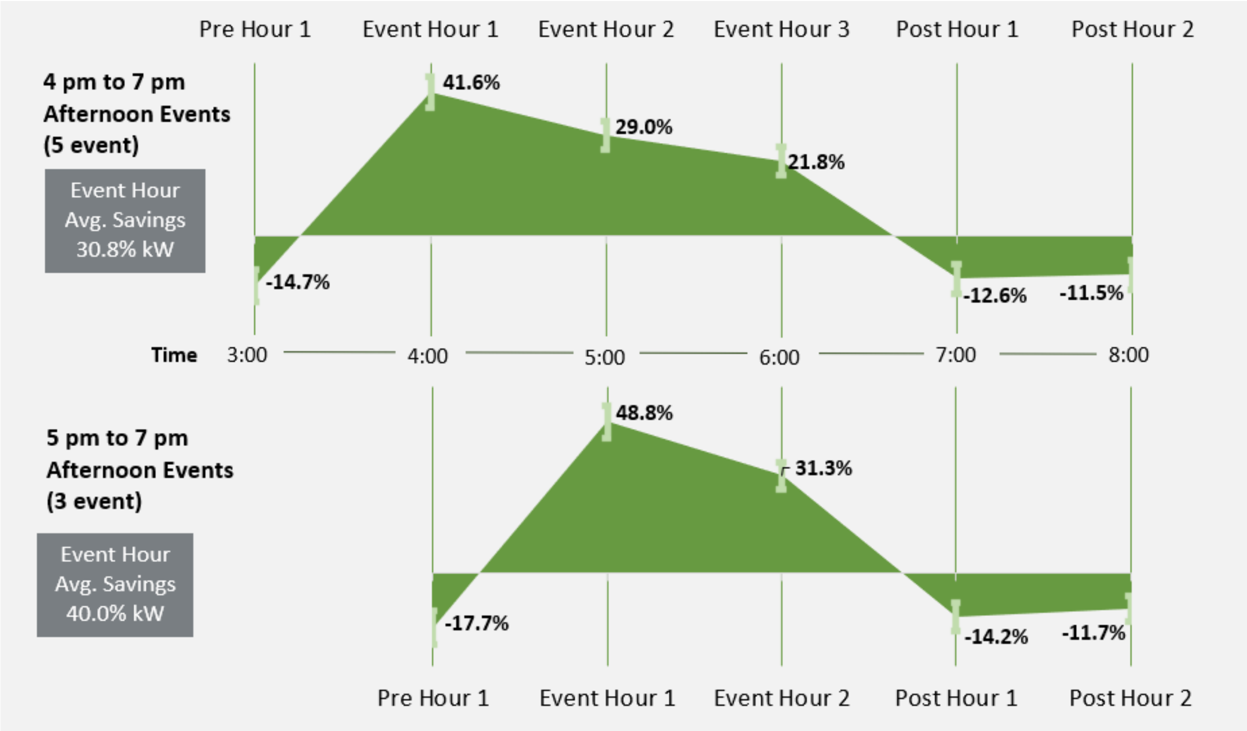
As in winter, participant electricity demand was higher than normal before and after events. Pre-cooling of participant homes increased electricity demand by about 0.4 kW or 14% across all events. After the events ended, demand snapped back by 0.4 kW and 0.3 kW (approximately 12-13%) in the first and second hours, respectively. Demand remained statistically greater than normal for about four hours after the events ended.

Figure 65 Average kW Demand Savings by Event Time – Summer 2018[148]



148 Ibid.

Figure 66 Average Percentage Demand Savings by Event Time – Summer 2018[149]



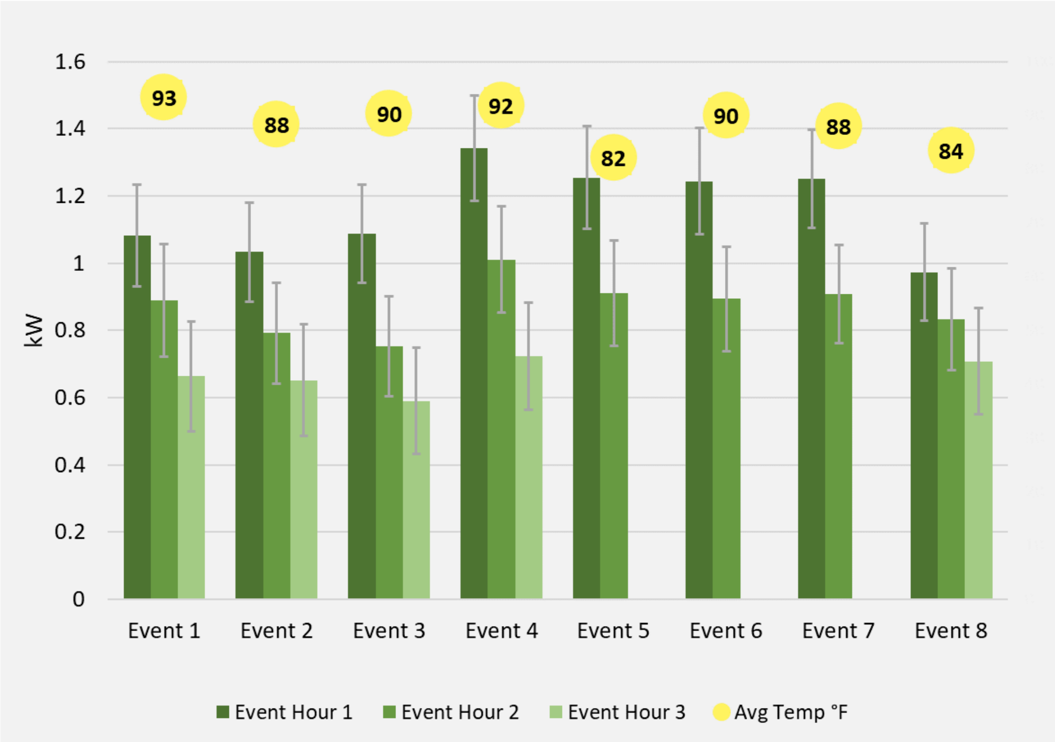
Demand Savings Estimates by Summer 2018 Event

Figure 67 shows the average demand savings per participant for each hour of the eight summer events. For most events, first-hour savings per customer ranged 1.0 kW and 1.4 kW, while third-hour savings per customer ranged between 0.8 kW and 1.0 kW for two-hour events and 0.6 kW and 0.8 kW for three-hour events. Savings during the first hour of all events except event 8 were greater than or equal to 1 kW. Overall, these findings are comparable to previous Rush Hour Rewards summer seasons.

During Event 8, Nest tested IDR, which sought to obtain more consistent demand savings across event hours and avoid savings degradation. Although first hour savings were less than 1 kW, Event 8 exhibited the least savings degradation among summer events. Savings decreased by 0.3 kW or 73% between the first and third hours. The smaller degradation of savings is consistent with the objectives of IDR. However, since IDR was only called for one event, it is not possible to draw very firm conclusions about its effectiveness.

[149] Ibid.

Figure 67 Average Demand Savings by Event – Summer 2018[150]



Appendix D contains point estimates of demand savings, pre-event and post-event demand impacts, and energy savings. The summer energy savings were estimated by summing load impacts across the pre-event hour, event hours, and the first four post-event hours. Load impacts for later post-event hours were not statistically significant and therefore not included in the energy savings calculations. For summer 2018, average conservation was negative, ranging between -0.6 kWh and -1.2 kWh, demonstrating that the program modestly decreased energy consumption.

Program Demand Savings for Summer 2018

Table 75 presents estimates of total Rush Hour Rewards program demand savings during summer 2018 by event hour and on average for each event. The estimates were obtained by multiplying the evaluated per-customer average demand savings by the number of treatment participants in each event.

[150] Ibid.

Table 75. Total Rush Hour Rewards Program Demand Savings (MW) – Summer 2018

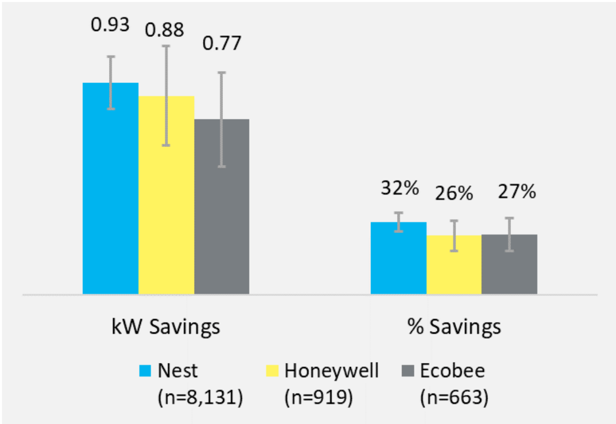
Event	Beginning and Ending Times	Demand Savings (MW)			
		Hour 1	Hour 2	Hour 3	Event Average
Event 1	4 p.m. – 7 p.m.	7.6	6.3	4.7	6.2
Event 2	4 p.m. – 7 p.m.	7.3	5.6	4.6	5.8
Event 3	4 p.m. – 7 p.m.	7.7	5.4	4.2	5.8
Event 4	4 p.m. – 7 p.m.	9.6	7.2	5.2	7.3
Event 5	5 p.m. – 7 p.m.	9.0	6.6	N/A	7.8
Event 6	5 p.m. – 7 p.m.	9.2	6.6	N/A	7.9
Event 7	4 p.m. – 6 p.m.	9.4	6.8	N/A	8.1
Event 8	4 p.m. – 7 p.m.	7.4	6.3	5.4	6.3
Hour Average		8.4	6.3	4.8	6.9

Across events, demand savings averaged 6.9 MW. Note the participants do not include control customers (n=894) who did not participate in events and would have contributed to PGE's summer DR capacity. Event 7, which began at 4 p.m. and lasted two hours, had the largest average demand savings of 8.1 MW. Event 2, which began at 4 p.m. and lasted three hours had the smallest average demand savings of 5.8 MW.

Comparison across Brands

Figure 68 compares the average savings per participant of smart thermostat brands across all event hours. Nest had the highest average kilowatt savings of 0.93 kW and percentage savings of 32%. Honeywell and Ecobee had savings of 0.88 kW per participant (26%) and 0.77 kW per participant (27%), but none of the differences was statistically significant. Honeywell's average savings estimates were diminished by the low savings estimated for Event 9.

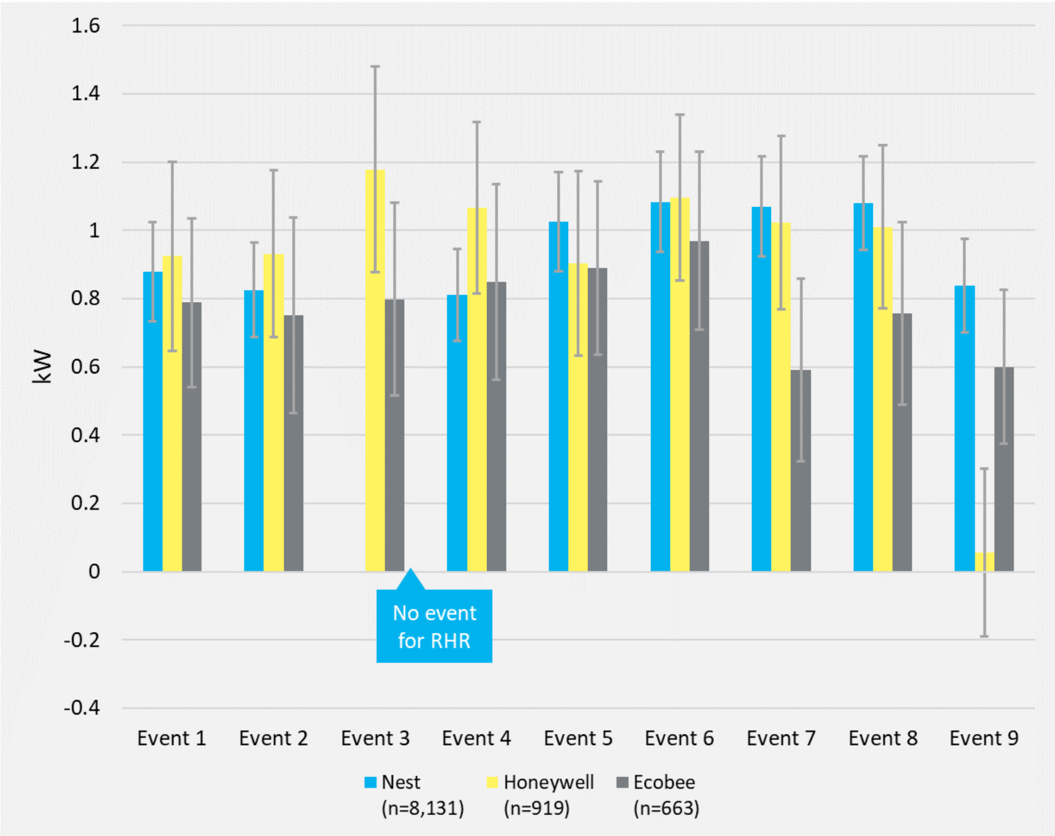
Figure 68. Average Demand Savings per Customer by Thermostat Brand – Summer 2018[151]



[151] Figure shows the average demand savings per participant. Nest thermostat savings estimates were obtained from Cadmus evaluation of the Rush Hour Rewards Program (2019).

Figure 69 compares the average demand savings per participant of the different brands by event. Nest and Honeywell smart thermostats generated similar demand savings, except for Event 9 when Honeywell's API malfunctioned, and Whisker Labs was unable to dispatch Honeywell thermostats. Ecobee thermostats consistently generated lower demand savings than Nest or Honeywell thermostats. Ecobee thermostats did not permit pre-cooling of homes, which would have limited the event-hour demand savings that could have been achieved. Differences in demand savings between thermostat brands may also reflect the effects of customers with lower savings potential selecting Ecobee thermostats rather than differences in performance of thermostat brands.

Figure 69. Average Demand Savings by Event and Thermostat Brand – Summer 2018[152]



Comparison of Evaluated Savings to Previous Seasons

Table 76 compares evaluation estimates of average demand savings per customer and percentage demand savings for the current and past Rush Hour Rewards seasons. The winter evaluated savings are averages across morning and evening events.

[152] Impacts were estimated using regression analysis of customer AMI meter data. Errors bars show 95% CIs estimated with standard errors clustered on customers. See Appendix B for details.

Table 76 Average Per-Participant Seasonal Demand Savings Comparison[153]

Season	Year	Average Demand Savings Per Participant		Avg. Event Temperature (°F)
		kW	Percentage	
Summer	2016	0.79	30%	91
	2017	1.01	38%	89
	2018	0.93	32%	88
Winter	2015/2016	0.59	21%	43
	2016/2017	0.93	27%	29
	2017/2018	0.62	23%	40

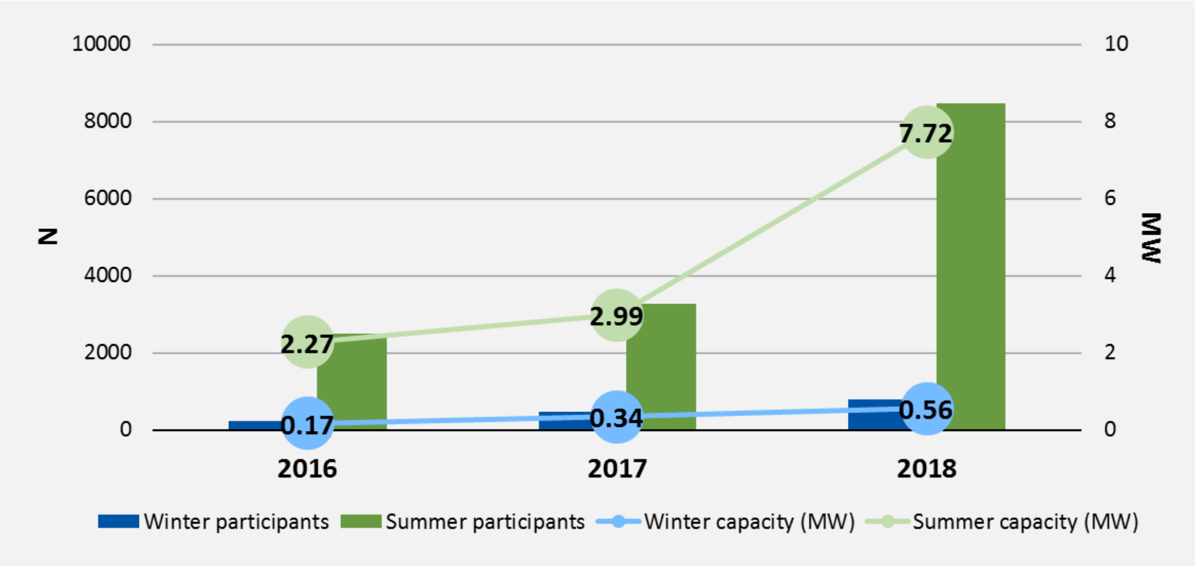
Evaluated demand savings for winter 2017/2018 and summer 2018 were smaller than those for the previous year but approximately equal to those from two years ago. Differences in evaluated savings may be due to changes between years in weather, participant population, and the relative frequency of winter morning and evening events. For example, winter 2016/2017 was significantly more severe than the other winters, with event hours temperatures ranging between 20°F and 34°F. The cold weather likely explains the higher demand savings for that season.

Contributions Towards Smart Thermostat Demand Response Planning Goal

PGE has a smart thermostat DR capacity goal of 25 MW and a participation goal of 24,000 by 2019. Figure 70 shows the contributions of the BYOT Rush Hour Rewards towards those goals by displaying annual winter and summer customer enrollments and estimates of DR capacity. For each season, capacity was estimated by multiplying total BYOT Rush Hour Rewards customer enrollments (including control group customers) by the average demand savings per Rush Hour Rewards participant. The savings per participant were estimated as the average of the evaluated savings across three years and equaled 0.71 kW in winter and 0.91 kW in summer; therefore, in this figure, changes in customer enrollments are the only driver of DR capacity growth.

[153] Evaluated savings for previous years obtained from Cadmus evaluations of Rush Hour Rewards Program. Results for winter 2015/2016 and summer 2016 are publicly available from https://edocs.puc.state.or.us/efdocs/HAQ/um1708haq163627.pdf.

Figure 70. Rush Hour Rewards DR Capacity and Participation Growth



In 2018, PGE possessed about 7.7 MW of summer DR capacity and 0.6 MW of winter DR capacity from the BYOT Rush Hour Program. Between 2017 and 2018, summer capacity increased by approximately 4.7 MW or 158% due to a net change in enrollment of 5,195 customers. Winter capacity increased by 0.22 MW or 63% due to a net change in enrollment of 304 customers.

Customer Experience

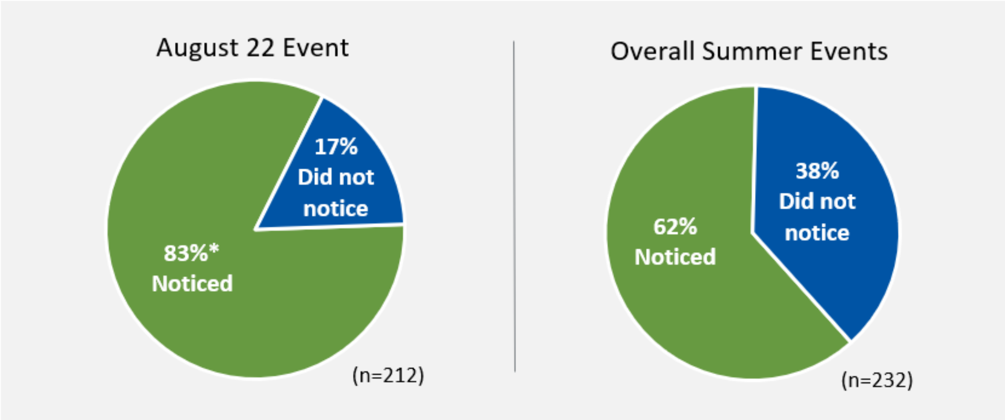
The summer 2018 event and experience surveys asked Rush Hour Rewards participants about their event awareness, participation challenges, comfort, satisfaction, and suggestions for improvement. The following sections describe the major findings from these surveys. Comparisons across thermostat brands and between Rush Hours Rewards and Connected Savings are provided at the end. Also, for comparing the most seasons to previous Rush Hour Rewards evaluations, survey results from Rush Hour Rewards for summer 2016 and winter 2015/2016 are provided in *Appendix E.*

Event Awareness

PGE called eight events for Rush Hour Rewards during summer 2018. The summer experience surveys asked test group respondents whether they noticed the summer events and how many they noticed. Most respondents (85%) recalled receiving event notifications prior to their occurrence (n=224). Sixty-two percent of respondents (n=232) said they noticed the events, and on average, they noticed 6.3 events (n=144) out of the eight events called. Respondents (n=184) mostly noticed the events because of the event message display on the Nest thermostat (72%) and the event notification from the smartphone app (65%) rather than because of a temperature change (36%).

More respondents said they noticed a single event when asked about the event shortly after it occurred than noticed any events when asked about them at the end of the season. Cadmus administered a summer event survey the day after the August 22 event. As shown in Figure 71, a significantly higher percentage of respondents said they noticed the August 22 event (83%) than said they noticed the overall summer events (62%).

Figure 71. Noticing of Events – Single Event Compared to Overall Season[154]



* Difference is significant with 90% confidence (p≤0.10).

Most respondents (93%) said participating in the summer events was easy (n=227). Specifically, 78% said it was *very easy* and 15% said it was *somewhat easy*. The 4% of respondents who found it difficult to participate in the events mentioned the following reasons:

- Summer was hotter this year (four respondents)
- Notifications were not early enough (two respondents)
- Health/medical reasons or baby in home (two respondents)

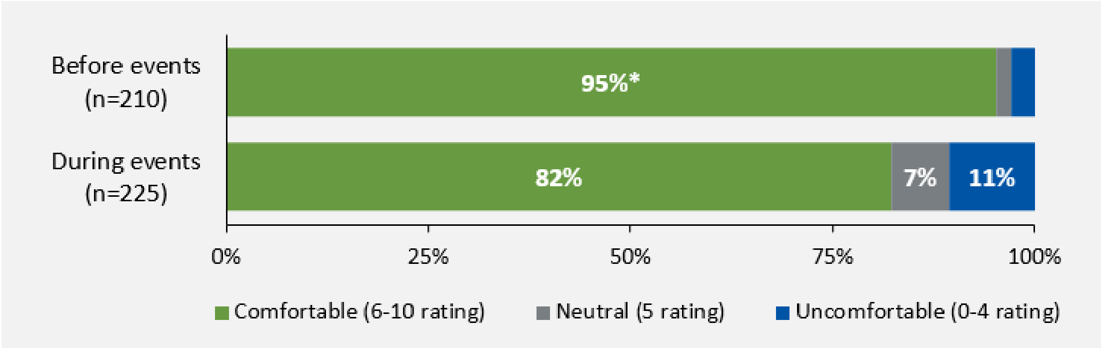
Event Comfort

A large majority of test group respondents were comfortable before and during the summer events. Figure 72 shows that before the events, 95% of respondents said their home's interior temperature was comfortable. During the events, 82% said they were comfortable, a significant decrease compared to the comfort level before the events, which suggests that the comfort of some customers was negatively affected. Still, most respondents reported feeling comfortable during the events.

Thirty-five percent of respondents (n=227) reported that they did override some of the summer events. Respondents who reported overriding (n=78) most often cited thermal discomfort as their reason (73%), followed by having guests visit (8%) and other household members overriding (5%).

[154] Event Survey Question: "Did you notice yesterday's high demand event between 4 p.m. and 7 p.m.?" Summer Experience Survey Question: "How many high demand events did you notice this past summer?"

Figure 72 Comfort Level Before and During Summer Events[155]



* Difference is significant with 90% confidence (p≤0.10).

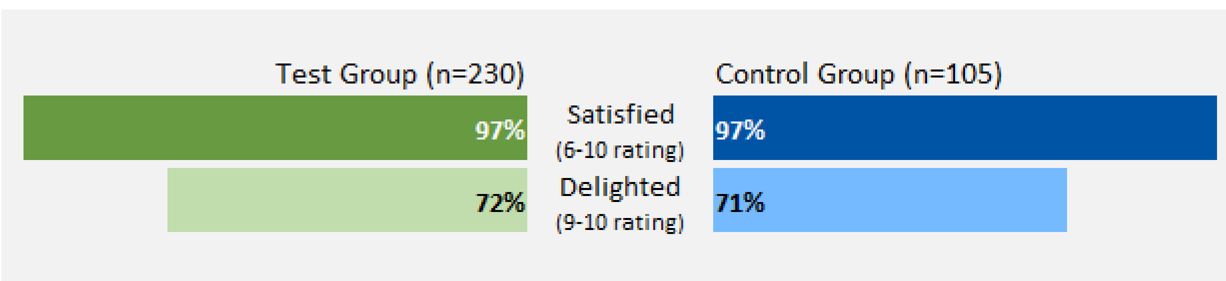
Satisfaction

Test and control group respondents rated their satisfaction with the smart thermostat, the incentive check, the program, and 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*.

Satisfaction with Smart Thermostat

Nearly all test and control group respondents were satisfied with their Nest smart thermostat. Figure 73 shows 97% of test and control group respondents were satisfied with their Nest smart thermostat. Seventy-two percent of test group respondents and 71% of control group respondents were delighted. There was no statistically significant difference between test and control group respondents in their satisfaction with their Nest smart thermostat. No difference was expected because participants already owned their smart thermostats prior to program enrollment.

