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November 1, 2019

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

Attn: Commission Filing Center

Re: UM 1827 Navigant Final Evaluation of PGE's Multifamily Water Heater Pilot

Enclosed is Navigant's final evaluation of Portland General Electric Company's (PGE's) Multifamily Water Heater (MFWH) Pilot for the Winter 2018-19 demand response (DR) season. PGE committed to providing a final evaluation to the Commission by the end of 2019 in PGE's UM 1827 supplemental filing in 2017. PGE contracted with a third-party evaluator (Navigant) to identify potential improvements to pilot processes including recruitment, enrollment, data management, installation, and event management. As part of the evaluation, Navigant also conducted seasonal interviews with PGE Staff, the third-party implementation vendor (CLEAResult), participating property managers, and impacted tenants after the event season. Navigant's evaluation report is enclosed.

The Navigant evaluation provided key findings into how customers are acquired; whether the customer had a positive experience; how PGE and its vendors integrate systems; and how water heaters performed during an event. Given that this is a pilot, PGE appreciates Navigant's findings and recommendations to improve it. Some of the valuable insights from the evaluation include:

- **Customer Acquisition:** Navigant suggested improved communications to property managers that focused on peer reviews and program benefits to enable increased market adoption.
- **Customer Experience:** While participants are generally very satisfied with the program, Navigant suggested providing more concise information to tenants moving in *after* installation to ensure they are aware of the program and their participation.
- **System Integrations:** Successful hardware and software integrations across multiple stakeholders are time consuming and can be more complex than anticipated.
- **Event Results:** The pilot's small sample size limited the ability to establish a statistically significant demand reduction value. Assets were broken into two groups (A and B) to provide an in-program control group, which exacerbated the already small sample size. Other limitations that impacted the evaluation outcomes included:
  - Wi-fi connectivity was only at an average of 57%; and
  - Intra-hour event calling procedures led to partial event data because Advanced Metering Infrastructure (AMI) only provides data in hourly intervals.

PGE has made significant changes to the pilot using the key findings identified in the evaluation. These programmatic enhancements are prioritized to maintain a positive customer experience, ensure that event data is valid and quantifiable, develop sustainable practices for system integrations, and drive market adoption to increase overall demand response value.

PGE has implemented the following improvements:

- **Improved messaging** during the sales process to drive market adoption. Property managers respond most enthusiastically to succinct, benefits-focused messages and testimonials from other property managers who have had positive experiences with the pilot. Messaging that was demand response focused has been toned down because demand response principles are too complicated and dissuaded property managers to participate. As a result of changing the messaging, the pilot has seen an uptake in property managers who are interested in participating.
- **Improved communications** with current tenants and those that move in after the installation. PGE will provide property managers with a simple one-page explanation of the program along with the Chinook Book incentive opportunity. The one-pager will also be included in new-tenant paperwork. PGE will send annual program emails to all tenants in partnership with property management.
- **Applied lessons learned** for ongoing systems integrations. PGE and vendors are working on development protocols concurrently instead of subsequentially which has streamlined the amount of time required to develop, test and implement solutions.
- **Introduced new technology** to improve connectivity rates. Given the poor connectivity rate (60%) of the Wi-Fi switches, PGE implemented a cell enabled switch, rather than relying on Wi-Fi connectivity, to achieve a more acceptable rate (90%) of controllable switches per event.
- **Updated event calling procedures** from intra-hour to hourly intervals. PGE changed how events were called starting in the 2019 Summer season. Events will start and stop on the hour so both telemetry and AMI data are in alignment and results can be better evaluated. PGE will also continue to explore moving meter readings to 15-minute intervals to offer more program flexibility. This procedural change will ensure that event results are valid and quantifiable.

The evaluation results have been instrumental in identifying program design and operational challenges, and opportunities for improvement. Shortly, PGE will be filing to extend the pilot's term and participation to address the challenges raised in the evaluation. Adding incremental units to the MFWH pilot is required to further test additional technologies with adequate sample sizes. Currently, there is an insufficient number of deployed units to determine the capacity value and how to optimize various use cases. This resource is critical to PGE's decarbonization strategy as well as our commitment to better serve and offer opportunities to our multifamily customers.

If you have any questions or require further information, please Kalia Savage at (503) 464-7432. Please direct all formal correspondence and requests to the following e-mail address pge.opuc.filings@pgn.com.