Figure 73 Satisfaction with Smart Thermostat[156]

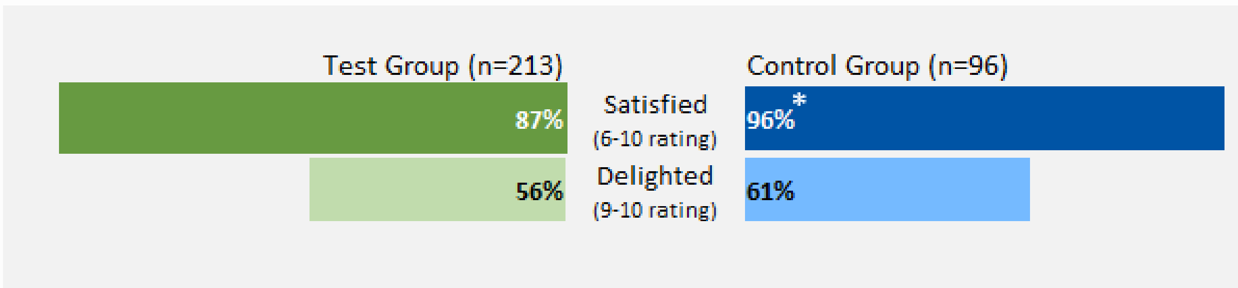


[155] Summer Experience Survey Questions: "Overall this past summer, how comfortable was the interior temperature of your home a few hours before the high demand events?" and "Overall this past summer, how comfortable was the interior temperature of your home during the high demand events?"
[156] Summer Experience Survey Question: "How satisfied are you with your Nest thermostat?"

Satisfaction with Incentive

Most respondents were satisfied with the incentive amount. A significantly higher proportion of control group respondents (96%) than test group respondents (87%) were satisfied with the incentive (Figure 74). This difference can be explained by the fact that control group participants did not experience any events (which might cause inconvenience) and still received the $25 incentive. Fifty-six percent of test group respondents and 61% of control group respondents were delighted with the incentive, though the difference was not significant.

Figure 74. Satisfaction with Incentive[157]

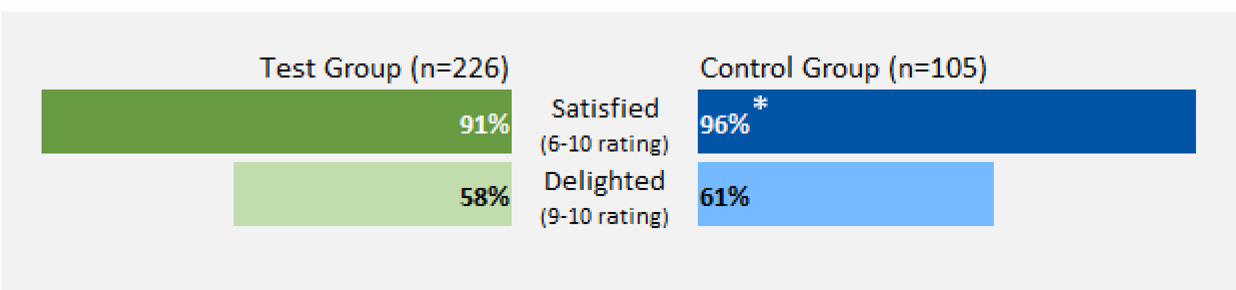


* Difference is significant with 90% confidence (p≤0.10).

Satisfaction with Program

Most respondents were satisfied with the program. A significantly higher proportion of control group respondents (96%) than test group respondents (91%) were satisfied with the program (Figure 75). Also, a higher proportion of control group respondents (61%) than test group respondents (58%) were delighted with the program, although the difference was not significant. The difference can be explained by the fact that control group participants did not experience any events.

Figure 75 Satisfaction with Program[158]



* Difference is significant with 90% confidence (p≤0.10).

The summer experience surveys asked test and control group respondents to explain their program satisfaction ratings. Cadmus analyzed these open-end explanations according to positive or negative

[157] Summer Experience Survey Question. "How satisfied were you with the incentive check you received for your participation this past summer?"
[158] Summer Experience Survey Question. "Please rate your overall satisfaction PGE's Smart Thermostat program using a 0 to 10 scale where a 0 means you are extremely dissatisfied and a 10 means you are extremely satisfied."

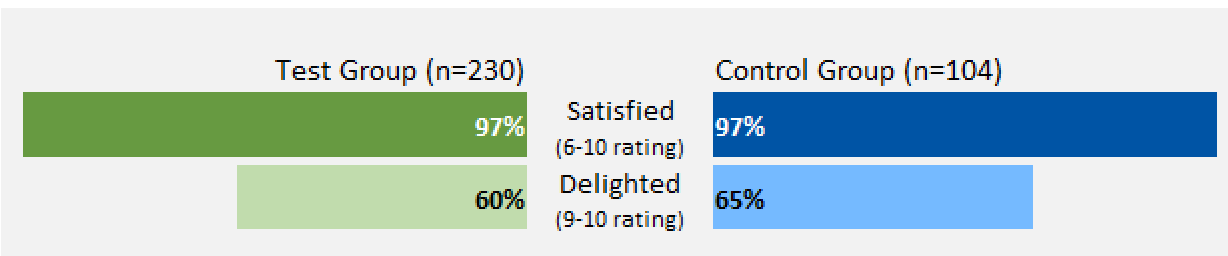
sentiment. Both test and control group respondents had largely positive comments about the program. Of the 133 topic mentions, positive comments from the test group respondents most often mentioned that the program is helpful to the customer (25%), works well (23%), and saves money (21%). Like responses from the test group, of the 60 topic mentions, positive comments from the control group respondents most often said that the program is helpful to the customer (32%), works well (23%), and saves money (18%).

Of the 133 topic mentions, negative comments about the program from the test group respondents most often cited the incentive amount (17%) and that participation in the program was not worth being uncomfortable (5%). Of the 60 topic mentions, the control group mostly made negative comments about the incentive amount (12%), followed by problems with using the smart thermostat (three respondents).

Satisfaction with Portland General Electric

Nearly all test and control group respondents were satisfied with PGE. As shown in Figure 76, the same proportion of test group (97%) and control group (97%) respondents were satisfied with PGE. A statistically similar proportion of control group respondents (65%) and test group respondents (60%) were delighted with PGE.

Figure 76 Satisfaction with PGE[159]



That the test group had lower *program* satisfaction than the control group suggests that some participants were inconvenienced by the events, but the equality of *utility* satisfaction between test and control group suggests that any inconvenience did not affect participants' satisfaction with PGE.

Customer Suggested Improvements

The summer experience surveys asked test and control group respondents for suggestions to improve the program. Test group respondents most often suggested these three improvements:

- Increase the incentive amount (30%)
- Send earlier pre-event notifications (14%)
- Provide a different incentive structure (13%)

Control group respondents (n=43) most often suggested these three improvements:

- Increase the incentive amount (21%)

[159] Summer Experience Survey Question: "Please rate your overall satisfaction with the PGE using a 0 to 10 scale where a zero means you are extremely dissatisfied and a 10 means you are extremely satisfied."

- Provide a different incentive structure (12%)
- Provide a performance/impact report for their household (9%)

Brand Comparison

Table 77 shows a comparison of the test group's responses across the three thermostat brands. Significant differences emerged between Nest, Ecobee, and Honeywell thermostats. A significantly higher percentage of Nest respondents (62%) and Ecobee respondents (63%) noticed the events compared to respondents with Honeywell thermostats (52%). A significantly higher percentage of Nest respondents reported feeling comfortable during events (82%) than Ecobee respondents (77%) and Honeywell respondents (73%).

Table 77 Test Group Survey Responses by Thermostat Brand

Survey Topic	Nest (n≤232)	Ecobee (n≤204)	Honeywell[160] (n≤220)
General event awareness	62% noticed events	63% noticed events	52% noticed events[161]
Average perceived number of events	6.3 events[162]	4.9 events	4.4 events
Comfort during events	82% comfortable[163]	77% comfortable	73% uncomfortable
Overriding events	35% overrode	33% overrode	38% overrode
Smart thermostat satisfaction	97% satisfied 72% delighted	98% satisfied 75% delighted[164]	95% satisfied 67% delighted
Incentive satisfaction	87% satisfied 56% delighted[165]	92% satisfied 61% delighted	88% satisfied 67% delighted
Program satisfaction	91% satisfied 58% delighted	95% satisfied 64% delighted	93% satisfied 64% delighted
Satisfaction with PGE	97% satisfied 60% delighted	97% satisfied 60% delighted	95% satisfied 70% delighted[166]

Comparison to Connected Savings

Cadmus compared the results of the Connected Savings test group survey to the results of the Rush Hour Rewards test group survey (Table 78). Both achieved similar satisfaction results but differed in the perceived number of events and comfort during events. Rush Hour Rewards test group respondents were significantly more comfortable during events (82%) than were Connected Savings' test group respondents (74%). This difference in comfort may be explained by the different temperature setbacks used by Whisker Labs versus Nest. Whisker Labs calibrated a three-degree setback while Nest calibrated a one-

[160] This excludes Honeywell Lyric thermostats. There were very few Honeywell Lyric responses (n≤27).
[161] Difference is significant with 90% confidence (p≤0.10).
[162] Ibid.
[163] Ibid.
[164] Ibid.
[165] Ibid.
[166] Ibid.

to five-degree setback. Nest's wider range in temperature meant it could calibrate setbacks specifically to the customer's comfort preferences compared to the one-size-fits-all calibration from Whisker Labs.

In addition, Rush Hour Rewards test group respondents perceived significantly more events on average (6.3) than Connected Savings test group respondents (4.8). The absence of pre-event notifications for Connected Savings probably explains the perception of a fewer number of events. The Nest thermostats used in Rush Hour Rewards sent pre-event notifications to its test group customers while the Ecobee and Honeywell thermostats used in Connected Savings did not.

Table 78 PGE Customer Satisfaction: Connected Savings vs. Rush Hour Rewards

Survey Topic	Rush Hour Rewards (n≤232)	Connected Savings (n≤218)
General event awareness	62% noticed events	58% noticed events
Average perceived number of events	6.3 events[167]	4.8 events
Comfort during events	82% comfortable[168]	74% comfortable
Overriding events	35% overrode	36% overrode
Smart thermostat satisfaction	97% satisfied 72% delighted	95% satisfied 70% delighted
Incentive satisfaction	87% satisfied 56% delighted	84% satisfied 56% delighted
Program satisfaction	91% satisfied 58% delighted	89% satisfied 56% delighted
Satisfaction with PGE	97% satisfied 60% delighted	94% satisfied 58% delighted

Implementation Delivery

PGE did not encounter any major implementation challenges with Rush Hour Rewards, now in its third year. PGE said program marketing, recruitment, and event management worked well.

By the end of summer 2018, 8,471 customers had enrolled in Rush Hour Rewards. On average, 3,068 customers enrolled in Rush Hour Rewards per year compared to the 1,662 customers who enrolled during the first year of Connected Savings. The higher rate of enrollment in Rush Hour Rewards can partly be attributed to Nest's larger share of the smart thermostat market. Another reason is that Nest sends out program promotions to eligible customers on a seasonal basis as well as employing several targeted marketing activities using social media ads and search engine marketing.[169] Ecobee and Honeywell, the manufacturers of the thermostats used for Connected Savings, send more limited marketing once a year.

Moreover, because Nest is both the manufacturer and the DR service provider, it could collect run-time data to determine the customer's HVAC system type and send targeted marketing about Rush Hour

[167] Ibid.

[168] Ibid.

[169] Cadmus conducted recruitment surveys for Rush Hour Rewards participants in 2016, but these did not include questions on length of time between purchase and program enrollment.

Rewards to eligible customers. This was a major advantage over Whisker Labs, which could not access data from Ecobee and Honeywell thermostats until the customer enrolled in Connected Savings.

PGE encountered one minor challenge with Nest pertaining to online marketing. PGE developed and tested an online awareness campaign for Rush Hour Rewards using online ads, Google key word searches, and social media. PGE found that the term “Nest” was the best word to use for the online campaign, but it was not allowed to use “Nest” as a key word due to trademark legalities. As a result, PGE had to place its online campaign idea on hold. This minor online marketing challenge, however, did not appear to impede program enrollment.

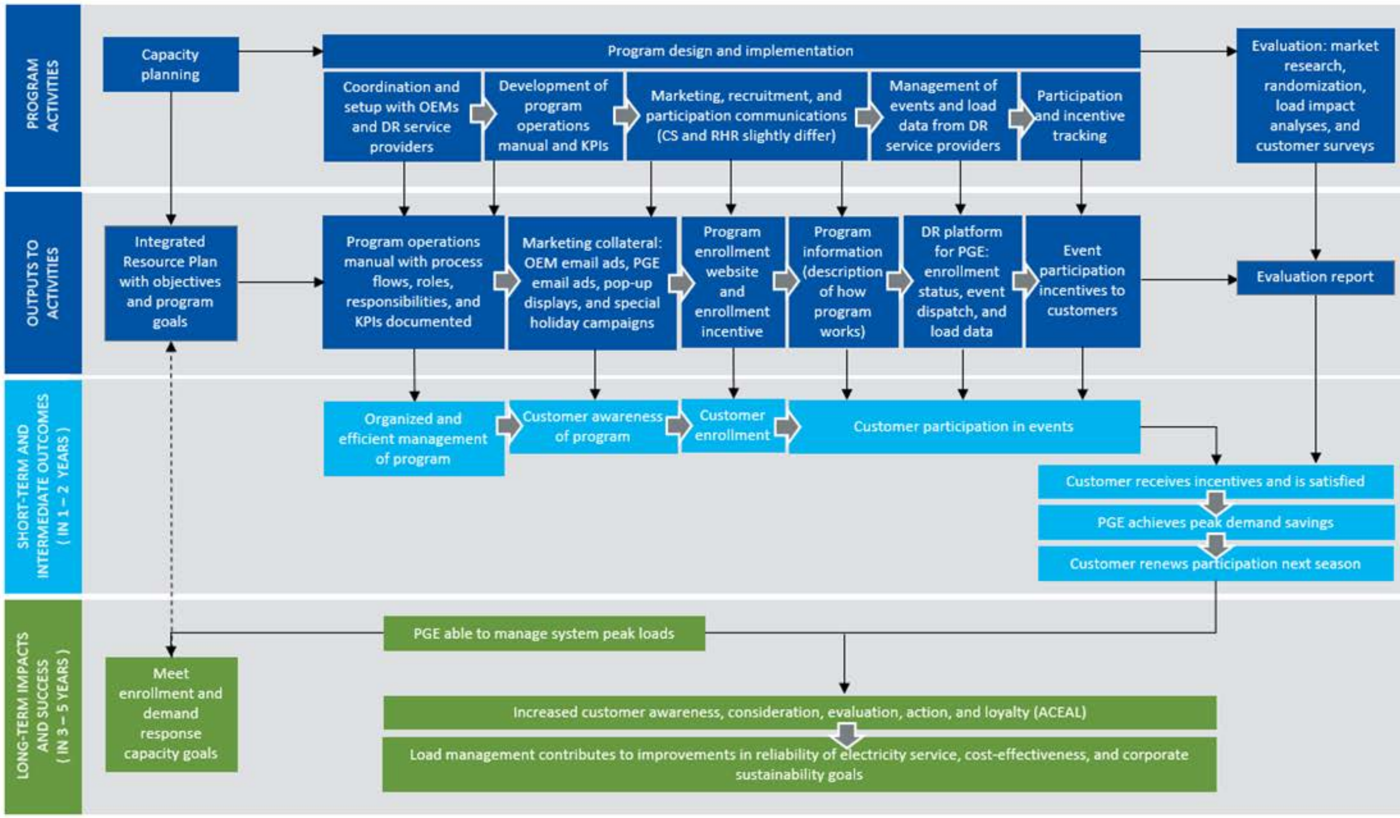
Logic Model Review

Figure 77 shows the logic model for Rush Hour Rewards. Cadmus reviewed the logic model against the evaluation findings and determined that Rush Hour Rewards operated as intended whereby the program activities and outputs produced the expected short-term and intermediate outcomes of demand savings and customer satisfaction.

Figure 77 Rush Hour Rewards Logic Model

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, PGE's Smart Thermostat Program will enroll customers and realize the goals of **24,000 enrolled smart thermostats by 2019 and 25 MW of demand response capacity by 2021**. Through collaboration with top-market original equipment manufacturers (OEMs) and DR service providers, and seasonal marketing campaigns, PGE will attract customers with a smart thermostat to enroll into the program. Giving customers control to opt out of DR events will ensure customer satisfaction and retain participants.



Conclusions and Recommendations

Based on the evaluation findings, Cadmus came to several conclusions and recommendations, described below.

Load Impacts

Rush Hour Rewards reduced peak electricity demand from residential air conditioning and space heating.

The program achieved average demand savings of 0.93 kW and 0.62 kW per participant for summer and winter, respectively. These savings represented 32% of summer event hour demand and 23% of winter event hour demand. Evaluated savings surpassed the PGE planning value for BYOT smart thermostat DR of 0.8 kW per participant, though winter savings were less than the 1.0 kW planning estimate.

Demand savings significantly degraded across event hours.

During summer events, savings decreased by approximately 0.2 kW and 0.3 kW (22-27%) between the first and second event hours; three-hour events saw a further degradation of 0.4 kW (39%) between the first and last event hour. Winter savings followed a similar trend, showing average degradation of 24% for morning events and 8% for afternoon events between the first and second hour, and 51% and 37% between the first and third hours, respectively. Because of degradation of demand savings over the hours of events, the average savings understates the available capacity during the first event hour and overstates available capacity during the last event hour. By working with its DR service providers to implement IDR strategies, PGE may be able to avoid savings degradation and better meet its capacity needs.

Rush Hour Rewards load control events increased customer loads before and after events but did not result in a negative conservation effect.

In summer, loads increased by about 14% before events because of pre-cooling and by about 13% after events because of snapback. In winter, loads increased by 20-30% before events and about 20%-30% after events. However, the pre-conditioning and snapback did not lead to an increase in energy consumption on event days.

Rush Hour Rewards moved PGE closer to reaching its goal of 25 MW of DR capacity from residential smart thermostats by 2021.

In summer 2018, Rush Hour Rewards had 8,471 participants and realized averaged demand savings of 6.9 MW per event hour. In winter 2017, Rush Hour Rewards had 785 participants and realized average demand savings of 0.32 MW per event hour. In combination with Connected Savings, PGE's residential smart thermostat program yielded an average demand savings of 7.6 MW per event hour for the summer 2018 event season. PGE's DR capacity from Rush Hour Rewards, which includes potential savings from control group customers, is 7.7 MW in summer and 0.6 MW in winter on average.

In summer, PGE can expect the same demand savings per customer from Connected Savings and Rush Hour Rewards participants.

There were no statistically significant differences in savings between thermostat brands (Ecobee, Honeywell, and Nest). In summer 2018, the average savings of 0.93 kW for Rush Hour Rewards customers was slightly higher than but statistically indistinguishable from the average savings for Connected Savings participants (0.84 kW).

Load Impact Recommendations

- PGE should continue recruiting customers for BYOT Rush Hour Rewards, provided it represents a cost-effective resource.
- PGE should continue to test IDR control algorithms to maintain a constant level of demand savings and to avoid degradation of savings across event hours.
- PGE should coordinate internally to ensure well-defined objectives, design, and key metrics of event dispatch that align goals of program delivery and capacity planning teams.

Customer Experience

Rush Hour Rewards delivered a positive customer experience and achieved high customer satisfaction.

Most test group respondents were satisfied with the program (91%). In the open-end comments, test group respondents most often mentioned that the program is helpful to the customer (25%), works well (23%), and saves money (21%). As suggestions for program improvement, they mentioned increasing the incentive amount (30%), sending earlier pre-event notifications (14%), and providing a different incentive structure (13%).

The load control events did not adversely affect comfort for most customers.

Sixty-two percent of test group respondents said they noticed the summer events. Most noticed the events because of the event message display on the Nest thermostat (72%) and the event notification from the smartphone app (65%) rather than because of a change in temperature (36%). Moreover, before the events, 95% of respondents said their home's interior temperature was comfortable. During the events, 82% said they were comfortable, a significant decrease compared to the comfort level before the events; nevertheless, a majority reported feeling comfortable during the events.

Sending a pre-event notification makes the events significantly more noticeable for customers.

On average, test group respondents perceived 6.3 events out of the eight events called during the summer. Respondents likely perceived close to the actual number of events called because Nest sent pre-event notifications to customers via the Nest thermostat screen and app. This hypothesis is supported by the fact that Ecobee and Honeywell did not send out pre-event notifications to its test group customers for Connected Savings, and these respondents perceived 4.8 events, significantly fewer than did Rush

Hour Rewards' respondents. Furthermore, Nest allows Rush Hour Rewards participants to adjust their notification settings and opt out of receiving any event notifications. Most Rush Hour Rewards respondents (85%) said they were notified of the events prior to their occurrence, suggesting that either (1) most participants preferred to receive pre-event notifications, (2) many were not aware they could change their event notification settings, or (3) participants tend to not opt out the default option. While notifications increase event awareness, it is ambiguous whether awareness enhances or detracts from customer welfare and satisfaction.

A wider-range temperature setback instead of a one-size-fits-all temperature setback may make for a more comfortable event experience.

Rush Hour Rewards and Connected Savings achieved similar program satisfaction results but differed in perceived comfort during events. Rush Hour Rewards' test group respondents were significantly more comfortable during events (82%) than Connected Savings' test group respondents (74%). This difference may be explained by the temperature setback strategy used by Nest versus Whisker Labs. Nest deployed a one- to five-degree setback specifically to each customer's comfort preferences and home thermal properties. Whisker Labs calibrated a three-degree one-size-fits-all setback that did not accommodate customer preferences.

PGE incurs a small decrement to customer satisfaction when smart thermostats are controlled.

Most test and control group respondents were satisfied with the program, but a significantly higher proportion of control group respondents (96%) than test group respondents (91%) were satisfied. Most test and control group respondents were also satisfied with the $25 incentive, but significantly more control group respondents were satisfied (96%) than test group respondents (87%). These differences between groups can be explained by the fact that control group participants did not experience any events (that is, their thermostats were not controlled), yet they still received the $25 incentive. There was no decrement to customer satisfaction with PGE; the same proportion of test group (97%) and control group (97%) respondents were satisfied with PGE.

Customer Experience Recommendation

- PGE should work with Nest to send Rush Hour Rewards participants reminders about the ability to adjust the event notification settings. This recommendation speaks to the notion that some customers may benefit from event awareness while others may not. Reminding customers that they can customize their event notifications may further enhance customer satisfaction. PGE can send out the reminder via email, and Nest can send the reminder through the smartphone app. The program has been running for three years, and a reminder may be helpful in getting long-time participants to review their notification settings while introducing newer participants to the notifications feature.

Implementation

The program's maturity has minimized implementation challenges.

Now in its third year, Rush Hour Rewards did not encounter any major implementation challenges. Program marketing, recruitment, and event management worked well. The only challenge, though minor, that PGE encountered was about using Nest's trademark for online marketing. PGE developed and tested an online awareness campaign for the program using online ads, Google key word searches, and social media. PGE found that "Nest" was the best word to use for the online campaign, but it was not permitted to use "Nest" as a key word because of trademark legalities. As a result, PGE had to place its online campaign idea on hold. This minor online marketing challenge did not appear to impede program enrollment.

Nest's strong market presence and more frequent marketing likely enabled Rush Hour Rewards to increase enrollments.

By the end of summer 2018, 8,471 customers had enrolled in Rush Hour Rewards, an average of 3,068 customers per year. The high enrollment rate for Rush Hour Rewards may be attributed to Nest's large share of the smart thermostat market. Another possible reason is Nest's frequent marketing. Nest sends program promotions to eligible customers on a seasonal basis and employs search engine marketing and targeted social media ads to drive the sales of its thermostats. In contrast, Connected Savings only enrolled 1,662 customers in its first year. Ecobee and Honeywell, manufacturers of the thermostats used for Connected Savings, send marketing once a year.

Targeted marketing was possible for Rush Hour Rewards because the smart thermostat manufacturer and the DR service provider were the same party.

Nest is both the smart thermostat manufacturer and the DR service provider for Rush Hour Rewards. Therefore, Nest can collect run-time data from its own thermostats to determine the customer's HVAC system type and use these data to find eligible customers and conduct targeted marketing. This was a major advantage over Whisker Labs, the DR service provider for Connected Savings, which could not collect such data from Ecobee and Honeywell thermostats until the customer enrolled in the program.

Implementation Recommendation

- PGE should consider having Nest take the lead on marketing the program to customers, using its large market reach and frequent, targeted marketing approach. Having Nest take the lead on Rush Hour Rewards' marketing would allow PGE to take the lead on marketing Connected Savings.

Appendix A - Data Preparation

This appendix explains how Cadmus prepared the AMI meter data for analysis.

AMI Meter Data

Cadmus collected AMI meter data for the winter season from December 1, 2017 through February 28, 2018 and for the summer season from May 1, 2018 through October 2, 2018 for Rush Hour Rewards participant customers. The AMI data included a mix of 15- and 60-minute interval readings.

To prepare the data for analysis, Cadmus performed the following steps:

1. Removed a small number of duplicate interval readings from the data.
2. Summed 15-minute interval kWh consumption data to obtain hourly interval consumption
3. Dropped a small number of outliers and hourly observations missing one or more 15-minute interval readings.
4. Combined the consumption of meters connected to the same thermostat
5. Since all events occurred on weekdays in January or February 2018 in the winter 2017/2018 season and July or August 2018 in the summer 2018 season, Cadmus removed holidays, weekends, and days outside of these months from the analysis sample.
6. Adjusted time stamp from end-of-period to start-of-period.
7. Adjusted winter AMI data time stamps from universal standard time (UTC) to Pacific Standard Time (PST).
8. Dropped one customer with two thermostats assigned to different test groups.
9. Dropped customers missing all AMI data.

Data Exclusions

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 in the same home and these thermostats had been assigned to test and control groups
- Appeared in a list of test and control group customers who were rejected from the program for a variety of reasons

Cadmus did not exclude net-generation customers (i.e., customer-sited solar) but did confirm with PGE that the metering data recorded gross demand, not net demand, for electricity.

Table 79 shows Connected Savings summer 2018 participant attrition counts.

Table 79 Rush Hour Rewards Data Analysis Exclusions by Season

Filter	Participant Counts	
	Winter 2017/2018	Summer 2018
Initial Analysis Sample	**785**	**8,471**
Multiple Assignments	1	5
Missing AMI Data	64	335
Final Analysis Sample	**720**	**8,131**

Appendix B - Model Specifications

Cadmus estimated event demand impacts by comparing the hourly consumption of customers in the test and control groups. Using data for event and non-event hours during the summer season, Cadmus estimated a panel regression of customer hourly energy consumption on control variables for hour of the day, weather, and assignment to the test group. 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 6

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

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

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

γ_k = Average effect per customer of a CDH on customer consumption 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, ..., 8, 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, …, 8, 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, …, 8, and equals 0 otherwise

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

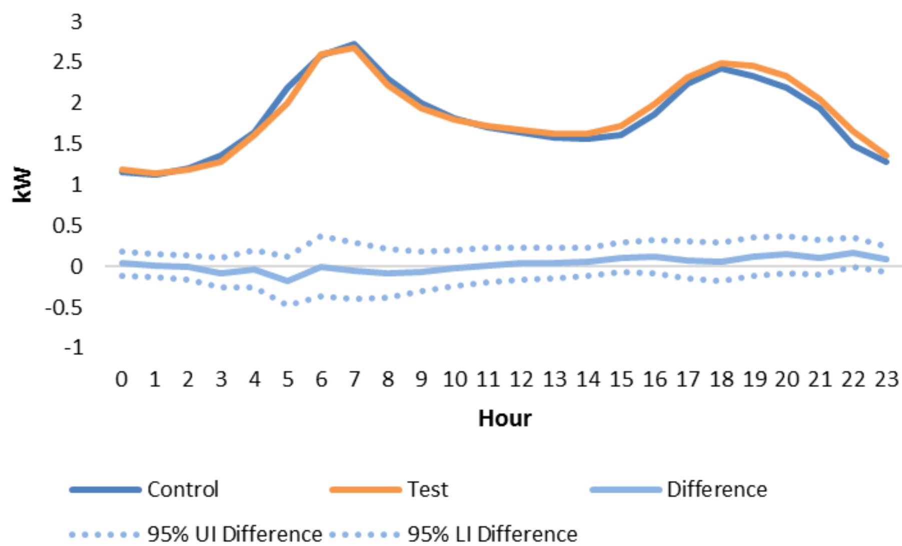
ε_{it} = Random error for customer 'i' in hour 't'

Cadmus estimated the panel model by OLS, clustering the standard errors on customers to allow within-customer correlation of hourly electricity consumption. The model included all non-holiday weekdays days in January or February 2018 for the winter 2017/2018 season and July or August 2018 for the summer 2018 season. To estimate average event hour savings or savings by event start time, Cadmus used the same specification as above, except that the pre-event hour, event hour, and post-event hour variables were not specific to the event number.

Appendix C - Equivalency Checks and Analysis Sample Summary Statistics

Figure 78 shows average consumption by hour on weekdays that were not event days or holidays during winter 2017/2018. It also plots the estimated difference and CIs around that estimate. The figure demonstrates that the difference between the two groups' consumption was small and statistically insignificant and that the randomized treatment and control groups were well-balanced. The balanced consumption suggests that the Rush Hour Rewards events did not affect consumption on non-event days, as would be expected.

Figure 78 Equivalency Consumption Plot – Winter 2017/2018



As a comparison, Figure 79, Figure 80, and Figure 81 show average consumption on 4 p.m. to 7 p.m., 5 p.m. to 8 p.m., and 7 a.m. to 10 a.m. event days, respectively. These plots present visual evidence of the impacts of events on customer demand without any modeling. The two-group's consumption remains balanced leading up to events, when each event's effects are then clearly demonstrable.

Figure 79 Average Consumption by Hour – Winter 2017/2018 (4 p.m. Events)

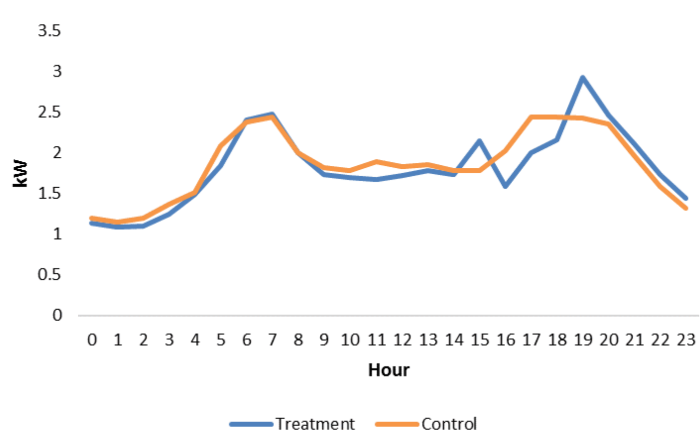


Figure 80 Average Consumption by Hour – Winter 2017/2018 (5 p.m. Events)

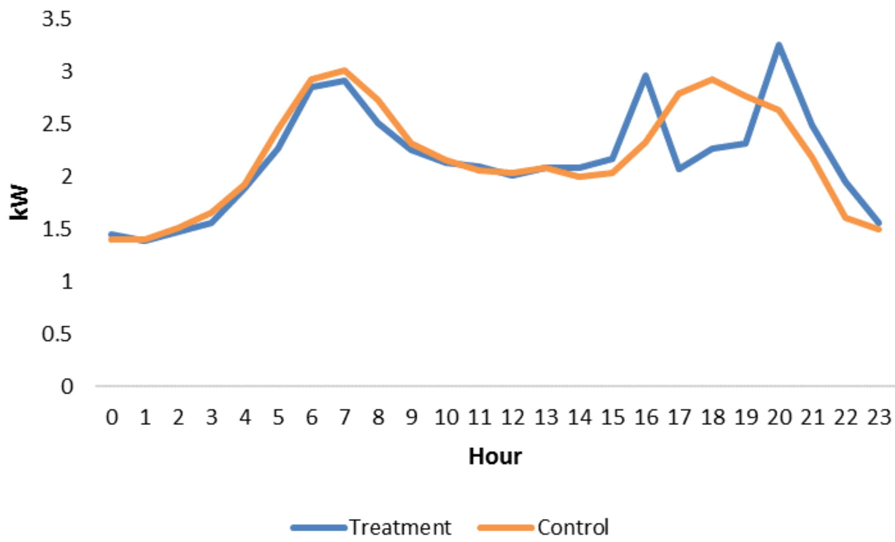


Figure 81 Average Consumption by Hour – Winter 2017/2018 (7 a.m. Events)

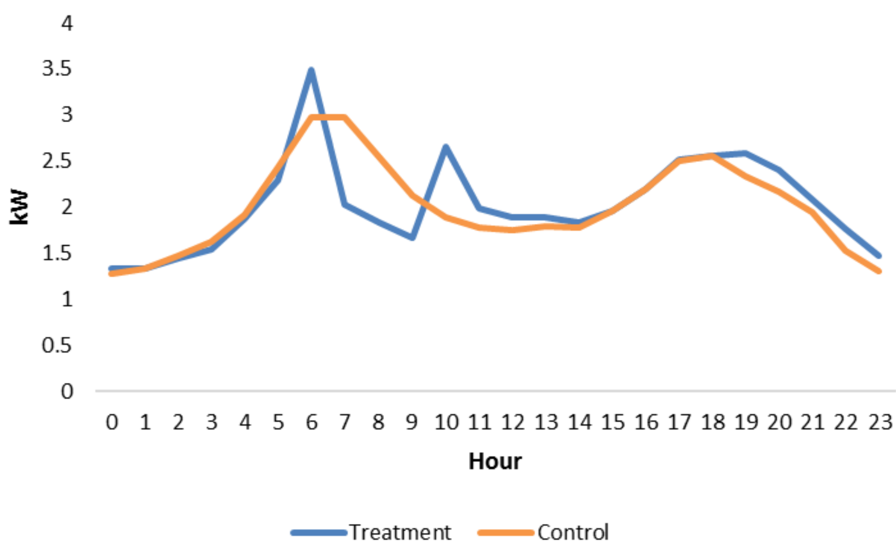
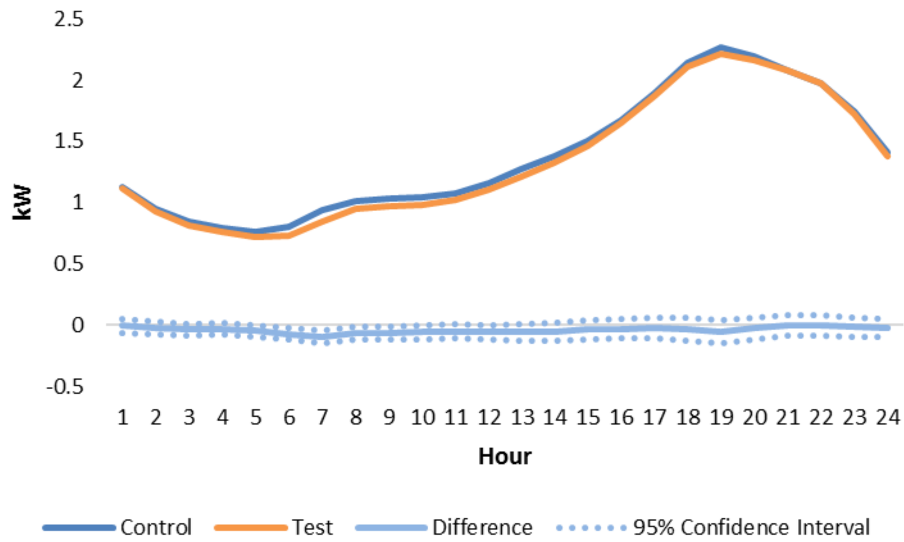


Figure 82 shows the equivalency plot for summer non-holiday and non-event weekdays. There were small but statistically significant differences between the randomized test and control groups during the morning hours but none during the afternoon and early evening hours when events occurred.

Figure 82 Equivalency Consumption Plot – Summer 2018



As a comparison, Figure 83 and Figure 84 plot the average demand per customer for customers in the test and control groups on days with events starting at 5 p.m. and 4 p.m., respectively. These plots present visual evidence of the impacts of events on customer demand without any modeling. The effects of pre-conditioning, temperature set back during events, and snapback are evident.

Figure 83 Average Consumption by Hour – Summer 2018 (5 p.m. Events)

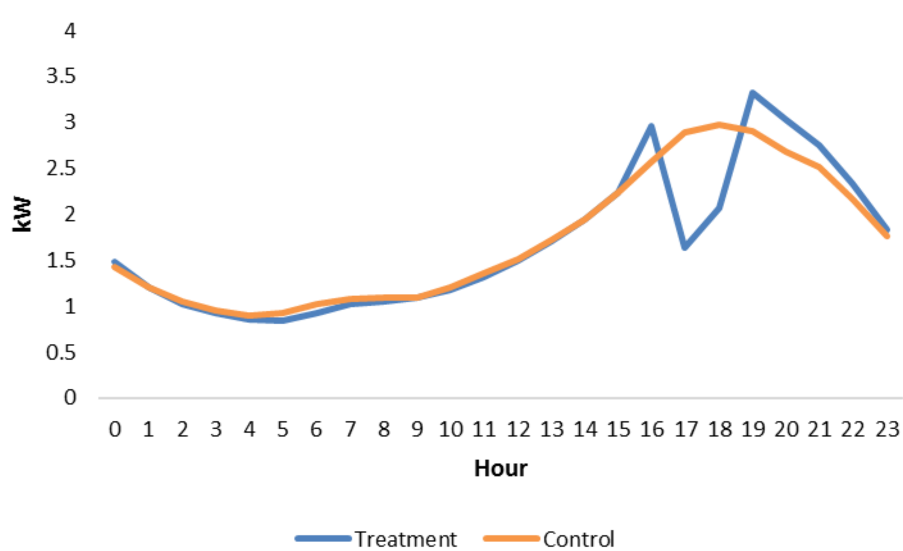
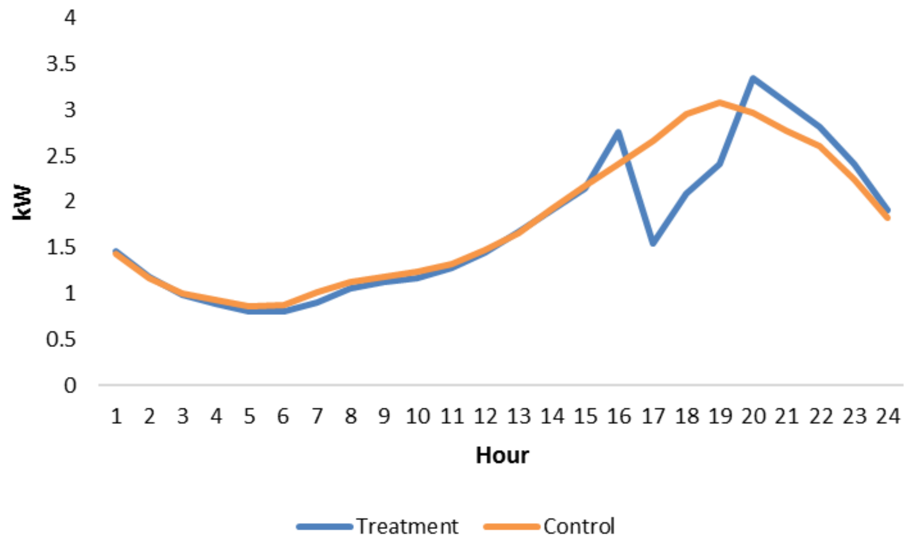


Figure 84 Average Consumption by Hour – Summer 2018 (4 p.m. Events)



Appendix D - Additional Impact Estimates

This appendix provides additional details about the pre-event and post-event demand impacts, including point estimates and conservation effect, for each season.

Winter 2017/2018

The following figures show the estimated demand impacts and baseline demand for winter events by the event start time. The estimated load impact is the estimated savings per customer from the event obtained from the regression model coefficients. Meter kW is metered customer demand from the AMI data. Model predicted is the customer load predicted by the regression model. The baseline is the counterfactual demand under the assumption that the event had not occurred. The model predicted, and counterfactual will only differ, if at all, during the one hour before the event, the event hours, and the eight hours after the event.

Figure 85, Figure 86, and Figure 87 present estimates of the average load impacts per hour per test group customer, by event start time. The figures show the model predicted loads, the estimated baseline, estimated load impacts, and the metered consumption.

Figure 85 Average Daily Load Impacts Per Participant – Winter 2017/2018 (4 p.m. Events)

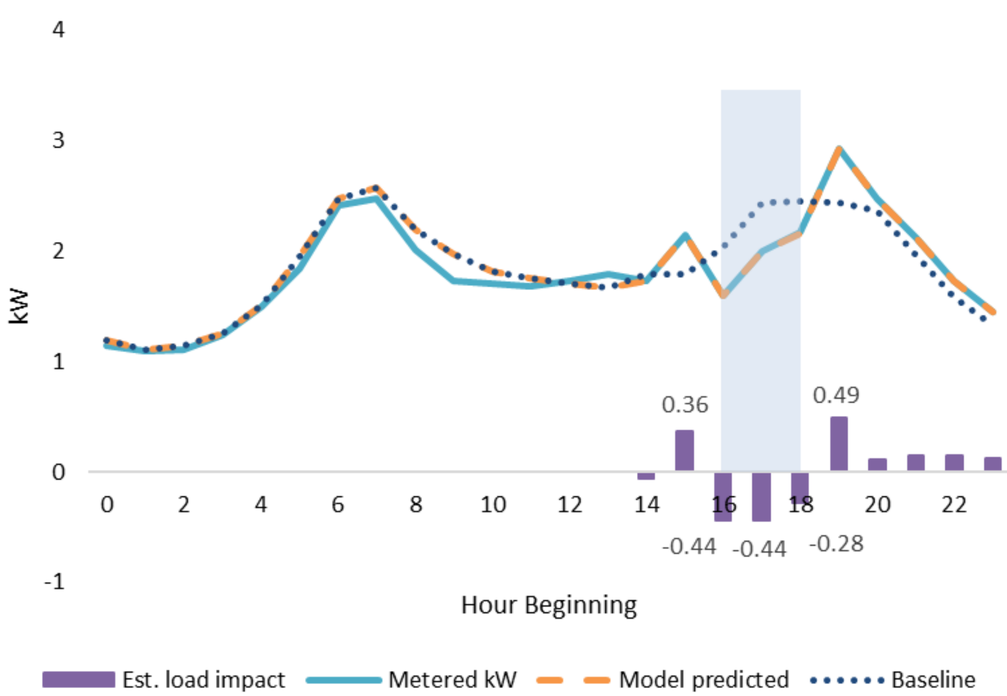


Figure 86 Average Daily Load Impacts Per Participant – Winter 2017/2018 (5 p.m. Events)

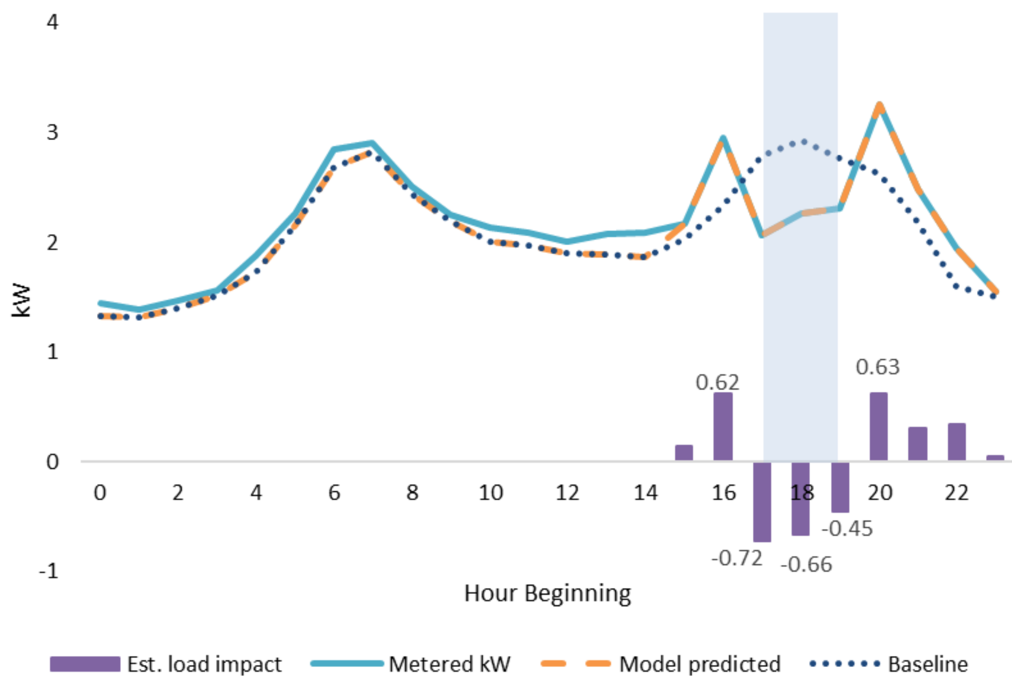


Figure 87 Average Daily Load Impacts Per Participant – Winter 2017/2018 (7 a.m. Events)

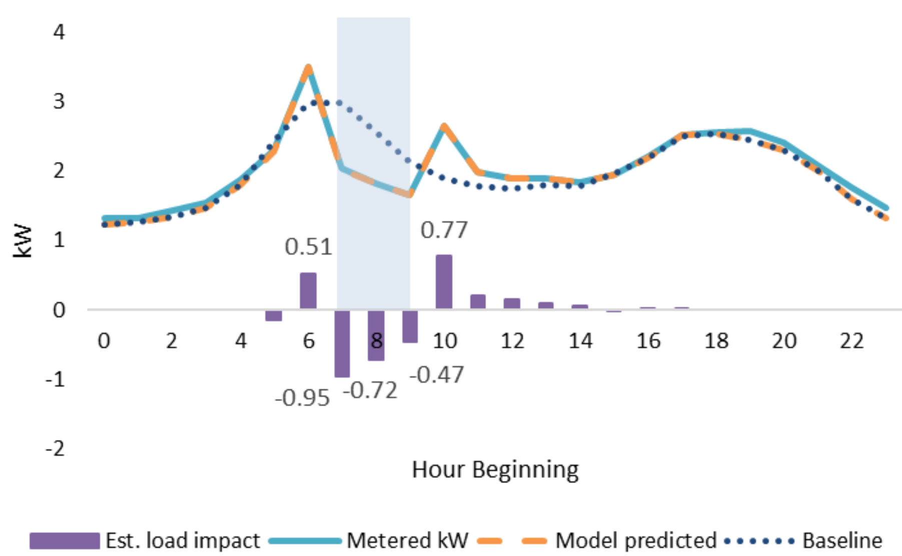


Table 80 provides the estimated load impacts and summaries for Rush Hour Rewards winter 2017/2018 events by start time. Table 81 shows the same information for every event.

Table 80 Load Impact Estimates by Event Start Time – Winter 2017/2018[170]

Event Hour	4:00 p.m. – 7:00 p.m. (1 event)	5:00 p.m. – 8:00 p.m. (4 events)	7:00 a.m. – 10:00 a.m. (3 events)
Pre-Event Hour 1	0.36**	0.62***	0.51**
Event Hour 1	-0.44***	-0.72***	-0.95***
Event Hour 2	-0.44**	-0.66***	-0.72***
Event Hour 3	-0.28*	-0.45***	-0.47***
Post-Event Hour 1	0.49***	0.63***	0.77***
Post-Event Hour 2	0.11	0.30**	0.21
Post-Event Hour 3	0.15	0.34***	0.14
Post-Event Hour 4	0.14	0.05	0.09
Event Avg. Demand Impact (kW)	**-0.39**	**-0.61**	**-0.72**
Event Hour Min. Demand Impact (kW)	**-0.28**	**-0.45**	**-0.47**
Event Hour Max. Demand Impact (kW)	**-0.44**	**-0.72**	**-0.95**
Avg. Energy Impact (kWh)	**-0.20**	**-0.27**	**-0.65**

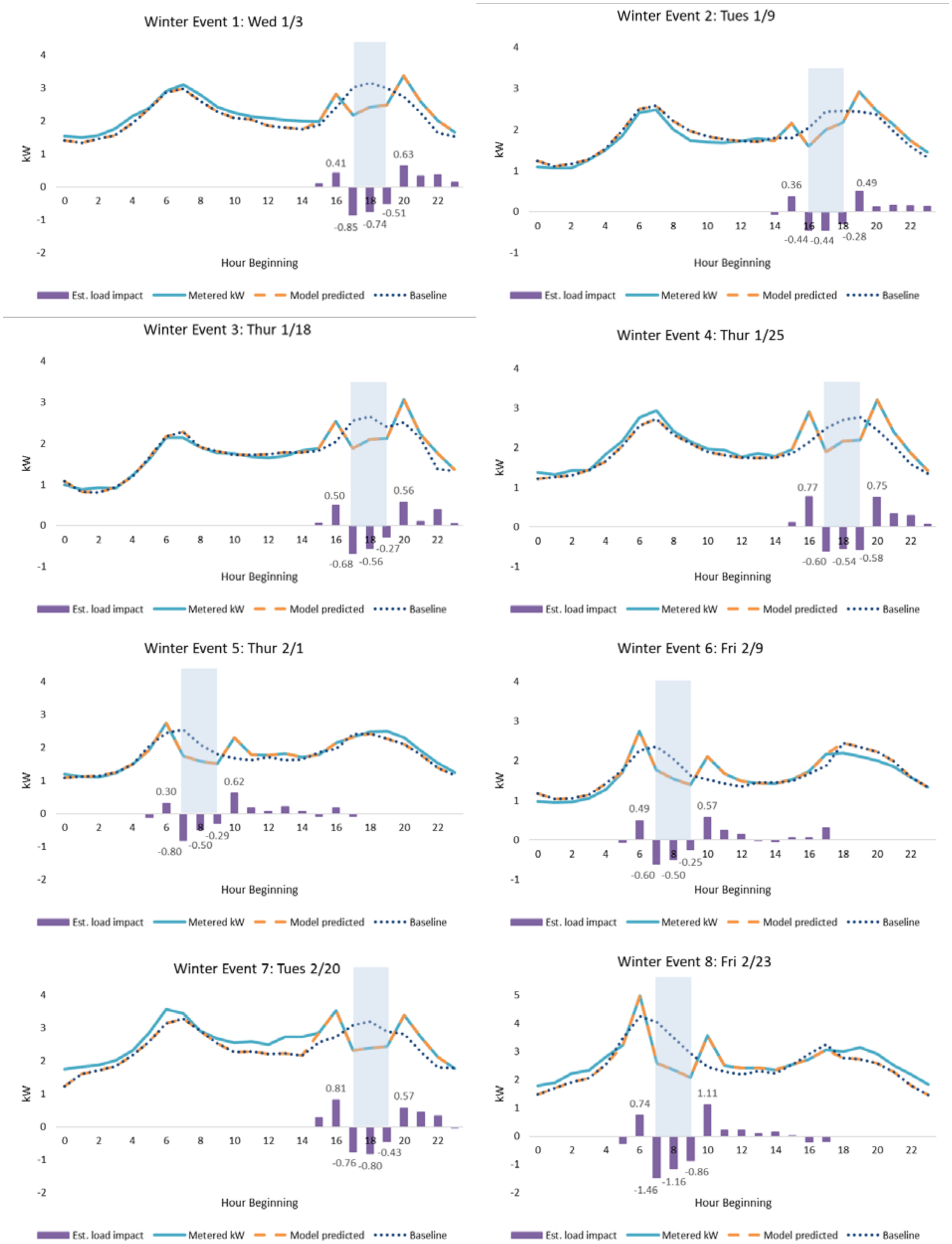
Table 81 Load Impact Estimates by Event – Winter 2017/2018[171]

Event Hour	Event							
	1	2	3	4	5	6	7	8
Pre-Event Hour 1	0.41**	0.36**	0.50***	0.77***	0.30	0.49**	0.81***	0.74**
Event Hour 1	-0.85***	-0.44***	-0.68***	-0.60***	-0.80***	-0.60***	-0.76***	-1.46***
Event Hour 2	-0.74***	-0.44**	-0.56***	-0.54**	-0.50***	-0.50***	-0.80***	-1.16***
Event Hour 3	-0.51**	-0.28*	-0.27	-0.58**	-0.29*	-0.25*	-0.43**	-0.86***
Post-Event Hour 1	0.63***	0.49***	0.56**	0.75***	0.62***	0.57***	0.57***	1.11***
Post-Event Hour 2	0.33*	0.11	0.10	0.34*	0.18	0.25*	0.44**	0.21
Post-Event Hour 3	0.37**	0.15	0.38***	0.29*	0.06	0.14	0.32**	0.23
Post-Event Hour 4	0.13	0.14	0.04	0.07	0.20	-0.01	-0.02	0.10
Event Avg. Demand Impact (kW)	**-0.70**	**-0.39**	**-0.50**	**-0.57**	**-0.53**	**-0.45**	**-0.66**	**-1.16**
Avg. Energy Impact (kWh)	**-0.73**	**-0.20**	**-0.34**	**0.14**	**-0.49**	**-0.04**	**-0.17**	**-1.42**

The thermostats are programmed to pre-cool homes in the hour leading up to events, and again after events, and consumption rebounds when thermostats return to their original setpoint. Cadmus determined the total energy impact of an event (shown in Table 80 and Table 81 as Average Reduction in kWh) by summing the pre-event hour, each event hour, and two post-event hour effects. Figure 88 provide detailed specific-event day impacts.