Sincerely,

Jay Tinker
Director, Rates and Regulatory Affairs

Encls

cc: UM 1827 Service List and Nick Sayen, OPUC

NAVIGANT

Multifamily Residential Demand Response Water Heater Pilot Evaluation

2018-2019 Report to the Oregon Public Utilities Commission

FINAL DRAFT

Prepared for:

NAVIGANT

**Multifamily Residential Demand
Response Water Heater Pilot Evaluation**

TABLE OF CONTENTS

NAVIGANT

**Multifamily Residential Demand
Response Water Heater Pilot Evaluation**

List of Figures

List of Tables

LIST OF ACRONYMS

AMI .... advanced metering infrastructure

ATE ....average treatment effect

ATT...average treatment effect on the treated

DR .... demand response

DRMS...demand response management system

OPUC……………..…………………………………………………………………Public Utility Commission of Oregon

PGE.. Portland General Electric Company

VPP ....virtual power plant

**Multifamily Residential Demand
Response Water Heater Pilot Evaluation**

DISCLAIMER

This report was prepared by Navigant Consulting, Inc. (Navigant) for Portland General Electric Company. The work presented in this report represents Navigant's professional judgment based on the information available at the time this report was prepared. Navigant is not responsible for the reader's use of, or reliance upon, the report, nor any decisions based on the report. NAVIGANT MAKES NO REPRESENTATIONS OR WARRANTIES, EXPRESSED OR IMPLIED. Readers of the report are advised that they assume all liabilities incurred by them, or third parties, as a result of their reliance on the report, or the data, information, findings and opinions contained in the report.

EXECUTIVE SUMMARY

Portland General Electric Company's (PGE's) Multifamily Residential Demand Response Water Heater Pilot offers multifamily property managers and tenants the opportunity to participate in PGE's efforts to maintain the grid and lower the cost of supplying power. The primary goal of the pilot is to achieve participation of 8,000 customers or up to 4 MW of Demand Response (DR) capacity by year-end 2019 as part of PGE's 77-MW-by-2021 DR commitment to the Public Utility Commission of Oregon (OPUC). Specific pilot objectives include:

- Quantifying the energy consumption that can be shifted to different times from:
    - Water heaters equipped with a communication interface that supports Direct Load Control Events or
    - Water heaters retrofitted with a control switch in the power supply to the tank
- Further informing the program design for a water heater demand response program
- Determining the appropriate incentive level for customers who choose to participate in a demand response program for water heaters
- Integrating and testing different technologies
- Implementing different demand response dispatch strategies

This report describes the process and impact evaluation findings for PGE's Multifamily Residential Demand Response Water Heater Pilot through the Winter 2018-19 DR season. Navigant serves as the independent evaluator for both the process and impact evaluations. This report to the OPUC is part of the deliverables provided by Navigant and covers evaluation activities conducted since Q3 2018.

Methodology

As part of the initial stage of the evaluation, Navigant and PGE developed a Multifamily Residential Demand Response Water Heater Pilot logic model as a guide to better understand the pilot design and to develop evaluation metrics. PGE will continue to periodically revisit and adapt the model as an ongoing guide for the developing pilot.

The process evaluation has sought to assess how well the Multifamily Residential Demand Response Water Heater Pilot is operating and to identify potential improvements to pilot processes, including recruitment, enrollment, data management, installation, and event management. Navigant conducted seasonal interviews with PGE staff, the contracted pilot implementation team, and participating property managers as well as a survey of participating tenants after the winter 2018-19 DR season.

The impact evaluation used AMI data to estimate the average DR impacts for each event in the winter 2018-19 DR season. Navigant submitted a data request to PGE to obtain participant tracking data, event data, and AMI interval data for all participating customers. To estimate event impacts, Navigant employed a fixed effects regression analysis.

Findings

The key takeaways from the evaluation to date are summarized below.

Process Evaluation Findings

The process evaluation interviews and surveys provided valuable context for the evaluated impacts as well as insights into possible improvements to pilot implementation. Key process-related findings include:

- **Technology integration and recruitment challenges delayed the pilot timeline.** Integrating the hardware and software necessary to implement this pilot proved to be a more challenging and

1

time-consuming task than initially expected, and the pilot was unable to conduct large-scale non-testing events in summer 2018 as originally planned. However, PGE, CLEAResult, and Enbala have developed a strong working relationship that focuses on solving problems quickly, and they have worked through many technical challenges together over the course of the pilot to date.