[170] 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 and 2 (demonstrating significance).
[171] Ibid.

Figure 88 Average Demand Impacts Per Participant for Winter Events



Summer 2018

Figure 89 and Figure 90 show the estimated demand impacts and baseline demand for summer events by the event start time. Each figure shows estimates of the average load impacts per customer, metered demand, estimated demand, and baseline demand.

Figure 89 Average Daily Load Impacts Per Participant – Summer 2018 (4 p.m. Events)

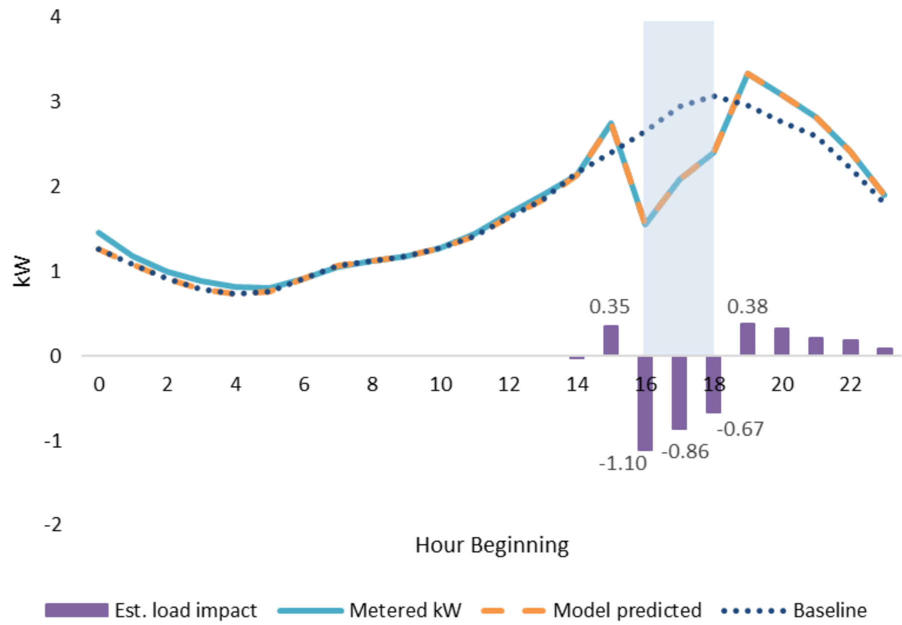


Figure 90 Average Daily Load Impacts Per Participant – Summer 2018 (5 p.m. Events)

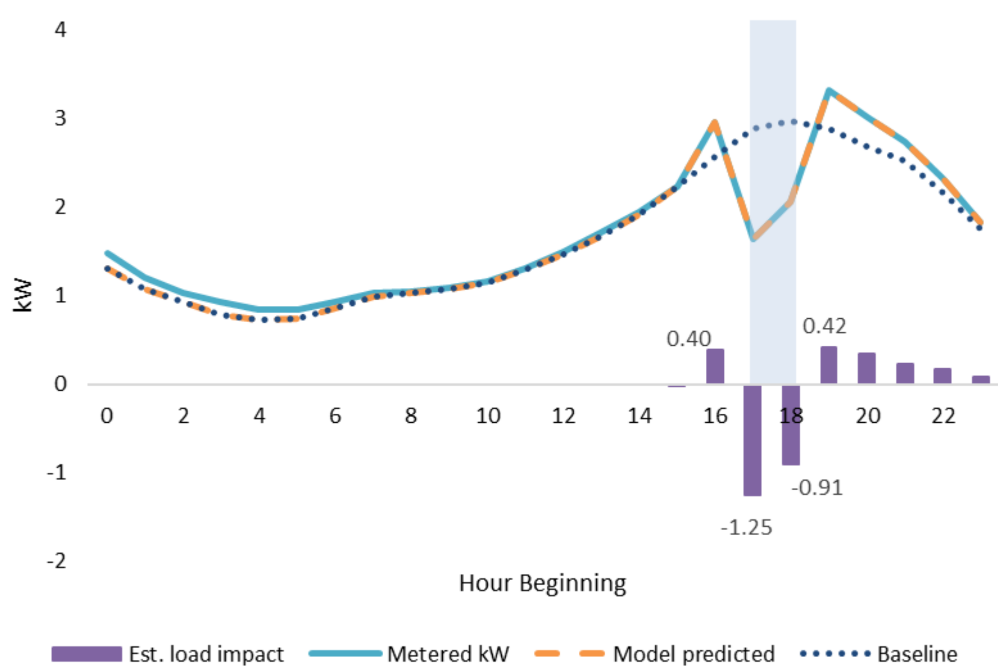


Table D-3 provides the estimated load impacts and summaries for Rush Hour Rewards summer 2018 events by start time. Table D-4 shows the same information for every event.

Table 82 Load Impact by Start Time – Summer 2018[172]

Event Hour	Summer 2018	
	4 p.m. to 7 p.m. (5 events)	5 p.m. to 7 p.m. (4 events)
Pre-Event Hour 1	0.35***	0.40***
Event Hour 1	***-1.10****	***-1.25****
Event Hour 2	***-0.86****	***-0.91****
Event Hour 3	***-0.67****	-
Post-Event Hour 1	0.38***	0.42***
Post-Event Hour 2	0.32***	0.34***
Post-Event Hour 3	0.21***	0.23***
Post-Event Hour 4	0.19***	0.17***
Event Avg. Demand Impact (kW)	**-0.88**	**-1.08**
Event Min Demand Impact (kW)	**-0.67**	**-0.91**
Event Max Demand Impact (kW)	**-1.10**	**-1.25**
Avg. Energy Impact (kWh)	**-1.18**	**-0.60**

Table 83 Load Impact by Event – Summer 2018[173]

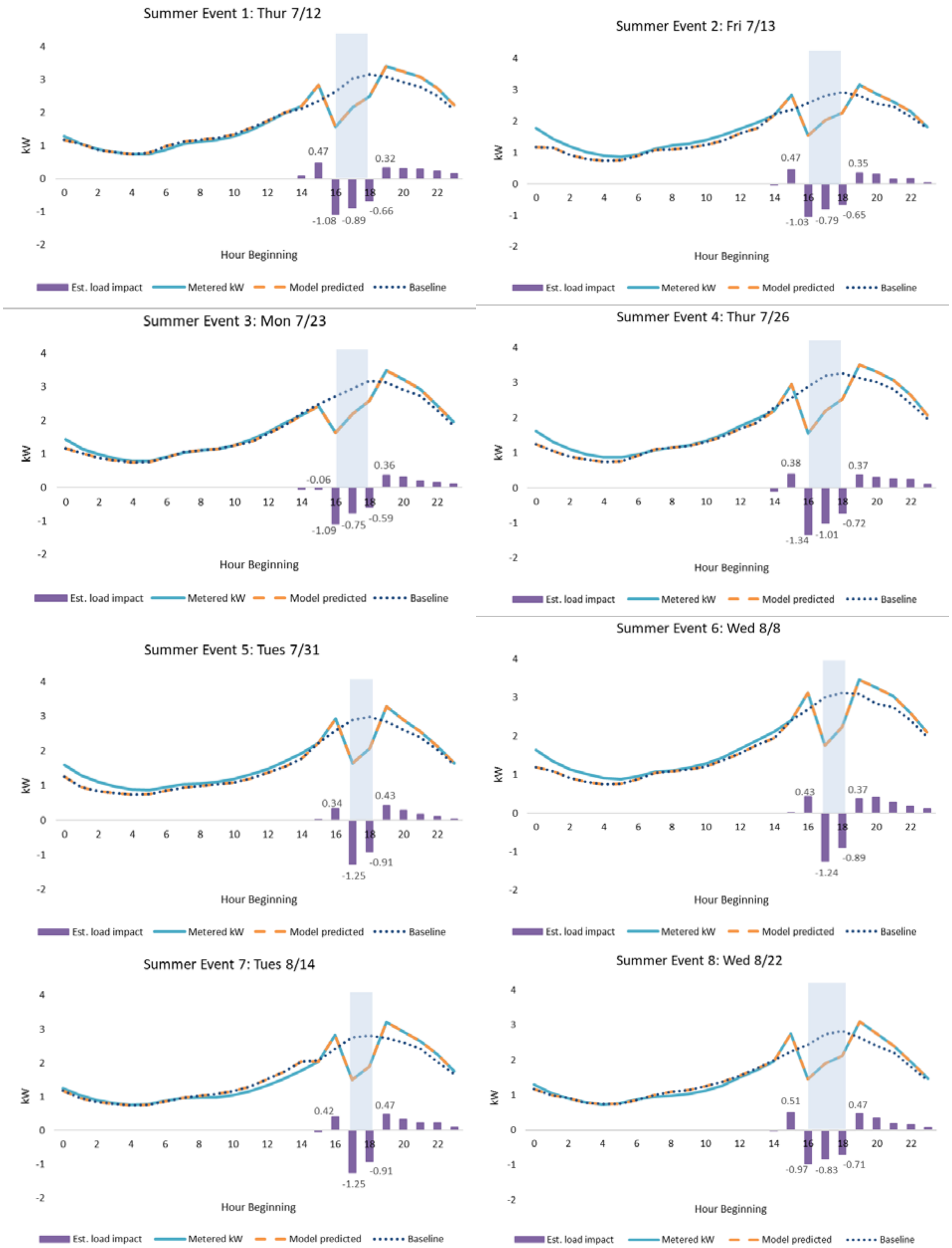
Event Hour	Event							
	1	2	3	4	5	6	7	8
Pre-Event Hour 1	0.47***	0.47***	-0.06	0.38***	0.34***	0.43***	0.42***	0.51***
Event Hour 1	***-1.08****	***-1.03****	***-1.09****	***-1.34****	***-1.25****	***-1.24****	***-1.25****	***-0.97****
Event Hour 2	***-0.89****	***-0.79****	***-0.75****	***-1.01****	***-0.91****	***-0.89****	***-0.91****	***-0.83****
Event Hour 3	***-0.66****	***-0.65****	***-0.59****	***-0.72****	-	-	-	***-0.71****
Post-Event Hour 1	0.32***	0.35***	0.36***	0.37***	0.43***	0.37***	0.47***	0.47***
Post-Event Hour 2	0.32***	0.32***	0.32***	0.30***	0.29***	0.42***	0.32***	0.35***
Post-Event Hour 3	0.29***	0.14*	0.20***	0.26***	0.17**	0.28***	0.22***	0.18***
Post-Event Hour 4	0.22***	0.17**	0.15**	0.25***	0.11	0.18***	0.22***	0.15***
Event Avg. Demand Impact (kW)	**-0.88**	**-0.83**	**-0.92**	**-1.03**	**-0.72**	**-1.07**	**-1.08**	**-0.84**
Avg. Energy Impact (kWh)	**-1.01**	**-1.03**	**-0.87**	**-1.52**	**-0.83**	**-0.46**	**-0.51**	**-0.86**

Cadmus determined the total energy impact of an event (shown in Table D-3 and Table D-4 as Average Reduction in kWh) by summing the pre-event hour, each event hour, and four post-event hour effects. Since events starting at 4 p.m. lasted an extra hour, their total reduction is significantly higher (1.18 kWh) than for events that started at 5 p.m. (0.60 kWh). Figure 91 provide detailed specific-event day impacts.

[172] 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 1-4 (demonstrating significance).

[173] Ibid.

Figure 91 Average Demand Impacts Per Participant by Event



Previous Seasons' Experience Survey Results

Table E-1 provides the experience survey results from summer 2016, which was the last time Cadmus administered the experience surveys for Rush Hours Rewards.

Table E-1. Summer 2016 Experience Survey Results

Survey Topic	Test Group (n≤666)	Control Group (n≤389)
General event awareness	89% noticed events	--
Comfort during events	72% comfortable	--
Overriding events	28% overrode	--
Smart thermostat satisfaction	87% satisfied[174] 55% delighted	92% satisfied 69% delighted[175]
Incentive satisfaction	83% satisfied 52% delighted	89% satisfied[176] 69% delighted[177]
Program satisfaction	86% satisfied 51% delighted	87% satisfied 64% delighted[178]
Satisfaction with PGE	92% satisfied 48% delighted	95% satisfied[179] 51% delighted

Table E-2 provides the experience survey results from winter 2015/2016 for Rush Hours Rewards.

[174] Difference is significant with 90% confidence ($p \leq 0.10$).
[175] Ibid.
[176] Ibid.
[177] Ibid.
[178] Ibid.
[179] Ibid.

Table E-2. Winter 2015/2016 Experience Survey Results

Survey Topic	Test Group (n≤52)	Control Group (n≤65)
General event awareness	77% noticed events	--
Comfort during events	92% comfortable	--
Overriding events	11% overrode	--
Smart thermostat satisfaction	94% satisfied[180] 69% delighted	82% satisfied 60% delighted
Incentive satisfaction	92% satisfied 54% delighted	91% satisfied 73% delighted[181]
Program satisfaction	96% satisfied[182] 63% delighted	81% satisfied 67% delighted
Satisfaction with PGE	90% satisfied 48% delighted	98% satisfied 48% delighted

[180] Ibid.
[181] Ibid.
[182] Ibid.

Appendix F - Cadmus Evaluation of PGE's Connected Savings 2017-2018

EVALUATION REPORT

April 24, 2019

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Executive Summary

As presented in its *2016 Integrated Resource Plan*,[183] in the next several years, PGE expects to face a shortfall in generating capacity from the planned closure of its Boardman facility in 2020 and the expiration of wholesale power contracts. At the same time, PGE plans to increase its production of electricity from intermittent renewable energy resources to comply with the requirements of Oregon Senate Bill 1547. In consideration of these developments, PGE's *2016 Integrated Resource Plan* calls for the use of DR to help manage system peak loads and help integrate renewable energy resources. The plan sets a goal of adding DR capacity of 77 MW in winter and 69 MW in summer.

PGE designed the Smart Thermostat Demand Response program to help it manage residential summer and winter peak energy demand. Through the program, PGE can control cooling and heating loads of participating customers through set-point adjustments to their smart thermostats. Customers who own a smart thermostat can participate in the program through the BYOT component, while customers who do not already have a smart thermostat can participate through a Direct Install component.

In 2015, PGE launched Rush Hour Rewards, a BYOT smart thermostat demand response pilot program implemented by Nest, to test peak demand savings and customer acceptance of DR and to increase engagement with customers who already owned smart thermostats. In 2017, PGE expanded its BYOT offerings to include Ecobee and Honeywell smart thermostats through its Connected Savings program, which is delivered by Whisker Labs. As of November 2018, the BYOT Rush Hour Rewards and Connected Savings programs had enrolled approximately 10,881 customers and tested load control events over eight seasons.

This evaluation focuses on the Connected Savings program. PGE initiated eight load control events in winter 2017/2018 and nine events during summer 2018. In general, PGE called events on extreme weather days when residential electricity demand for air conditioning or space heating was higher than normal. Through meter data analysis, interviews with PGE and Whisker Labs program managers, and on-line customer surveys, the evaluation assessed the load impacts, program implementation, and customer experience.

[183] Portland General Electric. November 15, 2016. *2016 Integrated Resource Plan*. https://www.portlandgeneral.com/our-company/energy-strategy/resource-planning/integrated-resource-planning/2016-irp

Conclusions and Recommendations

Based on the evaluation findings, Cadmus came to several conclusions and recommendations, described below.

Load Impacts

Connected Savings achieved the expected summer capacity savings of 0.8 kW per participant. [184]

Participants achieved average savings of 0.84 kW (or 27% of baseline demand) for the summer 2018 season, which was approximately equal to PGE's planning value for smart thermostat DR savings per participant of 0.8 kW.

Significant degradation of savings occurred across event hours.

Across all summer 2018 events, savings decreased by 0.4 kW or 37% between the first and second event hours, while three-hour events saw a further degradation of 0.7 kW or approximately 59% between the first and last event hour. Because of degradation of demand savings over the hours of events, the average savings understates the available capacity during the first event hour and overstates available capacity during the last event hour. By working with its DR service providers to implement IDR strategies, PGE may be able to avoid savings degradation. There may be opportunities for PGE to work with its DR service providers to optimize event dispatch and control algorithms to better meet its capacity needs.

Connected Savings load control events increased customer loads before and after events but did not result in a negative conservation effect.

Loads increased by an average of 6% before events due to pre-conditioning and up to 12% after events due to snapback. However, the pre-conditioning and snapback did not lead to an increase in energy consumption on event days.

Connected Savings moved PGE closer to reaching its goal of 25 MW of DR capacity from residential smart thermostats by 2021.

In summer 2018, Connected Savings had 1,662 participants and realized averaged demand savings of 0.7 MW per event hour. In combination with Rush Hour Rewards, PGE's residential smart thermostat program yielded an average demand savings of 7.6 MW per event hour for the summer 2018 event season.

[184] Cadmus did not evaluate the load impacts for Connected Savings in winter 2017/2018. Several issues prevented the impact analysis for this season. One issue was that control group customers experienced load control events. Another issue was that many customers who did not have electric heat were included in the winter 2017/2018 season, and these customers could not be reliably identified after an event.

In summer, PGE can expect the same demand savings per customer from Connected Savings and Rush Hour Rewards participants.

There were no statistically significant differences in savings between thermostat brands (Ecobee, Honeywell, and Nest). The average savings of 0.84 kW for Connected Savings customers aligned with the average savings for Rush Hour Rewards participants (0.93 kW) for summer 2018.

Load Impact Recommendations

- PGE should continue recruiting customers for BYOT Connects Savings, provided it represents a cost-effective resource.
- PGE should continue to test IDR control algorithms to maintain a constant level of demand savings and to avoid degradation of savings across event hours.
- PGE should coordinate internally to ensure well-defined objectives, design, and key metrics of event dispatch that align goals of program delivery and capacity planning teams.
- PGE should work with the program implementer to improve the approach to validating customer heating system type and HVAC configuration to ensure only appropriately configured HVAC system participate during the winter season.

Customer Experience

Connected Savings delivered a positive customer experience and achieved high customer satisfaction.

Most respondents said the online enrollment process was clear (91%), easy (87%), and quick (86%). Most test group respondents were satisfied with the program (89%). Test group respondents most often mentioned in the open-end comments that the program works well (33%), saves money (20%), and is helpful to the customer (16%). As suggestions for program improvement, test group respondents mentioned sending event notifications in advance (14%), sending notifications or program information via text or email (12%), and increasing the incentive amount (11%).

The load control events did not adversely affect comfort for most customers.

Fifty-eight percent of test group respondents said they noticed the summer events. Most noticed the events because of the event message display on the smart thermostat (72%) rather than because of a temperature change (52%) or the event notification from the smartphone app (19%). Moreover, before the events, 92% of respondents said their home's interior temperature was comfortable. During the events, 74% said they were comfortable, a significant decrease compared to the comfort level before the events; nevertheless, a majority reported feeling comfortable during the events.

Not sending a pre-event notification makes the events less noticeable for customers.

On average, test group respondents perceived 4.8 events out of the nine events called during the summer. Respondents likely perceived far fewer events than were called because Ecobee and Honeywell did not send any pre-event notifications to customers. This hypothesis is supported by the fact that Nest did send out pre-event notifications to its test group customers for Rush Hour Rewards, and Nest respondents perceived an average of 6.3 events, significantly more than perceived by Connected Savings' respondents. Some customers may benefit from receiving advance notifications, and PGE could consider giving Connected Savings participants the option of receiving them. Per customer feedback, 14% of survey respondents suggested PGE send event notifications in advance.

A wider-range temperature setback instead of a one-size-fits-all temperature setback may make for a more comfortable event experience.

Connected Savings and Rush Hour Rewards achieved similar program satisfaction results but differed in perceived comfort during events. Rush Hour Rewards' test group respondents were significantly more comfortable during events (82%) than Connected Savings' test group respondents (74%). This difference may be explained by the temperature setback strategy used by Nest versus Whisker Labs. Nest calibrated a one- to five-degree setback specifically to each customer's comfort preferences. Whisker Labs calibrated a three-degree one-size-fits-all setback that did not accommodate customer preferences.

PGE incurs a small decrement to customer satisfaction when smart thermostats are controlled.

Most test and control group respondents were satisfied with the program, but significantly more control group respondents were satisfied (96%) than test group respondents (89%). Most test and control group respondents were also satisfied with the $25 incentive, but significantly more control group respondents were satisfied (95%) than test group respondents (84%). These differences between groups can be explained by the fact that control group participants did not experience any events (that is, their thermostats were not controlled) and still received the $25 incentive. There was no decrement to customer satisfaction with PGE; a similar proportion of test group (94%) and control group (97%) respondents were satisfied with PGE.

Customer Experience Recommendation

- PGE and Whisker Labs should consider giving Connected Savings participants the option to receive pre-event notifications. Giving customers this option may further enhance customer satisfaction and would be responsive to the feedback of some customers. However, PGE should also weigh the costs of providing advance notifications, which could include lowered event participation, smaller savings, and reduced customer satisfaction.

Implementation

The lack of existing data on customers' smart thermostats and HVAC systems resulted in program marketing and recruitment challenges.

Unlike Nest who serves as both the smart thermostat manufacturer and the DR service provider, Connected Savings utilizes two different parties. Whisker Labs, the DR service provider for Connected Savings, could not collect data from Ecobee and Honeywell thermostats until the customer enrolled in the program. As a result, PGE did not know which customers had smart thermostats, which type they had, and what the home's HVAC system was *prior* to program enrollment. Most customer data came *after* customers had enrolled in the program and answered program eligibility questions. This severely limited PGE's ability to target program marketing to potential eligible customers. PGE did employ existing customer research on segmentation and used the Energy Trust of Oregon's smart thermostat rebate data to fill in some of the data gaps.

The average delay between when a customer installs a smart thermostat and when the customer enrolls in the program suggests an opportunity to accelerate enrollment.

Forty percent of recruitment survey respondents said they enrolled in Connected Savings within one month after installing their thermostat, and 36% said they enrolled more than one year after installation. Of the respondents who took longer than one month to enroll, 74% said the reason they did not enroll sooner was that they did not know about the program. These results reflect the smart thermostat manufacturers' original practice of marketing the program only once per year—that is, very few customers enrolled in the period between one month and one year after installation. PGE later worked with Ecobee and Honeywell to send out marketing emails on a quarterly basis to increase enrollment; the outcomes of marketing the program more frequently has yet to be evaluated.

PGE's own marketing efforts engaged customers more than marketing efforts from the smart thermostat manufacturers.

PGE employed the smart thermostat manufacturers' emails, the PGE website, and PGE emails to recruit customers. Of the three marketing efforts, customers took notice of PGE's marketing more than the manufacturers' marketing. When asked how they heard about the program, recruitment survey respondents most often said an email from PGE (48%), an email from a manufacturer (21%), and the PGE website (19%). PGE worked with the manufacturers to increase emails about the program from once a year to quarterly; however, PGE did not mention if it increased its own program email marketing efforts.

Customer education is needed about the connection of DR to smart thermostats.

Most respondents said they were aware of the concept of peak demand prior to enrolling (86%), but only one-third (37%) said they were aware of its connection to smart thermostats. Increasing awareness of this connection would strengthen program awareness and possibly boost enrollment. PGE acknowledged that educating customers about DR is critical to meeting its megawatt goal, but it was unable to conduct an awareness campaign prior to launching the Connected Savings program. PGE plans to educate the public on DR through mass-market channels (TV, social media, radio, and new articles). Currently, PGE provides education in the Direct Install program, for which installation technicians provide one-on-one education about smart thermostats and DR to customers.

Implementation Recommendations

- PGE should consider taking on a greater lead role on mass marketing Connected Savings to customers via email and direct mail, rather than relying on the manufacturers. The manufacturers can then focus on pushing out program promotions to eligible customers via the smartphone app, a channel PGE does not have access to or control over.
- PGE should increase marketing efforts specifically at the point of sale or point of installation. This could include the following:
  - Partnering with local retailers that carry smart thermostats to display program promotions
  - Partnering with local thermostat installation contractors to promote the program during the installation process
  - Intercepting customers about the program offering in an online marketplace
- PGE should develop educational content that emphasizes the smart thermostat's connection to DR. Rather than using words to explain, consider presenting engaging visuals such as an infographic flowchart or a short video that clearly illustrates the relationship.

Introduction

In the next several years, PGE will face a shortfall in generating capacity from the planned closure of its Boardman facility in 2020 and the expected expiration of wholesale power contracts. At the same time, PGE plans to increase its production of electricity from intermittent renewable energy resources to comply with the requirements of Oregon Senate Bill 1547. In consideration of these developments, PGE's *2016 Integrated Resource Plan* calls for the use of dispatchable resources including DR to help manage system peak loads and integrate renewable energy resources. The plan sets a goal of adding DR capacity of 77 MW in winter and 69 MW in summer.

Residential customers participating in DR programs will provide an important source of PGE's future DR capacity. These programs use price signals, load control, behavior-based treatments, or combinations of these to encourage customers to reduce demand during periods when it is costly for the utility to supply or distribute electricity.

DR represents a fundamental shift in a utility's relationship with its customers. Customers participating in DR programs do not simply consume utility-supplied electricity: they also provide peak capacity to utilities. To take full advantage of this evolving "prosumer" role, PGE will need to offer its customers new retail electricity rates or other incentives as well as compelling education, marketing, and program experience to encourage customers to participate.

In 2017, PGE launched Connected Savings, a BYOT smart thermostat DR program implemented by Whisker Labs, to test peak demand savings and customer acceptance of DR for customers with Ecobee and Honeywell smart thermostats. This program builds on PGE's success with the Rush Hour Rewards BYOT DR program for customers with Nest thermostats, launched in 2015. PGE seeks to understand insights into delivery, customer acceptance, satisfaction, and savings between the programs and to lay the groundwork for a future where most of its residential customers participate in DR programs.

For this evaluation, Cadmus assessed the design and delivery, load impacts, and customer experiences of Connected Savings in the winter 2017/2018 and summer 2018 event seasons. PGE tested smart thermostat DR using randomized controlled trials (RCTs), which provided highly credible evidence about the program treatment effects. The evaluation provides PGE with valuable information about the program's performance and presents insights that can be used to optimize PGE's future DR program offerings.

Program Description

PGE designed the Smart Thermostat Demand Response program to help manage residential summer and winter loads during hours of peak electricity demand. Through the program, PGE can enable load control of cooling and heating through participating customers' smart thermostats.

Bring-Your-Own Thermostat

The Smart Thermostat Demand Response program has two approaches to enroll customers: BYOT for customers who already own a smart thermostat and Direct Install for customers who do not own one (Figure 92). PGE launched the program in 2015, first as BYOT, recruiting customers who already owned a Nest thermostat to enroll in Rush Hour Rewards – the name that the DR service provider Nest used to market its program. PGE launched Rush Hour Rewards first because of Nest's dominant share of the smart thermostat market. In 2017, PGE extended the program and began recruiting customers with Ecobee, Honeywell Lyric, and other Honeywell Wi-Fi-enabled thermostats to enroll in Connected Savings, which is marketed by the DR service provider Whisker Labs. Connected Savings aimed to increase PGE's DR capacity further by leveraging the growing number of customers with a non-Nest thermostat.

Connected Savings

Figure 92 summarizes the BYOT Connected Savings Smart Thermostat Demand Response program design (in yellow) and shows how it differs from Rush Hour Rewards and Direct Install.

Figure 92 BYOT Connected Savings Smart Thermostat Demand Response Program Design

Bring-Your-Own Thermostat		Direct Install
Launched in Fall 2015	Launched in Fall 2017	Launched in Summer 2018
Customer already owns or purchases/installs their own… Nest	Customer already owns or purchases/installs their own… Ecobee, Honeywell Lyric, Honeywell other	Customer receives free or discounted… Nest, Ecobee …and free installation
Customer self-enrolls in **Rush Hour Rewards** and receives $25 for enrolling	Customer self-enrolls in **Connected Savings** and receives $25 for enrolling	Installation technician enrolls the customer in **Rush Hour Rewards or Connected Savings**
Customer receives $25 incentive per demand response season for event participation	Customer receives $25 incentive per demand response season for event participation	No incentives for event participation; customer agrees to a five-year commitment

Connected Savings operates similarly to Rush Hour Rewards but differs from Direct Install in which customers are eligible to participate and the incentives participants receive.

Goals and Objectives

PGE established several goals and objectives for the Smart Thermostat Demand Response program:

- Implement the program over winter and summer seasons by calling six to 10 peak demand events per season

- Enroll 24,000 customers by 2019
- Obtain customer participation in at least 50% of event hours per season
- Achieve positive customer experiences and high customer satisfaction
- Realize a demand reduction goal of 25 MW by 2021

Implementation

This section describes the implementation of BYOT Connected Savings.

Marketing and Recruitment

PGE and the smart thermostat manufacturers, Ecobee and Honeywell, began marketing Connected Savings to customers in fall 2017 and continue work together to market it. The marketing channels and strategies differed based on the target audience:

- **Customers who already have a qualifying smart thermostat.** Manufacturers sent out Connected Savings promotions via email and app notifications once a year to PGE customers who purchased or installed a qualifying smart thermostat. Because the manufacturers' privacy policies prohibit sharing customer information, PGE could not market Connected Savings directly to customers who had a qualifying smart thermostat.

- **Customers who have yet to purchase a qualifying smart thermostat.** To get these customers to purchase a smart thermostat, PGE promoted Ecobee and Honeywell smart thermostats on its website and sent out sales promotions via email. These sales promotions described Connected Savings and incentive offers, and marketing was ramped up during holiday periods such as Black Friday and Father's Day. PGE also collaborated with the Energy Trust of Oregon and promoted its $50 discount coupon toward the purchase of an Ecobee smart thermostat. PGE also marketed the sales of smart thermostats and Connected Savings promotions on its social media channels and paid online ads.

To encourage customers to enroll in Connected Savings, PGE offered a one-time $25 enrollment incentive. Customers received a $25 check in the mail after PGE verified the customer's program eligibility.

Enrollment Process

The promotion emails, direct mail, and web content directed customers to the Connected Savings enrollment web portal hosted by Whisker Labs. The portal's main page provided program information in a frequently-asked-question format. To enroll, customers logged in with their smart thermostat account credentials, entered their utility account information, and answered questions about their HVAC system to confirm program eligibility. Whisker Labs gave PGE the list of enrollees. PGE reviewed the list and approved the enrollees, then mailed the $25 enrollment incentive check a few weeks later.

Program Eligibility Requirements

To be eligible for Connected Savings, customers had to meet several 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 qualifying Ecobee smart thermostat, Honeywell Lyric smart thermostat, or Honeywell Wi-Fi thermostat installed that controls the HVAC system in the home
- Have a Wi-Fi network in the home

Participant Enrollments

Table 78. Connected Savings Participant Enrollments shows the participant enrollment counts, by brand and HVAC system, for the winter 2017/2018 and summer 2018 seasons. These participant counts reflect the approximate total enrollees as of the end of each event season (February 2018 and September 2018, respectively).

Table 84. Connected Savings Participant Enrollments

Category	Winter 2017/2018		Summer 2018	
	Count	Percentage of Total	Count	Percentage of Total
By Brand				
Ecobee	171	45%	732	44%
Honeywell Lyric	25	7%	90	5%
Honeywell Other	188	49%	840	51%
By HVAC System				
Central Air Conditioner	N/A	0%	1,358	81%
Heat Pump	384	100%	304	19%
Electric Furnace	0	0%	0	0%
Overall	**384**	**100%**	**1,662**	**100%**

Event Management

PGE contracted with Whisker Labs to provide the DRMS and load data aggregation services. Whisker Labs set up an online management platform, on which PGE can review the enrollment counts, check load forecasts, schedule events, and download data. When PGE was ready to call an event, it used the online management platform to schedule the event one day ahead. Once Whisker Labs received the event dispatch, it sent out Wi-Fi signals to adjust the smart thermostats settings on the event day.

The OPUC requires PGE to call six to 10 events per season. Events lasted two to three consecutive hours and occurred on weekday (non-holiday) afternoons or mornings, when electricity demand for space conditioning was greatest (that is, on cold days during winter and hot days during summer). The winter 2017/2018 event season ran from December 1, 2017, through February 28, 2018. The summer 2018 event season ran from June 1, 2018, through September 30, 2018. As shown in Table 79, PGE called eight events in winter 2017/2018 and nine events in summer 2018.

Table 85. Connected Savings Load Control Events

Season	Event	Date	Avg. Outdoor Temp.[185]	Start Time	Duration (hours)
Winter 2017/2018	1	1/3/2018	39°F	5:00 p.m.	3
	2	1/9/2018	46°F	5:00 p.m.	2
	3	1/18/2018	43°F	5:00 p.m.	3
	4	1/25/2018	43°F	5:00 p.m.	3
	5	2/1/2018	44°F	7:00 a.m.	3
	6	2/9/2018	44°F	7:00 a.m.	3
	7 (snow day)	2/20/2018	35°F	4:00 p.m.	3
	8	2/23/2018	28°F	7:00 a.m.	3
Summer 2018	1	7/12/2018	94°F	4:00 p.m.	3
	2	7/13/2018	89°F	4:00 p.m.	3
	3	7/16/2018	92°F	5:00 p.m.	2
	4	7/23/2018	90°F	4:00 p.m.	3
	5	7/26/2018	92°F	4:00 p.m.	3
	6	7/31/2018	82°F	5:00 p.m.	2
	7	8/8/2018	90°F	5:00 p.m. (IDR)	2
	8 (fire day)	8/14/2018	88°F	5:00 p.m. (IDR)	2
	9 (fire day)	8/22/2018	83°F	4:00 p.m. (IDR)	3

= snow day

= fire day

= IDR

During the last three events of summer 2018, PGE tested IDR for the first time for Connected Savings. 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 includes regulating the dispatch of load control signals to avoid big changes in aggregate loads due to simultaneous pre-conditioning before the event, the event initiation, or snapback after an event.

Test group participants did not receive any event notifications prior to the event. However, during the event, all thermostats and the smartphone apps of test group customers displayed information that an event was in progress.

An hour before the event, Honeywell thermostats pre-conditioned the home (by raising the interior temperature in winter or lowering the interior temperature in summer) to increase thermal comfort and to maximize the size and duration of the event demand savings. Ecobee thermostats, on the other hand,

[185] Outdoor temperature is the average temperature during event hours.

did not allow pre-conditioning of the home in preparation for any events. During winter and summer events, Whisker Labs deployed similar thermostat temperature setback strategies. Table 66 shows a summary of the event orchestration details and differences by brand.

Table 86. Event Orchestration Details and Differences by Brand

Brand	Pre-Event Notification	Event In-Progress Notification	Pre-Conditioning before Event	Temperature Setback during Event
Ecobee	None	Displayed on thermostat screen and app	None	3°F lower in winter; 3°F higher in summer
Honeywell Lyric	None	Displayed on thermostat screen and app	2°F pre-heating in winter; 2°F pre-cooling in summer	3°F lower in winter; 3°F higher in summer
Honeywell Other	None	Displayed on thermostat screen and app	2°F pre-heating in winter; 2°F pre-cooling in summer	3°F lower in winter; 3°F higher in summer

Test group participants could override the load control during events by adjusting the thermostat settings or hitting the event cancel button. If customers participated in at least 50% of event hours during a season, they received a $25 incentive check. Control group participants also received a $25 incentive check per event season even though their thermostats were not controlled.

Only customers with a heat pump could participate in both winter and summer seasons and could earn up to $50 in incentives per year. Customers with an electric furnace (winter) or central air conditioner (summer) participate in only one season and could earn $25 in incentives per year. PGE mailed out incentive checks to participants six to eight weeks after the end of the season.

Evaluation Methodology

This section describes Cadmus' methodology for evaluating Connected Savings.

Evaluation Objectives

PGE specified five evaluation objectives for Connected Savings:

- Estimate the average kilowatt impact per 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 load impacts, customer comfort, and satisfaction between Connected Savings thermostat brands and to Rush Hour Rewards Nest thermostat impacts
- Identify opportunities for improving program marketing, customer recruitment, program performance, cost-effectiveness, and customer satisfaction

Evaluation Approach

Table 81 Connected Savings Evaluation Activities lists the Connected Savings evaluation activities and how they address the evaluation objectives. Each activity is described in greater detail in the subsequent sections.

Table 87 Connected Savings Evaluation Activities

Activity	Description	Corresponding Evaluation Objective(s)	Outcome
Research design	Pre-season random assignment of participants into test or control group	1, 2, 3, 4	Accurate and precise estimates of impacts
Data collection and preparation	Collect and prepare analysis of individual-customer AMI meter interval consumption data	1, 2, 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 Whisker Labs program staff to understand program implementation processes, successes, and challenges	5	Thorough understanding and documentation of the program design and implementation
Logic model	A graphic that outlines the relationships between program activities, outputs, and expected outcomes	5	Documentation of program activities, associated outputs, and short-term and intermediate outcomes
Customer surveys	Recruitment, event, and seasonal experience surveys with participants	3, 4, 5	Findings on customer engagement, event awareness, comfort, and satisfaction

The Connected Savings evaluation presented in this report covers winter 2017/2018 and summer 2018 event seasons. PGE also asked Cadmus to evaluate Rush Hour Rewards for winter 2017/2018 and summer 2018, which is presented in a separate report. Note that this Connected Savings evaluation report will refer to results obtained from the Rush Hour Rewards evaluation for comparison purposes.

Evaluation Design

To estimate the impacts of thermostat controls, Cadmus worked with PGE to implement Connected Savings as a RCT, which involved randomly assigning program participants (residential customers with smart thermostats who met eligibility requirements) to a test group or control group. Test group customers experienced load control events, while control group customers did not. Customers were not informed about which group they had been assigned. Savings were estimated by comparing the test and control group demand during event hours. As the gold standard in program evaluation, this RCT is expected to produce unbiased estimates of the program savings.

However, the initial winter 2017/2018 was not implemented as an RCT. Because of the program's late launch in September 2017 and relatively low enrollment in the first season, PGE randomly assigned only 48 customers to the control group. In addition, PGE inadvertently dispatched events to the control group customers. Thus, all enrollees in the winter 2017/2018 season experienced load control events, so there was no randomized control group to estimate baseline demand. Additionally, many customers were enrolled and misclassified as having electric heating equipment for the winter season, for which it was not possible to determine the correct heating equipment type at the time of this evaluation. Load impacts were difficult to detect, and it was not possible to estimate the savings per customer for homes that had electric heating equipment. Because of these complications, Cadmus did not estimate savings for Connected Savings during the winter 2017/2018 season.

The summer 2018 evaluation was implemented as an RCT, but PGE, not Cadmus, conducted the randomization. Cadmus validated the random assignment by comparing the pre-treatment mean consumption of customers in the test and control groups. Going forward, Cadmus will perform random assignments prior to each season, as described above.

Table 82 shows summer 2018 random assignments of customers overall, by brand, and by HVAC system.

Table 88. Connected Savings Participant Random Assignments – Summer 2018

Category	Test Group		Control Group	
	Count	Percentage of Total	Count	Percentage of Total
By Brand				
Ecobee	380	45%	352	43%
Honeywell Lyric	51	6%	39	5%
Honeywell Other	412	49%	428	52%
By HVAC System				
Central Air Conditioner	685	81%	673	82%
Heat Pump	158	19%	146	18%
Electric Furnace	0	0%	0	0%
Overall	**843**		**819**	

Data Collection and Preparation

Cadmus collected and prepared several types of data for analysis:

- ***Participant enrollment data***, provided by PGE, tracked enrollment for test 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-minute and 60-minute intervals, measured using AMI meters. For usage periods prior to enrollment, only hourly data were available.
- ***Local weather data,*** including hourly average temperatures from December 2017 through September 2018 for five 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 billing data.
- ***Event data,*** including dates and times of all load control events, by season, were provided by PGE.

The AMI meter data recorded a customer's electricity consumption at 15- or 60-minute intervals and covered every month in which an event occurred. Cadmus aggregated all 15-minute interval consumption data to the customer-hour level and performed standard data-cleaning steps (detailed in *Appendix A*) 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 this with the hourly interval consumption data.

Cadmus used the enrollment and participation data to identify customers in the test and control groups, to develop survey sample frames, and to calculate test opt-out rates. These data provided several key fields for each customer, including:

- Assignment to test or control group
- Dates for participant enrollment and un-enrollment date, if applicable
- Customer ID and address
- Service point active status (confirming meter activity)

Appendix A also describes Cadmus' solutions to these issues. Robustness checks of the Connected Savings test savings estimates indicate that the estimates were not sensitive to the specific solutions Cadmus developed.

Analysis Samples

In cleaning and preparing the AMI meter data, Cadmus encountered several issues that had to be addressed before the data could be analyzed (see *Appendix A* for more detail on sample attrition):

- The timestamps on some AMI datasets were set to Coordinated Universal Time instead of Pacific Time
- AMI data was not provided for all customers

Table 83 shows the initial and final analysis samples for the summer 2018 season. The initial analysis sample includes all customers who were randomly assigned to a test or control group and whose billing account remained active at the beginning of each Connected Savings season. Customers who opted out of the program, moved, or discontinued electricity service before the season began were excluded from samples. The final analysis sample includes customers used in the impact estimation and excludes a small number of customers who had two thermostats assigned to different groups or who were missing AMI data.

Table 89. Connected Savings Program Final Analysis Sample Sizes

Thermostat Type	Summer 2018		
	Initial Analysis Sample (n)	Final Analysis Sample (n)	Analysis Sample Percentage
Ecobee	732	663	91%
Honeywell	930	919	99%
Total	**1,662**	**1,582**	**95%**

Cadmus verified that there were not statistically significant differences in consumption between test and control group customers in the final analysis sample on non-event days. *Appendix C* provides detailed balance test results.

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 test and control groups during each event hour.

Cadmus estimated savings by collecting individual customer AMI interval consumption data and by comparing the demand of customers in the randomized test 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 eight hours after each event. In addition to assignment to test or control group, the panel regression controlled for the impacts of hour of the day, the day of the week, weather, and differences between customers in their average demand.

Cadmus estimated the models by OLS and clustered the standard errors on customers to account for correlations over time in customer demand. Cadmus estimated alternative model specifications to test the estimates' robustness to specification changes and found that the results were very robust. *Appendix B* provides a more detailed description of the savings estimation.

Staff Interviews

Cadmus conducted three interviews with PGE program managers and Whisker Labs managers. The PGE interviews included the program manager, the program marketer, and the residential market manager, each with a unique perspective of the program process and objectives. Interviews focused on documenting the history of Connected Savings, how it operates, implementation challenges, and successes or lessons learned to date. Cadmus used information obtained from the interviews to design the logic model and customer surveys.

Logic Model

A logic model defines the program theory and outlines how a program should be expected to succeed, given its design. A program theory articulates and documents a program's primary objectives and its core assumptions, while the logic model graphically outlines the relationships between program activities, outputs, and expected outcomes. The logic model serves as a useful tool for program staff, implementers, and evaluators to determine whether a program is operating according to its stated goals, and whether the program's activities/outputs are producing the outcomes to support its theory. Cadmus developed a logic model for Connected Savings based using program materials and information obtained from the staff interviews. After developing the logic model, Cadmus reviewed it against the evaluation findings to determine whether Connected Savings operated as intended.

Customer Surveys

Cadmus designed and administered three online customer surveys:

- Event Survey – Summer 2018 season (fielded in August 2018)
- Recruitment Survey (fielded in October and December 2018)
- Experience Survey – Summer 2018 season (fielded in November 2018)[186]

Survey Design

To provide PGE with timely customer feedback, Cadmus administered the **event surveys** with test group participants during summer 2018, specifically, 24 hours after the August 22 event. The event surveys asked test group participants about their event awareness, thermal comfort, reasons for overriding the load control, and satisfaction.

Cadmus designed the **recruitment surveys** to provide PGE with marketing, recruitment, and customer engagement insights as well as baseline satisfaction metrics. Customers who enrolled in Connected Savings between the last summer 2018 event and before any winter 2018/2019 events were contacted for the recruitment surveys. The survey asked how customers heard about the program, their motivations for enrolling, feedback on the enrollment process, awareness of DR, and satisfaction.

Cadmus administered the **experience surveys** to test and control participants a few days after they received their incentive check. The experience surveys asked test group participants about their event awareness, thermal comfort, reasons for overriding the load control, and satisfaction. Control group customers were only asked questions about satisfaction.

Each survey took respondents less than seven minutes to complete. Respondents did not receive an incentive or reward for completing the surveys.

Survey Sampling and Response Rates

Cadmus contacted the census of participants with an active PGE account at the time of survey fielding. Table 84. Customer Survey Samples and Response Rates: Event Survey – Summer 2018, Table 85, and Table 86 show the number of participants contacted, brand, HVAC system, and response rate for the three surveys. On average, the three surveys achieved a high response rate of 32% across brands and HVAC systems. Response rates did not differ for the most part by brand or by HVAC system. The recruitment survey yielded the highest response rate among the three surveys.

[186] Cadmus did not administer an experience survey for winter 2017/2018 because evaluation activities did not commence until August 2018. Surveying customers about past winter events in the middle of summer would have confused them, and their recollection of the winter event season may not have been accurate or reliable.

Table 90. Customer Survey Samples and Response Rates: Event Survey – Summer 2018

	Original Sample[187] (Number of Records)	Adjusted Sample (Successfully Emailed)	Number of Completes	Response Rate
By Brand				
Ecobee	47	47	17	36%
Honeywell Lyric	386	385	135	35%
Honeywell Other	355	354	141	40%
By HVAC System				
Central Air Conditioner	655	654	243	37%
Heat Pump	133	132	50	38%
Overall	**788**	**786**	**293**	**37%**

Table 91. Customer Survey Samples and Response Rates: Recruitment Survey

	Original Sample[188] (Number of Records)	Adjusted Sample (Successfully Emailed)	Number of Completes	Response Rate
By Brand				
Ecobee	143	136	50	37%
Honeywell Lyric	13	13	10	77%
Honeywell Other	148	148	64	43%
By HVAC System				
Central Air Conditioner	200	199	86	43%
Heat Pump	99	93	37	40%
Electric Furnace	5	5	1	20%
Overall[189]	**304**	**297**	**124**	**42%**

[187] Cadmus selected a census of records for the survey.
[188] Ibid.
[189] When the survey was administered, participants had not yet been randomly assigned to the test or control group.

Table 92. Customer Survey Samples and Response Rates: Experience Survey – Summer 2018

	Original Sample[190] (Number of Records)	Adjusted Sample (Successfully Emailed)	Number of Completes	Response Rate
By Assignment				
Test	806	803	218	27%
Control	802	799	233	29%
By Brand				
Ecobee	708	704	204	29%
Honeywell Lyric	85	85	27	32%
Honeywell Other	815	813	220	27%
By HVAC System				
Central Air Conditioner	1,312	1,309	360	28%
Heat Pump	296	293	91	31%
Overall	**1,608**	**1,602**	**451**	**28%**

Survey Data Analysis

Cadmus compiled frequency outputs, coded open-end survey responses, and ran statistical tests to determine whether survey responses differed significantly by assignment, brand, and to Rush Hour Rewards. Findings are presented in the next section under Customer Experience and Implementation Delivery.

Findings

This section provides detailed findings about Connected Savings demand savings, customer experience with the program, and program implementation challenges and lessons learned.

Load Impacts

Table 87 Connected Savings Demand Savings by Thermostat Type – Summer 2018 presents the average demand savings per customer during DR events. Across all event hours, the program reduces demand by an average of 0.84 kW per participant (27% of baseline demand). Demand savings is similar across the different thermostat brands, with Ecobee at 0.77 kW per participant (27%) and Honeywell at 0.88 kW per participant (26%). Overall, demand savings approximated PGE's summer planning value for BYOT smart thermostat DR of 0.8 kW per participant.

[190] Cadmus selected a census of records for the survey.

Table 93 Connected Savings Demand Savings by Thermostat Type – Summer 2018

Category	Sample Size (n of participants)	Estimated Baseline Load (kW)[191]	Evaluated Demand Savings[192]			
			kW savings per participant	Absolute Precision	Relative Precision	Percentage
Summer 2018						
Ecobee	663	2.90	0.77	±0.21	±27%	**27%**
Honeywell	919	3.36	0.88	±0.22	±25%	**26%**
Total	**1,582**	**3.16**	**0.84**	**±0.16**	±18%	**27%**

Summer 2018

During the Connected Savings summer 2018 season, PGE launched five events starting at 4 p.m. that lasted three hours and four events starting at 5 p.m. that lasted two hours.

Figure 93 presents the average kilowatt impacts per customer for one hour prior to the event, each event hour, and two hours after the event ended. Figure 79 show the corresponding percentage savings. The program achieved average demand savings of 0.78 kW for the three-hour events (4 p.m.) and 0.96 kW for the two-hour events (5 p.m.).

During summer events, savings peaked in the first hour, then diminished through the remaining hours, which follows a similar trend identified in previous evaluations of Rush Hour Rewards; however, the degradation was more extreme for the three-hour events (4 p.m.) than the two-hour events (5 p.m.). Between the first and second events hours, savings had decreased by 0.4 kW or approximately 37%, on average for all events. For three-hour events, the difference in savings between the first and third event hour was 0.7 kW or approximately 59%.