- **Pilot staff learned that the most persuasive recruiting message is not about demand response.** Property managers respond most enthusiastically to succinct, benefits-focused messages and testimonials from other property managers who have had positive experiences with the pilot; education about demand response was not useful in persuading property managers to participate.

- **Property managers and customers are highly satisfied with the installation process**, with a few suggestions for minor improvements. Interviewed property managers praised the pilot's communications and the ease of the installation process, and tenants were also highly satisfied with the installers' timeliness and professionalism.

- **Tenant satisfaction could be improved with additional communication.** Satisfaction is significantly higher among the tenants who recalled receiving communication about how the pilot works than those who did not recall such communication; however, less than half recalled receiving any communication about how the pilot works. Furthermore, few participants are aware of the Chinook Book incentive, which is the primary tenant benefit.

- **Some tenants believe that they are experiencing hot water issues as a result of the pilot.** Of surveyed tenants that are aware that they're participating in the pilot, 10% believe that the pilot is causing them to run out of hot water. Note that the sample size for the tenant survey was relatively small due to the limited population of participants, so 10% equaled just ten people, and none of the interviewed property managers indicated that they had ever received this complaint. Pilot staff report receiving very few complaints about cold water issues. Future surveying will explore this issue in more depth.

- **Improved data tracking and reporting would improve pilot management and evaluation.** PGE and CLEAResult staff both expressed a desire for better reporting from Enbala and Aquanta, to enable faster diagnostics of connectivity issues and obtain better insight into event performance. The impact evaluation uncovered some inefficiencies and errors in data tracking procedures that—if improved—could enable better QC and faster identification of issues for pilot managers, as well as easier impact evaluation.

This report further documents Navigant's recommendations for process improvements and areas for PGE staff's consideration as the pilot moves forward, based on findings from the surveys and interviews.

Impact Evaluation Findings

Only a few events produced statistically significant demand reductions that are measurable in the AMI data. Of the 56 events called during the winter season, only four had average demand reduction impacts that were positive and statistically different from zero in the AMI data analysis. The analysis was complicated by the fact that most AMI data is hourly, but events often started and ended on the quarter or half hours, thereby diluting the measurable impact in partial event hours. A "full hour" analysis revealed higher average savings relative to the full event result. In addition to the partial hour issue, several other factors limited the effectiveness of the AMI data analysis for evaluating this first season of DR events, including a small population of participants and connectivity issues. These factors may or may not persist in the evaluation of later DR seasons; see Section 4.2 for more discussion of alternative impact evaluation methodologies that PGE and Navigant may pursue in the future.

Table 1 summarizes the pilot's average per event impacts as well as the range.

Table 1. Winter 2018-2019 Impacts per Event

Metric	Season Average	Minimum	Maximum
Per Device **kW** Impact (ATE)	-0.004	-0.124	0.075
Per Device Full Hour **kW** Impact	0.039	-0.031	0.132
Per Controlled Device **kW** Impact (ATT)	-0.037	-0.856	0.272
Per Controlled Device Full Hour **kW** Impact	0.135	-0.140	1.069
Total Pilot Event **MW** Impact	-0.003	-0.069	0.058

Source: Navigant analysis

1. BACKGROUND

1.1 Pilot Description

The Multifamily Residential Demand Response Water Heater Pilot achieves peak demand reductions by controlling water heaters in participating multifamily buildings. The pilot implementation is managed by CLEAResult under contract to PGE, and Enbala provides the demand response management system (DRMS) for the pilot. The pilot recruits property owners and managers of multifamily buildings to enroll in the pilot. Once a property is enrolled, the pilot installs switches on all eligible, accessible water heaters as well as Wi-Fi equipment[1] to enable the switches to receive signals to disrupt power to the water heater during events. When events are called, any water heater that is actively heating and visible to Enbala's dispatch system Concerto is available for participation. Concerto sends a signal to these switches to disrupt the power to the water heater to prevent it from heating, and then monitors the tank to estimate if it has drained to 50% of its capacity. If it has, the switch will release the tanks from the event. If not, the switch will continue to prevent the tank from heating until the event is over. This is meant to ensure that tenants' usage of hot water is not negatively affected during events.