Pre-cooling and snapback increased participant loads before and after events. Pre-cooling of participant homes increased electricity demand by about 0.2 kW or 6% before afternoon events. After events ended, demand increased above usual levels, as thermostat settings returned to normal. After events, there was an increase in demand or snapback of between 0.3 kW and 0.4 kW per participant home or 10-12%. Demand remained statistically greater than normal for about four hours after the events ended.

[191] Estimated baseline is average control group consumption across all event hours.
[192] Impacts are estimated using premise AMI meter data. Cadmus calculated the percentage demand reduction as the kilowatt demand reduction estimate divided by average control customer's demand per hour across all events. Impact estimates are the percentage demand reduction during load control events; blue indicates significance at 95%.

Figure 93 Average kW Demand Savings by Event Start Time – Summer 2018[193]

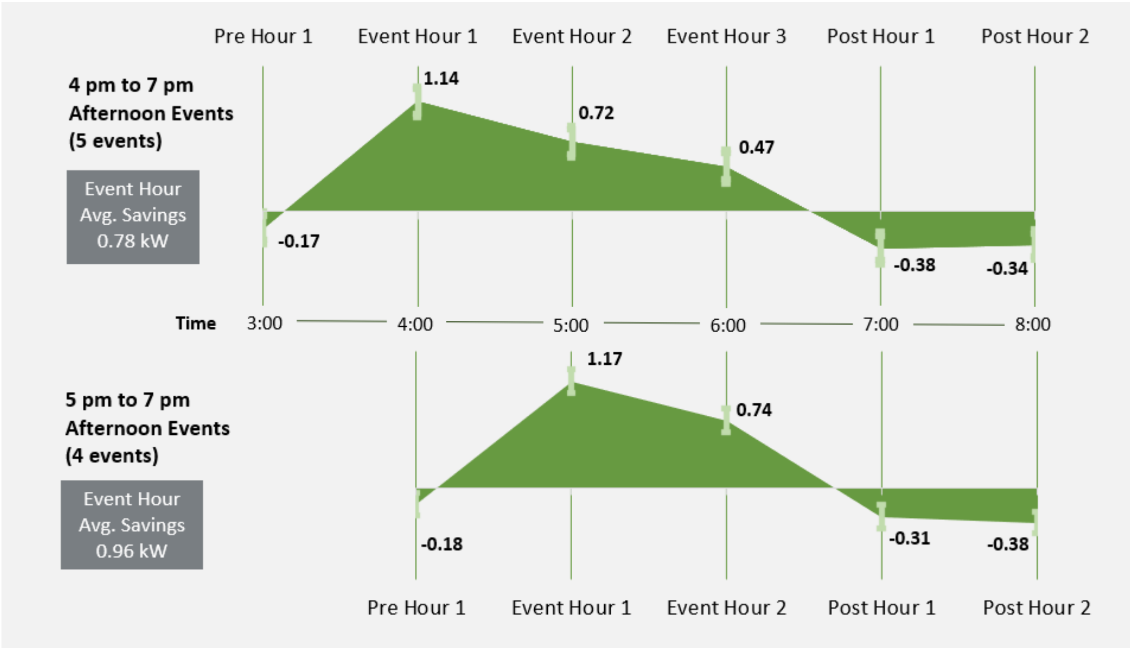
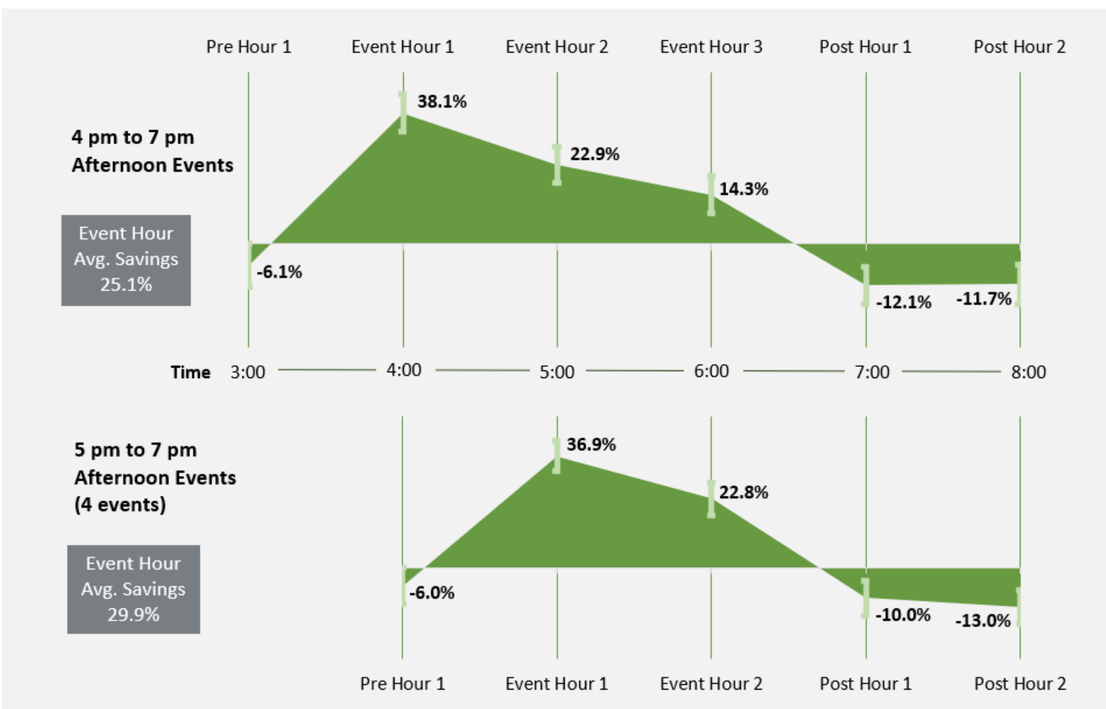


Figure 94 Percentage Demand Savings by Event Start Time – Summer 2018[194]



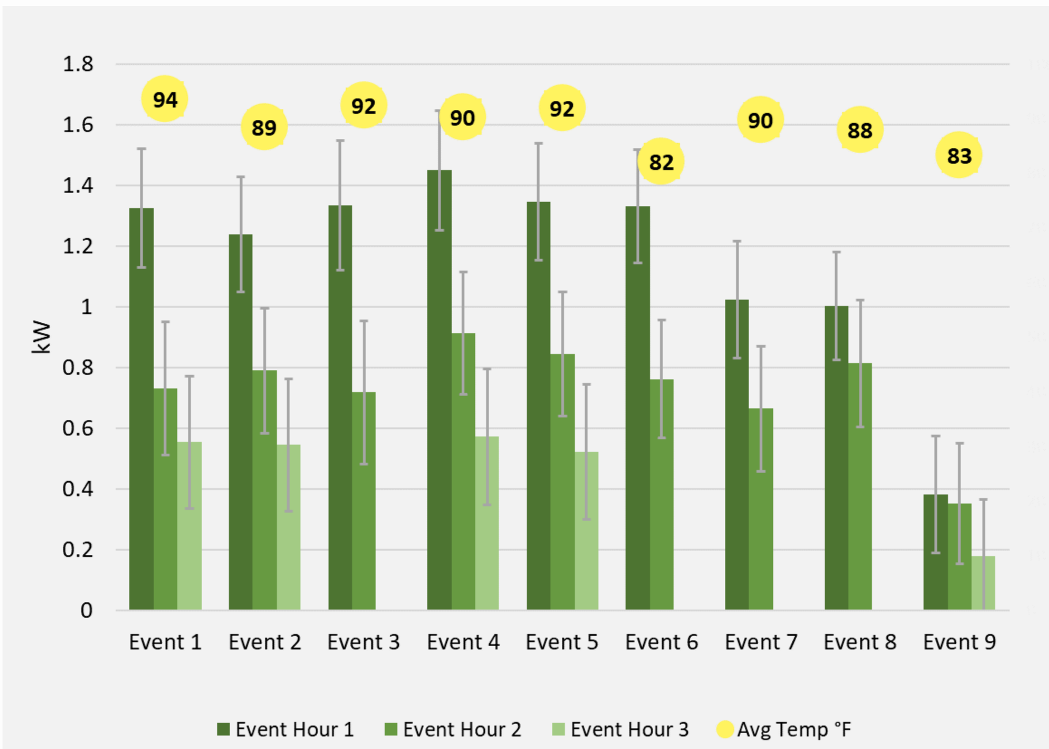
[193] Impacts were estimated using regression analysis of customer AMI meter data. Errors bars show 95% CIs estimated from standard errors clustered on customers. See Appendix B for details.
[194] Ibid.

Demand Savings Estimates by Summer Event

Figure 95 shows the average demand reduction per customer for each hour of the nine summer events. Degradation of savings across event hours is also evident for each event. For most events, first hour savings per customer ranged from 1.0 kW and 1.4 kW, while last hour savings per customer ranged from 0.5 kW and 0.8 kW. [195]

During Event 7, Event 8, and Event 9, Whisker Labs tested IDR, which sought to obtain more consistent demand savings across event hours and avoid savings degradation. Although first hour savings were less than other events (which exceeded 1.2 kW), Event 7 and Event 8 exhibited lower savings degradation than other summer events. Savings decreased by approximately 0.7 kW or 41% between the first and third hours for three-hour events. The smaller degradation of savings is consistent with the objectives of IDR. However, since IDR was only called for several events, it is not possible to draw very firm conclusions about its effectiveness.

Figure 95 Average Demand Savings by Event – Summer 2018[196]



Appendix D contains point estimates of demand savings, pre-event and post-event demand impacts, and energy savings impacts. Energy savings for summer were estimated by summing load impacts across the pre-event hour, event hours, and the first four post-event hours. Load impacts for later post-event hours

[195] For Event 9, note that the demand reductions were reduced due to a connectivity issue with the Honeywell application programming interface (API), resulting in no savings for Honeywell participants. This is shown in further detail in the comparison by brand in Figure 6.

[196] Errors bars show 95% CIs estimated with standard errors clustered on customers.

were not statistically significant and therefore not included in the energy savings calculation. On average, conservation was negative, ranging between -0.5 kWh and -0.9 kWh per customer, demonstrating that the program slightly decreased energy consumption.

Program Demand Savings for Summer 2018

Table 89 presents estimates of total Connected Savings program demand savings during summer 2018 by event hour and on average for each event. The estimates were obtained by multiplying the estimated per-customer average demand savings by the number of participants in each event.

Table 94. Total Connected Savings Program Demand Savings (MW) – Summer 2018

Event	Event Description	Average Demand Savings (MW)			
		Hour 1	Hour 2	Hour 3	Event Average
Event 1	Two-Hour (4 p.m.)	1.0	0.6	0.4	0.7
Event 2	Two-Hour (4 p.m.)	1.0	0.6	0.4	0.7
Event 3	Three-Hour (5 p.m.)	1.0	0.6	N/A	0.8
Event 4	Two-Hour (4 p.m.)	1.1	0.7	0.4	0.8
Event 5	Two-Hour (4 p.m.)	1.1	0.7	0.4	0.7
Event 6	Three-Hour (5 p.m.)	1.1	0.6	N/A	0.8
Event 7	Three-Hour (5 p.m.)	0.8	0.5	N/A	0.7
Event 8	Three-Hour (5 p.m.)	0.8	0.7	N/A	0.8
Event 9	Two-Hour (4 p.m.)	0.3	0.3	0.1	0.3
Hour Average		0.9	0.6	0.4	0.7

Across events, demand savings averaged 0.7 MW. Note participants do not include control customers (n=819) who did not participant in events and would have contributed to PGE’s summer DR capacity. Events typically ranged between 0.7 MW and 0.8 MW, except for Event 9 which was lower due to an API malfunction affecting Honeywell thermostats (discussed below).

Comparison across Brands

Figure 96 compares the average savings across smart thermostat brands across all event hours. Nest had the highest average savings of 0.93 kW (32%). Honeywell and Ecobee had savings of 0.88 kW per participant (26%) and 0.77 kW per participant (27%), but none of the differences was statistically significant. Honeywell’s average savings estimates were diminished by the low savings estimated for Event 9.

Figure 96 Average Demand Savings per Customer by Thermostat Brand – Summer 2018[197]

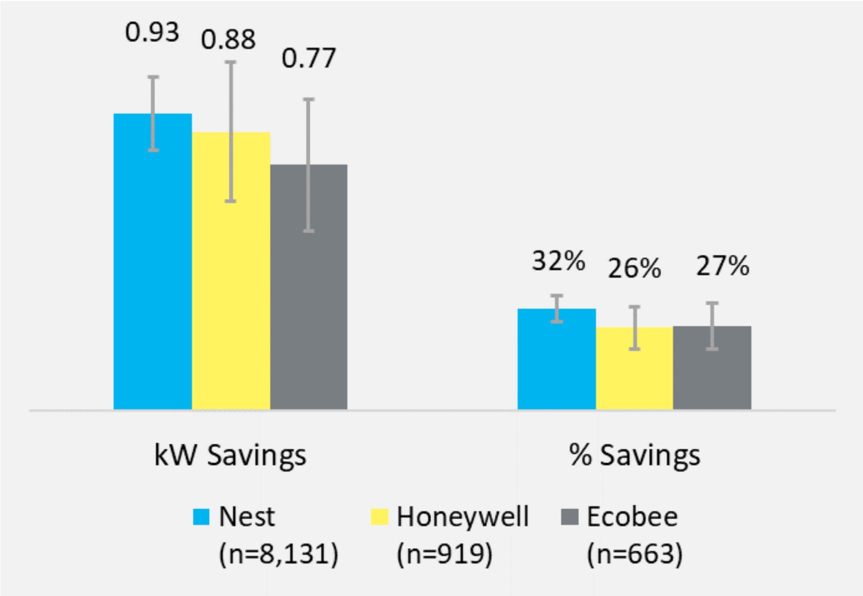
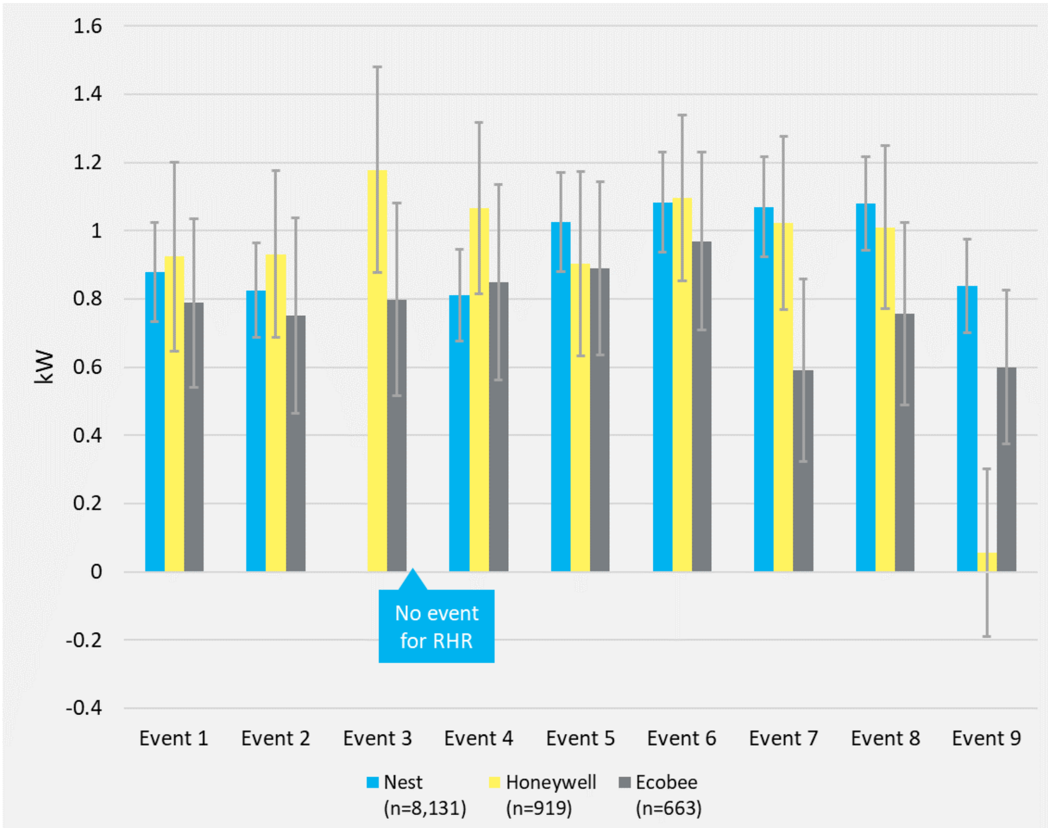


Figure 97 compares the average demand savings per participant of the different brands by event. Nest and Honeywell smart thermostats generated similar demand savings, except for Event 9 when Honeywell's API malfunctioned, and Whisker Labs was unable to dispatch Honeywell thermostats. Ecobee thermostats consistently generated lower demand savings than Nest or Honeywell thermostats. Ecobee thermostats did not permit pre-cooling of homes, which would have limited the event-hour demand savings that could have been achieved. Differences in demand savings between thermostat brands may also reflect the effects of customers with lower savings potential selecting Ecobee thermostats rather than differences in performance of thermostat brands.

[197] Figure shows the average demand savings per participant. Honeywell and Ecobee thermostat savings estimates were obtained from Cadmus evaluation of the Connected Savings (2019).

Figure 97 Average Demand Savings by Event and Thermostat Brand – Summer 2018[198]



Customer Experience

The summer 2018 event and experience surveys asked Connected Savings participants about their event awareness, participation challenges, comfort, satisfaction, and suggestions for improvement. The following sections describe the major findings from these surveys. Comparisons across thermostat brands and between Connected Savings and Rush Hours Rewards are provided at the end.

Event Awareness and Participation

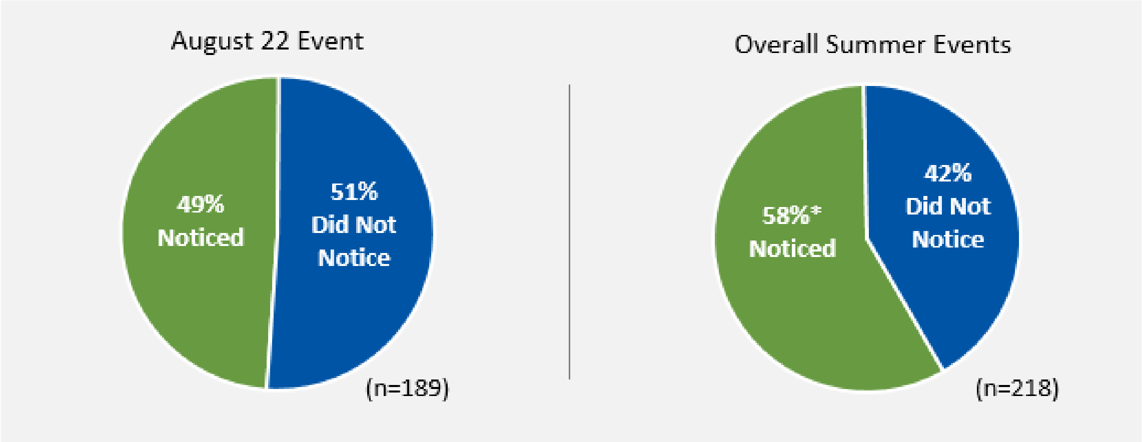
PGE called nine events for Connected Savings during summer 2018. The summer experience surveys asked test group respondents whether they noticed the summer events and how many they noticed. Fifty-eight percent of respondents (n=218) said they noticed the events and, on average, they noticed 4.8 events (n=126) out of the nine called. Respondents (n=127) noticed mostly because of the event message display on the smart thermostat (72%) rather than because of a temperature change (52%) or event notification from the smartphone app (19%).

More respondents said they noticed the events when asked in the context of a whole season compared to noticing a single event. Cadmus administered a summer event survey the day after the August 22

[198] Errors bars show 95% CIs estimated with standard errors clustered on customers.

event. As shown in Figure 98, a significantly lower percentage of respondents said they noticed the August 22 event (49%) than said they noticed the overall summer events (58%).

Figure 98 Noticing of Events – Single Event Compared to Overall Season[199]



* Difference is significant with 90% confidence (p≤0.10).

Most respondents (85%) said participating in the summer events was easy (n=211). Specifically, 73% said it was *very easy* and 12% said it was *somewhat easy*. The 3% of respondents who found it difficult to participate in the events mentioned the following reasons:

- High temperatures (three respondents)
- Having guests or visitors around (three respondents)
- Other household members controlling the thermostat (three respondents)
- Summer was hotter this year (three respondents)

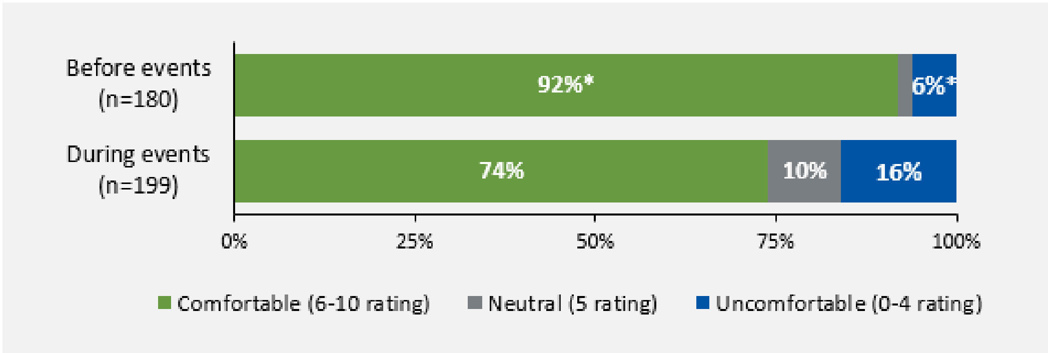
Event Comfort

A large majority of test group respondents were comfortable before and during the summer events. Figure 99 shows that before the events, 92% of respondents said their home's interior temperature was comfortable. During the events, 74% said they were comfortable, a significant decrease compared to the comfort level before events, which suggests that the comfort of some customers was negatively affected. Still, most respondents reported feeling comfortable during the events.

Thirty-six percent of respondents (n=215) reported that they did override some of the summer events. Respondents who reported overriding (n=71) most often cited thermal discomfort as their reason (70%), followed by other household members overriding (13%) and having guests visit (11%).

[199] Summer 2018 Event Survey Question. "Did you notice yesterday's high demand event between 4 p.m. and 7 p.m.?" Summer 2018 Experience Survey Question. "How many high demand events did you notice this past summer?"

Figure 99 Comfort Level Before and During Summer Events[200]



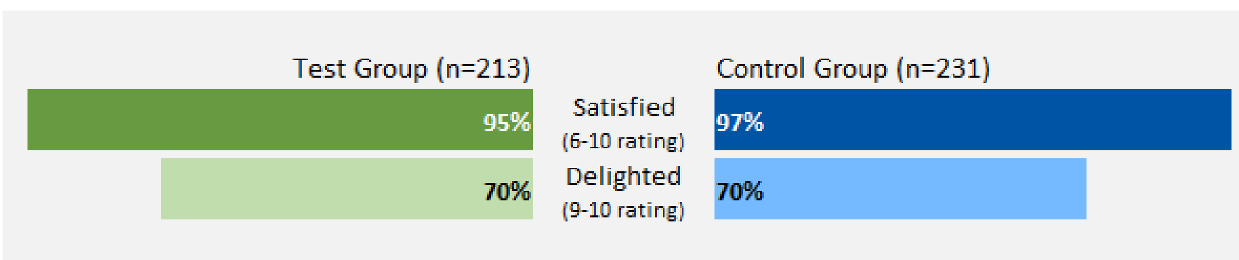
* Difference is significant with 90% confidence (p≤0.10).Satisfaction

Test and control group respondents rated their satisfaction with the smart thermostat, the incentive check, the program, and PGE, using a 0 to 10 scale, where 0 meant *extremely dissatisfied* and 10 meant *extremely satisfied*. PGE defines a 6 to 10 rating as *satisfied* and a 9 or 10 rating as *delighted*.

Satisfaction with Smart Thermostat

Nearly all test and control group respondents were satisfied with their smart thermostat. Figure 100 shows that 95% of test group respondents and 97% of control group respondents were *satisfied* with their thermostat. The same percentage of test group (70%) and control group (70%) respondents were *delighted*. There was no statistically significant difference between test and control group respondents in satisfaction with their smart thermostat. No difference was expected because participants already owned their smart thermostats prior to program enrollment.

Figure 100 Satisfaction with Smart Thermostat[201]



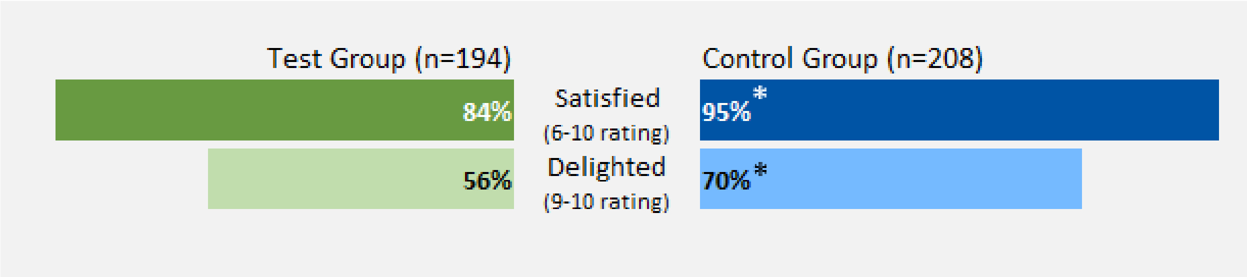
Satisfaction with Incentive

Most respondents were satisfied with the incentive amount. A significantly higher proportion of control group respondents (95%) than test group respondents (84%) were *satisfied* with the incentive

[200] Summer 2018 Experience Survey Questions. "Overall this past summer, how comfortable was the interior temperature of your home a few hours before the high demand events?" and "Overall this past summer, how comfortable was the interior temperature of your home during the high demand events?"
[201] Summer 2018 Experience Survey Question. "How satisfied are you with your smart thermostat?"

(Figure 101). Also, a significantly higher proportion of control group respondents (70%) than test group respondents (56%) were *delighted* with the incentive. This difference can be explained by the fact that control group participants did not experience any events (which might cause inconvenience) and still received the $25 incentive.

Figure 101 Satisfaction with Incentive[202]

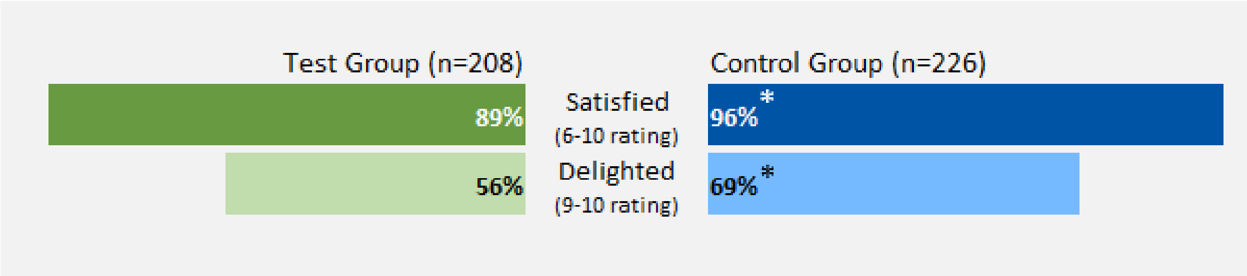


* Difference is significant with 90% confidence (p≤0.10).

Satisfaction with Program

Most respondents were satisfied with the program. A significantly higher proportion of control group respondents (96%) than test group respondents (89%) were *satisfied* with the program (Figure 102). Also, a significantly higher proportion of control group respondents (69%) than test group respondents (56%) were *delighted* with the program. Once more, the difference can be explained by the fact that control group participants did not experience any events.

Figure 102 Satisfaction with Program[203]



* Difference is significant with 90% confidence (p≤0.10).

The summer experience surveys asked test and control group respondents to explain their program satisfaction ratings. Cadmus analyzed their open-end explanations according to positive or negative sentiment. Both test and control group respondents had largely positive comments about the program. Of the 131 topic mentions, positive comments from the test group respondents most often mentioned

[202] Summer 2018 Experience Survey Question. "How satisfied were you with the incentive check you received for your participation this past summer?"

[203] Summer 2018 Experience Survey Question. "Please rate your overall satisfaction PGE's Smart Thermostat program using a 0 to 10 scale where a 0 means you are extremely dissatisfied and a 10 means you are extremely satisfied."

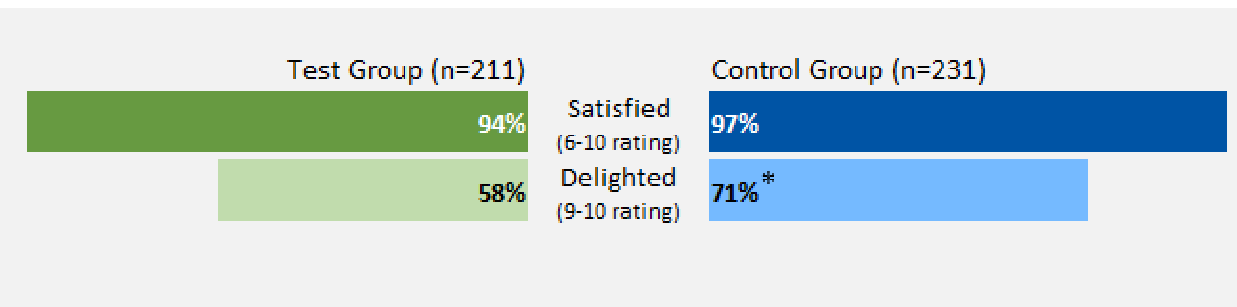
that the program works well (33%), saves money (20%), and is helpful to the customer (16%). Like the responses of the test group, of the 148 topic mentions, positive comments from the control group respondents most often said that the program works well (62%), saves money (21%), and is helpful to the customer (17%). The control group did not experience any events, which explains why far more control group respondents than test group respondents mentioned that the program works well.

Of the 131 topic mentions, negative comments from the test group respondents most often cited the event notifications not being early enough (13%), the incentive being too small or slow to receive (11%), and thermal discomfort during events (5%). Of the 148 topic mentions, negative comments from the control group respondents most often related to the incentive being too small or slow to receive (5%), [the lack of] event notifications (4%), and problems with using the smart thermostat (2%). Again, the control group did not experience any events so had fewer negative comments.

Satisfaction with Portland General Electric

Nearly all test and control group respondents were satisfied with PGE. As shown in Figure 103, a similar proportion of test group (94%) and control group (97%) respondents were *satisfied* with PGE. However, a significantly higher proportion of control group respondents (71%) than test group respondents (58%) were *delighted* with PGE.

Figure 103 Satisfaction with Portland General Electric[204]



* Difference is significant with 90% confidence (p≤0.10).

That the test group had lower *program* satisfaction than the control group suggests that some participants were inconvenienced by the events, but the similarity of *utility* satisfaction between test and control group suggests that any inconvenience did not affect participants' satisfaction with PGE.

[204] Summer 2018 Experience Survey Question. "Please rate your overall satisfaction with the PGE using a 0 to 10 scale, where a 0 means you are extremely dissatisfied and a 10 means you are extremely satisfied."

Customer Suggested Improvements

The summer experience surveys asked test and control group respondents for suggestions to improve the program. Test group respondents (n=73) most often suggested these three improvements:

- Send event notifications in advance (14%)
- Send notifications or program information via text or email (12%)
- Increase the incentive amount (11%)

Control group respondents (n=83) most often suggested these three improvements:

- Provide a performance/impact report for the household (12%)
- Fix the thermostat glitches (11%)
- Provide transparency on how the thermostat was changed (8%)

Test and control group respondents differed in their program improvement suggestions. Test group respondents tended to ask for pre-event notifications and a higher incentive amount while control group respondents tended to ask for proof that the thermostat was activated during events.

Brand Comparison

Table 76 shows a comparison of the test group's survey responses across the three smart thermostat brands used in the Connected Savings program. Significant differences emerged between Ecobee and other Honeywell thermostats (not Lyric). The number of Honeywell Lyric survey respondents was too small (fewer than 27) to conduct statistical significance testing. A significantly higher percentage of Ecobee respondents noticed the events (63%) compared to respondents with other Honeywell thermostats (52%).

Table 95. Test Group Survey Responses by Thermostat Brand

Survey Topic	Ecobee (n≤204)	Honeywell Other (n≤220)	Honeywell Lyric[205] (n≤27)
General event awareness	63% noticed events[206]	52% noticed events	54% noticed events
Average perceived number of events	4.9 events	4.4 events	5.7 events
Comfort during events	77% comfortable	73% comfortable	64% comfortable
Overriding events	33% overrode	38% overrode	45% overrode
Smart thermostat satisfaction	98% satisfied 75% delighted[207]	95% satisfied 67% delighted	90% satisfied 56% delighted
Incentive satisfaction	92% satisfied 61% delighted	88% satisfied 67% delighted	84% satisfied 53% delighted
Program satisfaction	95% satisfied 64% delighted	93% satisfied 64% delighted	80% satisfied 44% delighted
Satisfaction with PGE	97% satisfied 60% delighted	95% satisfied 70% delighted**	92% satisfied 62% delighted

Comparison to Rush Hour Rewards

Cadmus compared the results of the Connected Savings test group survey to the results of the Rush Hour Rewards test group survey (Table 91). Both achieved similar satisfaction results but differed in the perceived number of events and comfort during events. Rush Hour Rewards test group respondents were significantly more comfortable during events (82%) than were Connected Savings' test group respondents (74%). This difference in comfort may be explained by the different temperature setbacks used by Whisker Labs versus Nest. Whisker Labs calibrated a three-degree setback while Nest calibrated a one- to five-degree setback. Nest's wider range in temperature meant it could calibrate setbacks specifically to the customer's comfort preferences compared to the one-size-fits-all calibration from Whisker Labs.

In addition, Rush Hour Rewards test group respondents perceived significantly more events on average (6.3) than Connected Savings test group respondents (4.8). The absence of pre-event notifications for Connected Savings probably explains the perception of a fewer number of events. The Nest thermostats used in Rush Hour Rewards sent pre-event notifications to its test group customers while the Ecobee and Honeywell thermostats used in Connected Savings did not.

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[205] The total number of responses was too small to conduct statistical significance testing for this group.
[206] Difference is significant with 90% confidence (p≤0.10).
[207] Ibid.

Table 96. Test Group Survey Response Comparisons: Connected Savings versus Rush Hour Rewards

Survey Topic	Connected Savings (n≤218)	Rush Hour Rewards (n≤232)
General event awareness	58% noticed events	62% noticed events
Average perceived number of events	4.8 events	6.3 events[208]
Comfort during events	74% comfortable	82% comfortable[209]
Overriding events	36% changed settings	35% changed settings
Smart thermostat satisfaction	95% satisfied 70% delighted	97% satisfied 72% delighted
Incentive satisfaction	84% satisfied 56% delighted	87% satisfied 56% delighted
Program satisfaction	89% satisfied 56% delighted	91% satisfied 58% delighted
Satisfaction with PGE	94% satisfied 58% delighted	97% satisfied 60% delighted

Implementation Delivery

Not unusual for the first year of a program, PGE encountered several implementation challenges with Connected Savings. These challenges occurred in the marketing, recruitment, and HVAC system verification. This section documents these challenges and lessons learned.

Marketing

Connected Savings initially did not have frequent, coordinated marketing efforts from the thermostat manufacturers. The manufacturers of Ecobee and Honeywell thermostats initially marketed the program only once during the year to PGE customers who registered a qualifying smart thermostat. PGE also reported that Ecobee and Honeywell ran sales campaigns less often than did Nest to attract customers who have yet to purchase a smart thermostat.

PGE took several steps to address the manufacturers' marketing gaps related to Connected Savings:

- Worked with the manufacturers to have them send out emails about the program on a quarterly basis to customers who purchased or installed a qualifying smart thermostat
- Promoted Ecobee and Honeywell smart thermostats on PGE's website to engage customers who had yet to purchase a smart thermostat
- Sent out Ecobee and Honeywell sales promotions to PGE customers via email during major shopping-related holidays such as Father's Day and Black Friday (the sales promotions mentioned the program and incentive offers)

Of these three marketing efforts (manufacturers' emails, the PGE website, and PGE emails), customers took notice of PGE's marketing more than the manufacturers' marketing. When asked how they heard

[208] Ibid.
[209] Ibid.

about the program, recruitment survey respondents (n=124) most often said an email from PGE (48%), followed by an email from the manufacturer (21%) and the PGE website (19%).

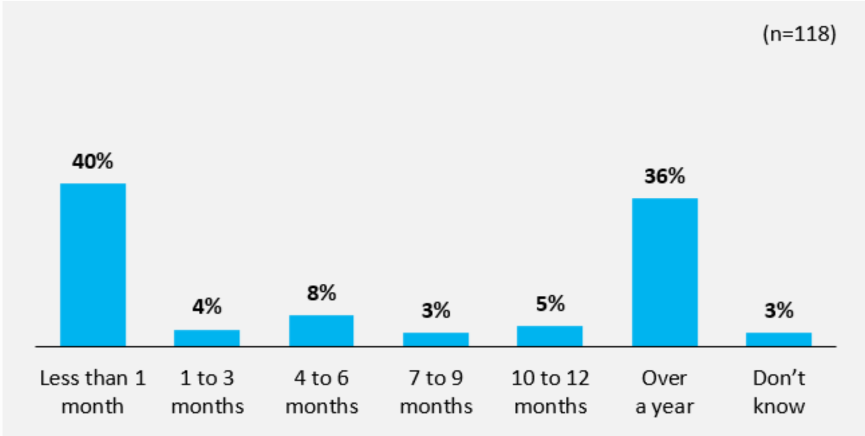
PGE had little to no data on customer's smart thermostat and HVAC system to use for targeted marketing. Unlike Nest who serves as both the smart thermostat manufacturer and the DR service provider, Connected Savings utilizes two different parties. Whisker Labs, the DR service provider for Connected Savings, could not collect data from Ecobee and Honeywell thermostats until the customer enrolled in the program. As a result, PGE did not know which customers had smart thermostats, what type they had, and what the home's HVAC system was *prior* to program enrollment. This information was collected during the online enrollment process and given to PGE *after* customers enrolled. This severely limited PGE's ability to target program marketing to eligible customers. PGE took the following steps to address some of the marketing data gap:

- Used existing customer research on DR and smart thermostats and, from this, selected and marketed to two customer segments (Innovative Investors and Totally Tech), which were the most likely to have a smart thermostat and to participate in the program
- Used Energy Trust of Oregon data to determine which PGE customers received a smart thermostat rebate

Recruitment

More customers could have enrolled in Connected Savings if they had been informed more frequently about the program offering. By the end of summer 2018, 1,662 customers had enrolled in Connected Savings. In comparison, 2,492 customers had enrolled in Rush Hour Rewards by the end of its first summer season in 2016. Although Nest has a larger share of the smart thermostat market than Ecobee and Honeywell, how often program promotions are sent to eligible customers can impact enrollment. Forty percent of recruitment survey respondents said they enrolled in Connected Savings within one month after installing their thermostat (Figure 89). In contrast, 36% of respondents said they enrolled more than one year after installation. Of the respondents who took longer than one month to enroll (n=65), 74% said the reason they did not enroll sooner was that they did not know about the program.

Figure 104. Length of Time between Installation and Enrollment[210]



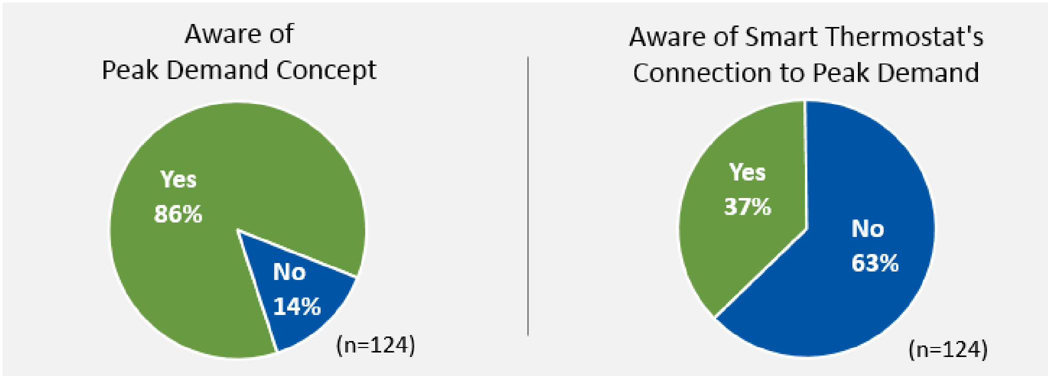
The results shown in Figure 13 align with the manufacturers' initial once-a-year marketing approach; a substantial proportion of respondents said they enrolled within one month after installation and another substantial proportion enrolled over one year later, with very few enrolling in the months between. Having the manufacturers change to a quarterly promotion should help increase enrollment and garner more consistent enrollment throughout the year. Note, however, that the effect of increasing the frequency of the manufacturer's program marketing has yet to be evaluated.

Despite the delayed enrollment, customers had a positive experience with the online enrollment process for Connected Savings. Most customers were able to quickly and easily enroll into the program through Whisker Lab's portal: 91% of respondents said the online enrollment process was clear, 87% said it was easy, and 86% said it was quick (n=124).

Most customers who enrolled were aware of the concept of peak demand, but the majority were not aware of their smart thermostat's connection to peak demand. As shown in Figure 14**,** 86% of recruitment survey respondents said they were aware of peak demand, but only 37% said they were aware of how smart thermostats can be used to manage peak demand. PGE acknowledged that educating customers about DR is critical to meeting its megawatt goal, but it was unable to launch an awareness campaign prior to program launch. PGE plans to educate the public on DR through mass-market channels (TV, social media, radio, and new articles) in conjunction with the DR Testbed pilot.[211] Currently, PGE provides this education only in the Direct Install program, through which installation technicians provide one-on-one education to customers on smart thermostats and DR.

[210] Recruitment Survey Question. "How long was your smart thermostat installed in your home before enrolling in the program?"
[211] Portland General Electric Company. October 2018. *Testbed Application Proposal*, Advice No. 18-14. Prepared for the OPUC.

Figure 105. Customer Awareness of DR[212]



HVAC System Verification

PGE relied on customer self-reports and Whisker Labs data to determine the type of HVAC system; these data were not always available and accurate. During the online enrollment process, customers answered questions about their HVAC system to confirm their program eligibility. PGE and Whisker Labs reported that many customers answered “don’t know” or incorrectly answered “heat pump” to qualify for summer and winter seasonal incentives.

Whisker Labs took the following actions to figure out the customer’s HVAC system type and improve the accuracy of these data:

- Reviewed the HVAC system’s run-time data as captured in the smart thermostat and used the data’s load shape to assess whether the customer had an air conditioner or heat pump; however, run-time data were not available for Honeywell Lyric thermostats
- Modified the HVAC system questionnaire from yes/no format to ask multiple choice questions

After observing the challenges with HVAC system verification in Connected Savings, PGE designed the Direct Install approach of the Smart Thermostat Demand Response program to overcome the challenges. In Direct Install, an installation technician works with the customer to identify the home’s HVAC system type during the scheduling process, then verifies the HVAC system type during on-site installation.

Logic Model Review

Figure 91 shows the logic model for Connected Savings. Cadmus reviewed the logic model against the evaluation findings and determined that Connected Savings operated as intended whereby the program activities and outputs produced the expected short-term and intermediate outcomes of demand savings and customer satisfaction.

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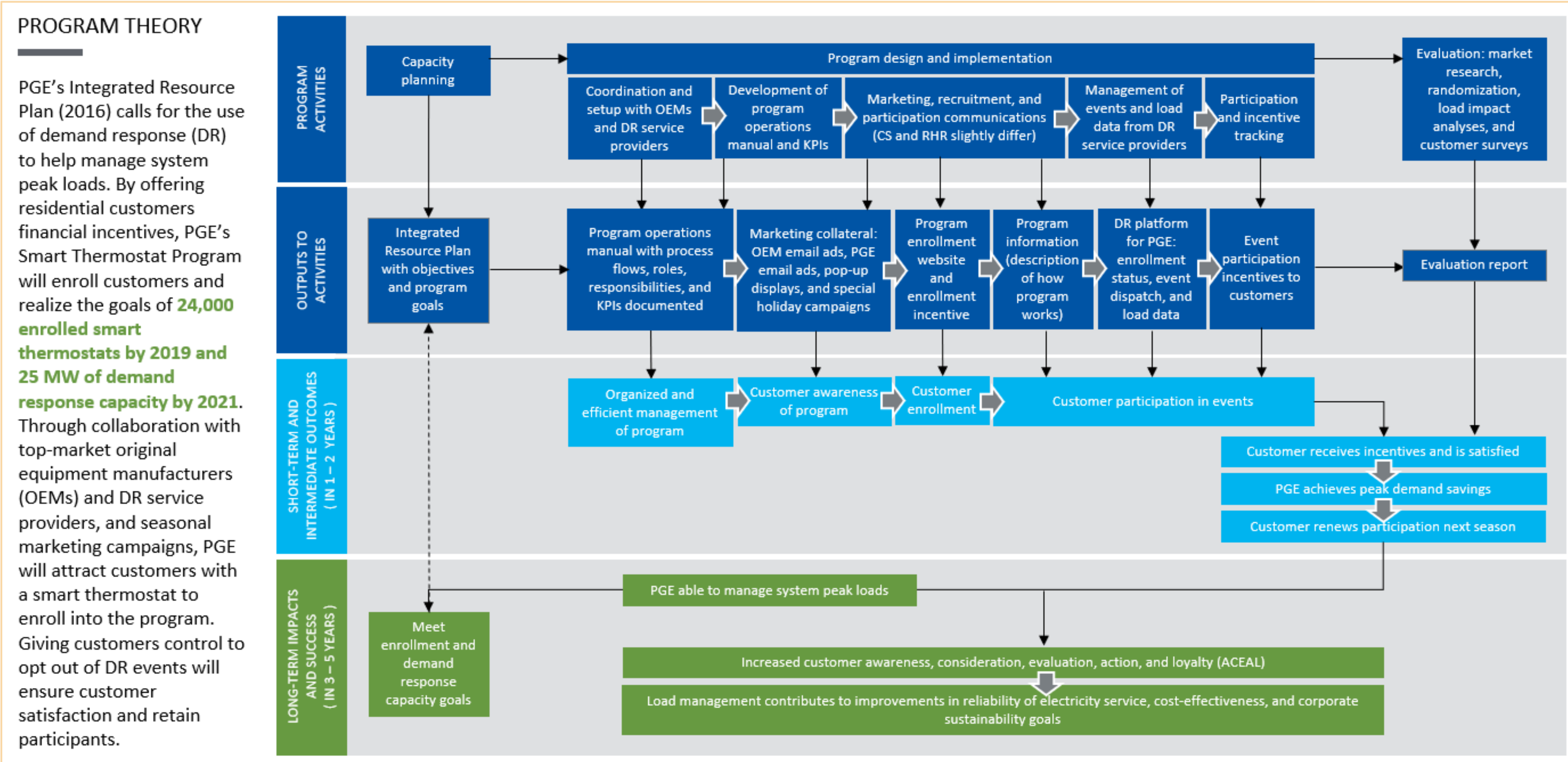
[212] Recruitment Survey Questions. “There are specific times of the day when the demand for electricity is at its highest, especially during the summer and winter. Before joining the program, were you aware of this high electricity demand?” and “Before joining the program, were you aware that smart thermostats can connect with PGE to shift electricity consumption from times when electricity demand is at its highest?”

Figure 106. Connected Savings Logic Model



Conclusions and Recommendations

Based on the evaluation findings, Cadmus came to several conclusions and recommendations, described below.

Load Impacts

Connected Savings achieved the expected summer capacity savings of 0.8 kW per participant.

Participants achieved average savings of 0.84 kW (or 27% of baseline demand) for the summer 2018 season, which was approximately equal to PGE's planning value for smart thermostat demand response savings per participant of 0.8 kW.

Significant degradation of savings occurred across event hours.

Across all summer 2018 events, savings decreased by 0.4 kW or 37% between the first and second event hours, while three-hour events saw a further degradation of 0.7 kW or approximately 59% between the first and last event hour. Because of degradation of demand savings over the hours of events, the average savings understates the available capacity during the first event hour and overstates available capacity during the last event hour. By working with its DR service providers to implement IDR strategies, PGE may be able to avoid savings degradation. There may be opportunities for PGE to work with its DR service providers to optimize event dispatch and control algorithms to better meet its capacity needs.

Connected Savings load control events increased customer loads before and after events but did not result in a negative conservation effect.

Loads increased by an average of 6% before events due to pre-conditioning and up to 12% after events due to snapback. However, the pre-conditioning and snapback did not lead to an increase in energy consumption on event days.

Connected Savings moved PGE closer to reaching its goal of 25 MW of DR capacity from residential smart thermostats by 2021.

In summer 2018, Connected Savings had 1,662 participants and realized averaged demand savings of 0.7 MW per event hour. In combination with Rush Hour Rewards, PGE's residential smart thermostat program yielded an average demand savings of 7.6 MW per event hour for the summer 2018 event season.

In summer, PGE can expect the same demand savings per customer from Connected Savings and Rush Hour Rewards participants.

There were no statistically significant differences in savings between thermostat brands (Ecobee, Honeywell, and Nest). The average savings of 0.84 kW for Connected Savings customers aligned with the average savings for Rush Hour Rewards participants (0.93 kW) for summer 2018.

Load Impact Recommendations

- PGE should continue recruiting customers for BYOT Connects Savings, provided it represents a cost-effective resource.
- PGE should continue to test IDR control algorithms to maintain a constant level of demand savings and to avoid degradation of savings across event hours.
- PGE should coordinate internally to ensure well-defined objectives, design, and key metrics of event dispatch that align goals of program delivery and capacity planning teams.
- PGE should work with the program implementer to improve the approach to validating customer heating system type and HVAC configuration to ensure only appropriately configured HVAC system participate during the winter season.

Customer Experience

Connected Savings delivered a positive customer experience and achieved high customer satisfaction.

Most respondents said the online enrollment process was clear (91%), easy (87%), and quick (86%). Most test group respondents were satisfied with the program (89%). Test group respondents most often mentioned in the open-end comments that the program works well (33%), saves money (20%), and is helpful to the customer (16%). As suggestions for program improvement, test group respondents mentioned sending event notifications in advance (14%), sending notifications or program information via text or email (12%), and increasing the incentive amount (11%).

The load control events did not adversely affect comfort for most customers.

Fifty-eight percent of test group respondents said they noticed the summer events. Most noticed the events because of the event message display on the smart thermostat (72%) rather than because of a temperature change (52%) or the event notification from the smartphone app (19%). Moreover, before the events, 92% of respondents said their home's interior temperature was comfortable. During the events, 74% said they were comfortable, a significant decrease compared to the comfort level before the events; nevertheless, a majority reported feeling comfortable during the events.

Not sending a pre-event notification makes the events less noticeable for customers.

On average, test group respondents perceived 4.8 events out of the nine events called during the summer. Respondents likely perceived far fewer events than were called because Ecobee and Honeywell did not send any pre-event notifications to customers. This hypothesis is supported by the fact that Nest did send out pre-event notifications to its test group customers for Rush Hour Rewards, and Nest respondents perceived an average of 6.3 events, significantly more than perceived by Connected Savings' respondents. Some customers may benefit from receiving advance notifications, and PGE could consider giving Connected Savings participants the option of receiving them. Per customer feedback, 14% of survey respondents suggested PGE send event notifications in advance.

A wider-range temperature setback instead of a one-size-fits-all temperature setback may make for a more comfortable event experience.

Connected Savings and Rush Hour Rewards achieved similar program satisfaction results but differed in perceived comfort during events. Rush Hour Rewards' test group respondents were significantly more comfortable during events (82%) than Connected Savings' test group respondents (74%). This difference may be explained by the temperature setback strategy used by Nest versus Whisker Labs. Nest calibrated a one- to five-degree setback specifically to each customer's comfort preferences. Whisker Labs calibrated a three-degree one-size-fits-all setback that did not accommodate customer preferences.

PGE incurs a small decrement to customer satisfaction when smart thermostats are controlled.

Most test and control group respondents were satisfied with the program, but significantly more control group respondents were satisfied (96%) than test group respondents (89%). Most test and control group respondents were also satisfied with the $25 incentive, but significantly more control group respondents were satisfied (95%) than test group respondents (84%). These differences between groups can be explained by the fact that control group participants did not experience any events (that is, their thermostats were not controlled) and still received the $25 incentive. There was no decrement to customer satisfaction with PGE; a similar proportion of test group (94%) and control group (97%) respondents were satisfied with PGE.

Customer Experience Recommendation

- PGE and Whisker Labs should consider giving Connected Savings participants the option to receive pre-event notifications. Giving customers this option may further enhance customer satisfaction and would be responsive to the feedback of some customers. However, PGE should also weigh the costs of providing advance notifications, which could include lowered event participation, smaller savings, and reduced customer satisfaction.

Implementation

The lack of existing data on customers' smart thermostats and HVAC systems resulted in program marketing and recruitment challenges.

Unlike Nest who serves as both the smart thermostat manufacturer and the DR service provider, Connected Savings utilizes two different parties. Whisker Labs, the DR service provider for Connected Savings, could not collect data from Ecobee and Honeywell thermostats until the customer enrolled in the program. As a result, PGE did not know which customers had smart thermostats, which type they had, and what the home's HVAC system was *prior* to program enrollment. Most customer data came *after* customers had enrolled in the program and answered program eligibility questions. This severely limited PGE's ability to target program marketing to potential eligible customers. PGE did employ existing customer research on segmentation and used the Energy Trust of Oregon's smart thermostat rebate data to fill in some of the data gaps.

The average delay between when a customer installs a smart thermostat and when the customer enrolls in the program suggests an opportunity to accelerate enrollment.

Forty percent of recruitment survey respondents said they enrolled in Connected Savings within one month after installing their thermostat, and 36% said they enrolled more than one year after installation. Of the respondents who took longer than one month to enroll, 74% said the reason they did not enroll sooner was that they did not know about the program. These results reflect the smart thermostat manufacturers' original practice of marketing the program only once per year—that is, very few customers enrolled in the period between one month and one year after installation. PGE later worked with Ecobee and Honeywell to send out marketing emails on a quarterly basis to increase enrollment; the outcomes of marketing the program more frequently has yet to be evaluated.

PGE's own marketing efforts engaged customers more than marketing efforts from the smart thermostat manufacturers.

PGE employed the smart thermostat manufacturers' emails, the PGE website, and PGE emails to recruit customers. Of the three marketing efforts, customers took notice of PGE's marketing more than the manufacturers' marketing. When asked how they heard about the program, recruitment survey respondents most often said an email from PGE (48%), an email from a manufacturer (21%), and the PGE website (19%). PGE worked with the manufacturers to increase emails about the program from once a year to quarterly; however, PGE did not mention if it increased its own program email marketing efforts.

Customer education is needed about the connection of DR to smart thermostats.

Most respondents said they were aware of the concept of peak demand prior to enrolling (86%), but only one-third (37%) said they were aware of its connection to smart thermostats. Increasing awareness of this connection would strengthen program awareness and possibly boost enrollment. PGE acknowledged that educating customers about DR is critical to meeting its megawatt goal, but it was unable to conduct an awareness campaign prior to launching the Connected Savings program. PGE plans to educate the public on DR through mass-market channels (TV, social media, radio, and new articles). Currently, PGE provides education in the Direct Install program, for which installation technicians provide one-on-one education about smart thermostats and DR to customers.

Implementation Recommendations

- PGE should consider taking on a greater lead role on mass marketing Connected Savings to customers via email and direct mail, rather than relying on the manufacturers. The manufacturers can then focus on pushing out program promotions to eligible customers via the smartphone app, a channel PGE does not have access to or control over.
- PGE should increase marketing efforts specifically at the point of sale or point of installation. This could include the following:
  - Partnering with local retailers that carry smart thermostats to display program promotions
  - Partnering with local thermostat installation contractors to promote the program during the installation process
  - Intercepting customers about the program offering in an online marketplace
- PGE should develop educational content that emphasizes the smart thermostat's connection to DR. Rather than using words to explain, consider presenting engaging visuals such as an infographic flowchart or a short video that clearly illustrates the relationship.

Appendix A - Data Preparation

This appendix explains how Cadmus prepared the AMI meter data and handled ineligible customers and account closures.

AMI Meter Data

Cadmus collected AMI meter data for Connected Savings participants from May 1, 2018, through October 2, 2018. The AMI data included a mix of 15- and 60-minute interval readings.

To prepare the data for analysis, Cadmus performed the following steps:

1. Removed a small number of duplicate interval readings from the data.
2. Summed 15-minute interval consumption data to obtain hourly interval consumption
3. Dropped a small number of outliers and hourly observations missing one or more 15-minute interval readings.
4. Combined the consumption of meters connected to the same thermostat
5. Since all events occurred on weekdays in July or August 2018, Cadmus removed holidays, weekends, and days outside of July or August.
6. Adjusted time stamp from end of read period to start of read period.
7. Dropped one customer with two thermostats assigned to different test groups.
8. Dropped customers missing all AMI data.

Ineligible Customers and Account Closures

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 (test or control). Cadmus did not create assignments for the summer 2018 season.
- Appeared in a list of test and control group customers who were rejected from the program for a variety of reasons

Cadmus did not exclude net generation customers but did confirm with PGE that the metering data recorded gross demand, not net demand, for electricity.

Table A-1 shows Connected Savings summer 2018 participant attrition counts.

Table A-1. Connected Savings Participant Attrition – Summer 2018

Filter	Participant Counts
Initial Analysis Sample	**1,662**
Multiple Assignments	1
Missing AMI Data	79
Final Analysis Sample	**1,582**

Appendix B - Model Specifications: Event-Based Tests

Cadmus estimated event demand impacts by comparing the hourly consumption of customers in the test and control groups. Using data for event and non-event hours during the summer season, Cadmus estimated a panel regression of customer hourly energy consumption on control variables for hour of the day, weather, and assignment to the test group. 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 7

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

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
DH_{it}	=	Heating or CDH for customer 'i' in hour 't' for a given base temperature
γ_k	=	Average effect per customer of a CDH on customer consumption 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'

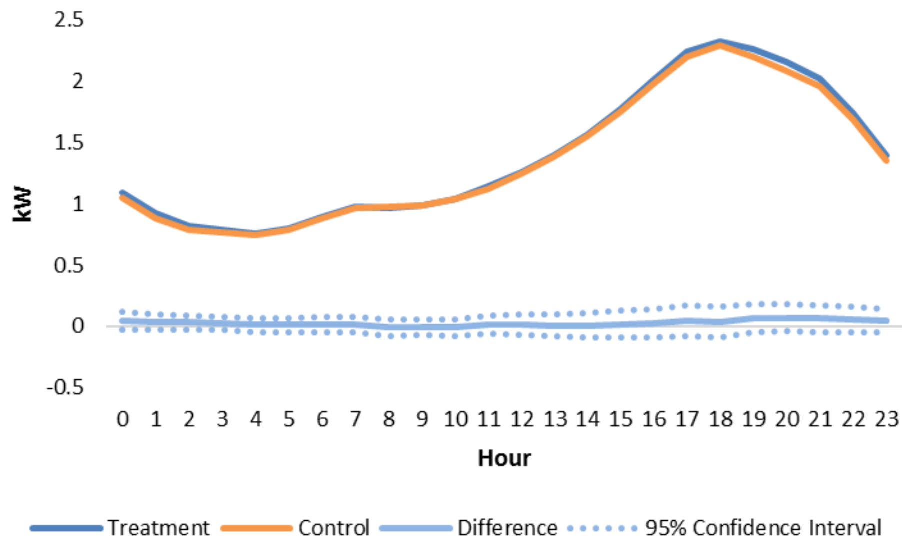
ε_{it} = Random error for customer 'i' in hour 't'

Cadmus estimated the panel model by OLS, clustering the standard errors on customers to allow within-customer correlation of hourly electricity consumption. The model included all non-holiday weekdays days in July or August 2018. To estimate average event hour savings or savings by event start time, Cadmus used the same specification as above, except that the pre-event hour, event hour, and post-event hour variables were not specific to the event number.

Appendix C - Equivalency Checks and Analysis Sample Summary Statistics

Figure C-1 shows average consumption by hour on summer 2018 weekdays that were not event days or holidays. It also plots the estimated difference and confidence estimate around that estimate. The figure demonstrates that the hourly differences between the two groups' consumption were small and statistically insignificant.

Figure C-1. Equivalency Consumption Plot



As a comparison, Figure C-2 and Figure C-2 show average consumption on 5 p.m. to 7 p.m. event days and 4 p.m. to 7 p.m. event days, respectively. The test and control groups' consumption remain balanced in the hours leading up to events. The event's effects are clearly demonstrable.

Figure C-2. Average Consumption by Hour – Summer 2018 (5 p.m. Events)

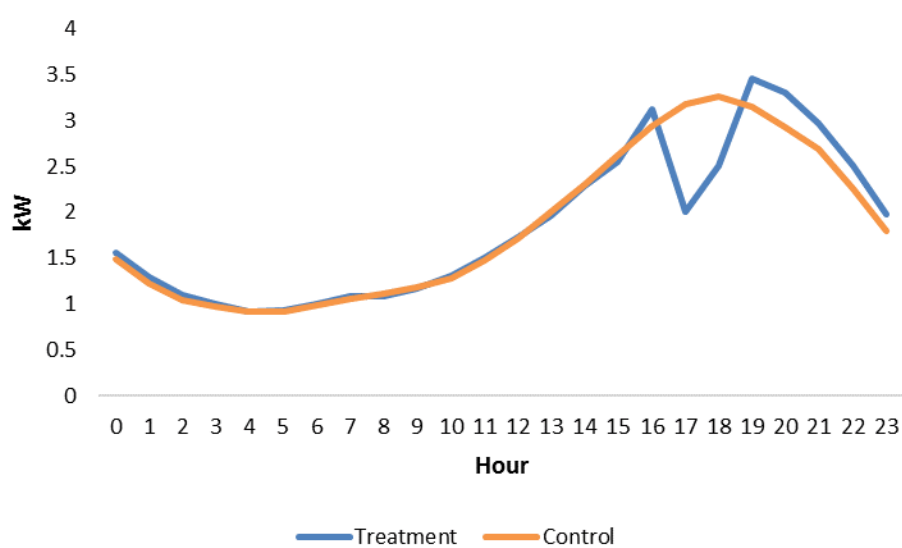
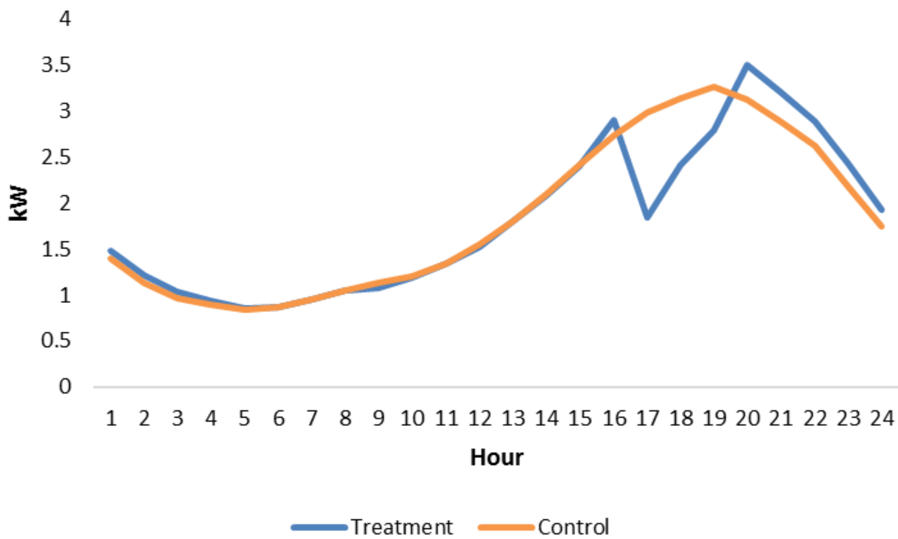


Figure C-3. Average Consumption by Hour – Summer 2018 (4 p.m. Events)



Appendix D - Additional Impact Findings

This appendix provides additional details about the pre-event and post-event demand impacts, including point estimates and conservation effect, for each season.

Figure D-1 and Figure D-2 present estimates of the average load impacts per hour per test group customer, by event start time. Each figure shows estimates of the average load impacts per customer, metered demand, estimated demand, and baseline demand. The estimated load impact is the estimated savings per customer from the event obtained from the regression model coefficients. Meter kW is metered customer demand from the AMI data. Model predicted is the customer load predicted by the regression model. The baseline is the counterfactual demand under the assumption that the event had not occurred. The model predicted, and counterfactual will only differ, if at all, during the one hour before the event, the event hours, and the eight hours after the event.

Figure D-4. Average Daily Load Impacts Per Participant– Summer 2018 (4 p.m. Events)

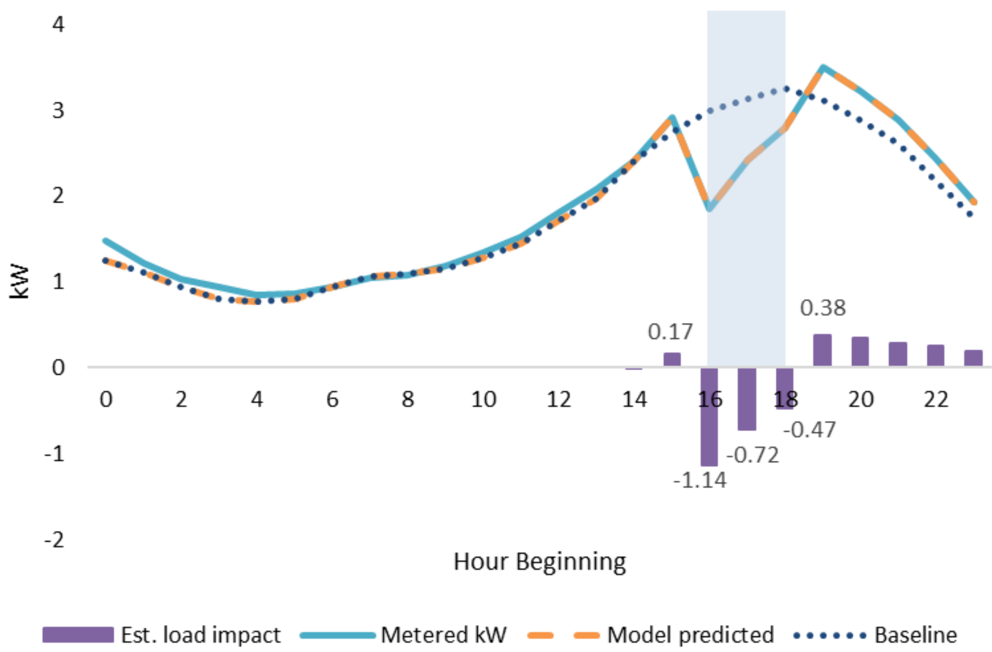


Table D-2. Connected Savings Demand Reduction by Event by Start Time – Summer 2018[213]

Event Hour	4 p.m. to 7 p.m. (5 events)	5 p.m. to 7 p.m. (4 events)
Pre-Event Hour 1	0.17*	0.18**
Event Hour 1	***-1.14****	***-1.17****
Event Hour 2	***-0.72****	***-0.74****
Event Hour 3	***-0.47****	--
Post-Event Hour 1	0.38***	0.31***
Post-Event Hour 2	0.34***	0.38***
Post-Event Hour 3	0.28***	0.29***
Post-Event Hour 4	0.26***	0.25***
Event Avg. Demand Impact (kW)	**-0.78**	**-0.96**
Event Hour Min. Demand Impact (kW)	**-0.47**	**-0.74**
Event Hour Max. Demand Impact (kW)	**-1.14**	**-1.17**
Avg. Energy Impact (kWh)	**-0.91**	**-0.50**

Table D-3. Connected Savings Demand Reduction by Event – Summer 2018[214]

Event Hour	Event								
	1	2	3	4	5	6	7	8	9
Pre-Event Hour 1	0.23**	0.23**	0.17	0.23**	0.24**	0.25**	0.07***	0.23**	-0.08
Event Hour 1	***-1.33****	***-1.24****	***-1.34****	***-1.45****	***-1.35****	***-1.33****	***-1.03****	***-1.00****	***-0.38****
Event Hour 2	***-0.73****	***-0.79****	***-0.72****	***-0.91****	***-0.84****	***-0.76****	***-0.67****	***-0.81****	***-0.35****
Event Hour 3	***-0.55****	***-0.55****	-	***-0.57****	***-0.52****	-	-	-	***-0.18****
Post-Event Hour 1	0.30***	0.35***	0.49***	0.40***	0.50***	0.47***	0.17	0.15	0.33***
Post-Event Hour 2	0.27**	0.41***	0.39***	0.30***	0.42***	0.31***	0.43***	0.39***	0.28***
Post-Event Hour 3	0.24**	0.41***	0.26**	0.31***	0.23**	0.23**	0.40***	0.26***	0.19**
Post-Event Hour 4	0.18*	0.43***	0.30***	0.29***	0.19*	0.15*	0.33***	0.24**	0.21***
Event Avg. Demand Impact (kW)	**-0.87**	**-0.86**	**-1.03**	**-0.98**	**-0.91**	**-1.05**	**-0.85**	**-0.91**	**-0.30**
Avg. Energy Impact (kWh)	**-1.39**	**-0.74**	**-0.45**	**-1.41**	**-1.13**	**-0.69**	**-0.28**	**-0.55**	**0.01**

The thermostats are programmed to pre-cool homes in the hour leading up to events, and again after events, and consumption rebounds when thermostats return to their original setpoint. Cadmus determined the total energy impact of an event (shown in Table D-1 and Table D-2 as Average Reduction in kWh) by summing the pre-event hour, each event hour, and four post-event hour effects. Since events starting at 4 p.m. lasted an extra hour, their total reduction is significantly higher (0.91 kWh) than for events that started at 5 p.m. (0.50 kWh). Figure D-3 provide detailed specific-event day impacts.

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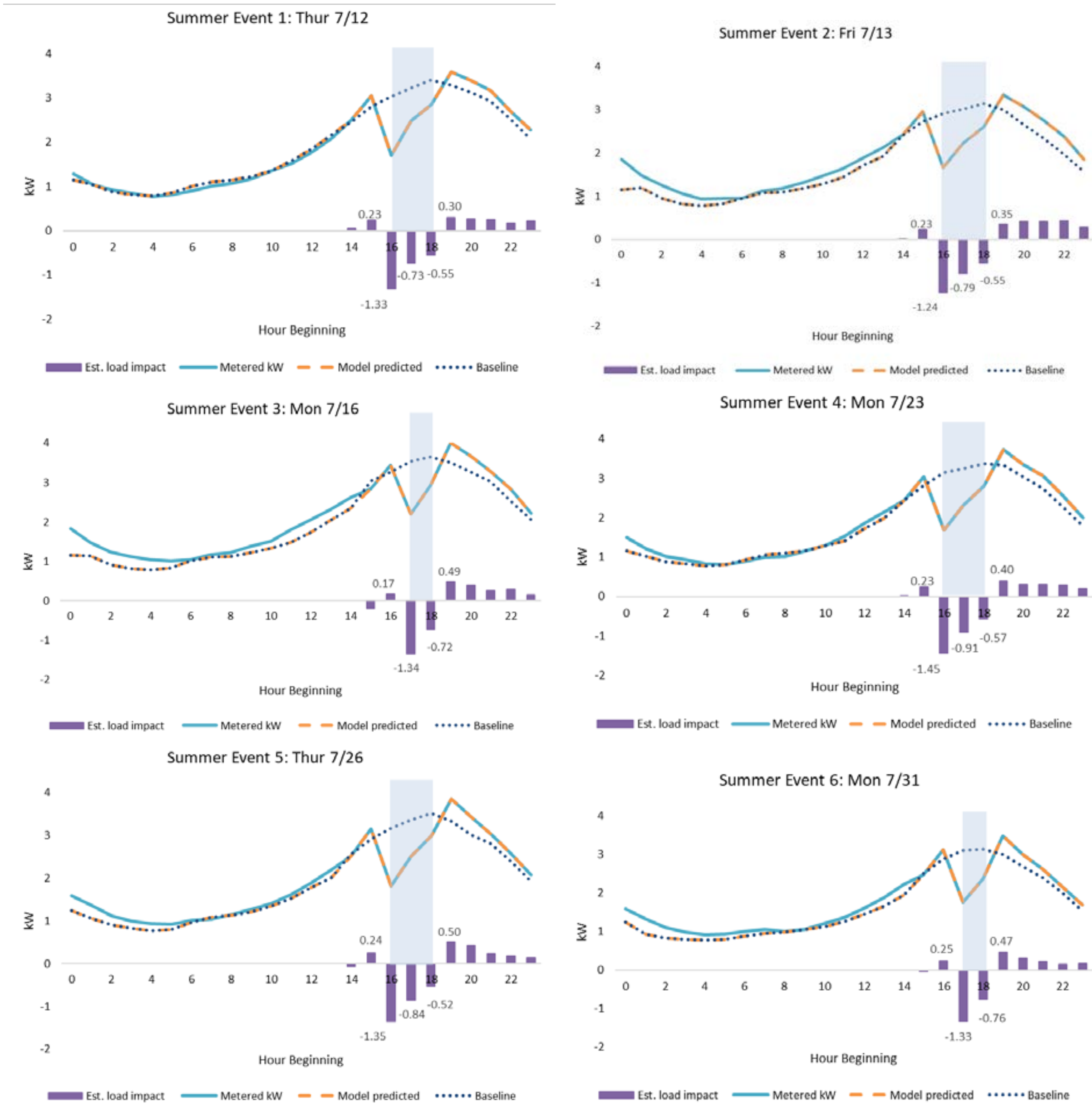
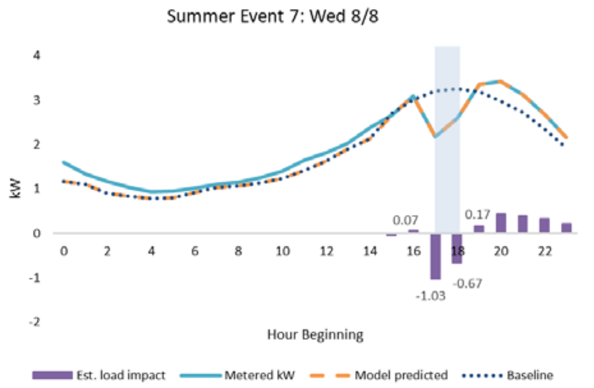
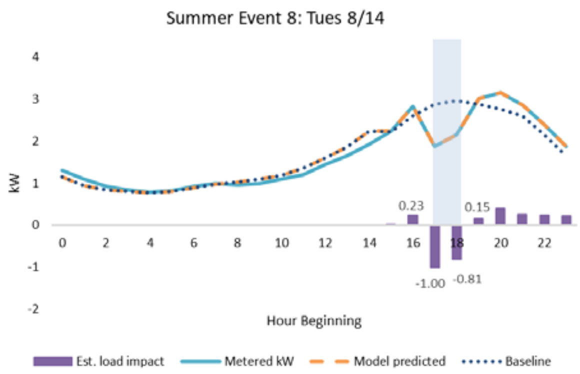
[213] Estimates obtained from Cadmus panel regression analysis of customer hourly electricity demand. ***, **, * denotes the estimate is statistically significant at the 1%, 5%, and 10% levels. Energy impacts were estimated by summing the load impacts across the pre-event hour 1, event hours, and post-event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

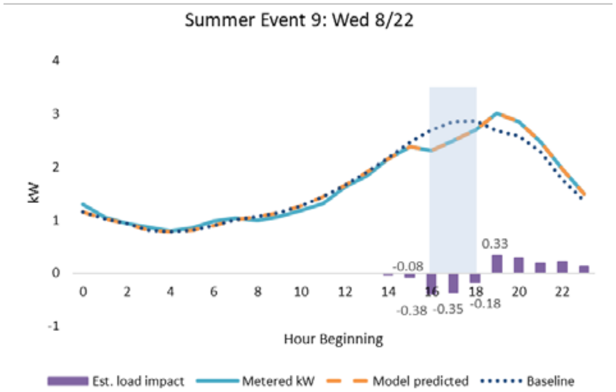
[214] Ibid.

Figure D-5. Average Daily Load Impacts per Participant by Event – Summer 2018




Summer Event 7: Wed 8/8
kW
Hour Beginning
0.07
0.17
-1.03
-0.67
Est. load impact
Metered kW
Model predicted
Baseline


Summer Event 8: Tues 8/14
kW
Hour Beginning
0.23
0.15
-1.00
-0.81
Est. load impact
Metered kW
Model predicted
Baseline


Summer Event 9: Wed 8/22
kW
Hour Beginning
0.33
-0.08
-0.38
-0.35
-0.18
Est. load impact
Metered kW
Model predicted
Baseline

PGE

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