Participating property owners receive financial incentives for each installed water heater. Tenants receive access to Chinook Book online coupons as their reward for participation. Tenants can opt out of the pilot if they desire.

The pilot's first demand response season ran from December 12th, 2018 to February 28, 2019. PGE called up to two events per weekday, excluding holidays, at varying times of day and for various lengths of time.

1.2 Pilot Objectives

The Multifamily Residential Demand Response Water Heater Pilot staff identified several market barriers that the pilot design aims to address:
- Water heating is a major contributor to residential energy consumption, yet a low innovation product category.[2]
- Water heaters are the lowest engagement household appliance; residential customers rarely interact with or even look at their water heater unless something goes wrong with it.
- Two-way water heater switches and communications modules are relatively new, expensive, and minimally tested.
- Manufacturers assume that the target audience for connected water heaters are single family households, and thus have not yet manufactured lower cost connected water heaters or marketed connected water heaters to multifamily customers.
- The incremental costs of water heaters with advanced features fall on property managers, but property managers have little incentive to install anything but the most basic, low-cost water heaters because the upgrades are not valued enough by tenants to justify charging higher rent.

The ultimate objective of the pilot is to obtain OPUC approval of a full program roll-out. Specific pilot objectives include:

- Quantifying the energy consumption that can be shifted to different times from:
  - Water heaters equipped with a communication interface that supports Direct Load Control Events or
  - Water heaters retrofitted with a control switch in the power supply to the tank
- Further informing the program design for a water heater demand response program

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[1] Note that future installations will include switch equipment using cellular technology rather than Wi-Fi.

[2] There are some innovations occurring in residential water heating equipment, but they are not priced for or geared towards the multifamily residential market.

- Determining the appropriate incentive level for customers who choose to participate in a demand response program for water heaters
- Integrating and testing different technologies
- Implementing different demand response dispatch strategies

1.3 Target Audience

Pilot staff identified several target audiences that the pilot seeks to influence. The initial targets for recruitment are the owners and property managers of 25+ unit multifamily buildings. Property managers are typically the pilot's first point of contact, though the property owners are the ultimate decision-makers. Then pilot staff work closely with the property managers and maintenance managers to coordinate the installations and assist the property managers in communicating to the tenants about the pilot. Recruitment has been focused on the 50 largest property management companies managing properties with 25+ units; PGE estimates that those 50 companies manage approximately 95,000 units (apartments) in total.

A secondary target audience is manufacturers of water heaters, water heater switches, and communications modules. The pilot works directly with several switch manufacturers as vendors, and also aims to persuade water heater manufacturers to integrate communications modules into lower cost water heaters, which would reduce pilot implementation costs. Prior to the pilot's efforts, only high cost "smart" water heaters included communications capabilities, and multifamily properties typically install low cost, basic water heaters in their tenants' units.

2. EVALUATION METHODOLOGY

2.1 Kickoff Meeting and Logic Model

Logic model development was initiated during a working session held with Navigant, PGE, and CLEAResult staff on August 23rd, 2018. The staff in attendance at the working session including PGE pilot managers and evaluation staff as well as CLEAResult's implementation manager. The logic model diagram and measurement metrics were then detailed in an iterative process with input from PGE's pilot manager. The logic model is intended to be a living document that can be updated by PGE pilot staff throughout the course of implementing the pilot, and informed the design of interview guides and the tenant survey conducted as part of the process evaluation. The logic model is located in Appendix A.

2.2 In-Depth Interviews

Navigant conducted two rounds of interviews with PGE staff, implementers, and participating property managers. The objective of the first round of interviews was to orient PGE and Navigant staff to stakeholder views and set a baseline for subsequent interviews to delve more deeply into lessons learned and recommendations for improvement. The second round of interviews focused on lessons learned during the first demand response season conducted in winter 2018-19.

	Interviews Conducted in November-December 2018	Interviews Conducted in March-May 2019
PGE pilot manager	1	1
CLEAResult project manager and implementation staff	3	4
Enbala project manager	1	1
Property Managers	2	6

2.3 Tenant Survey

The sample frame for the tenant survey included all tenants at participating properties who had devices installed and activated on or before January 31st, 2019, and therefore would have experienced at least one month of events during the winter 2018-2019 DR season which ended on February 28th.

Navigant programmed and fielded the survey through the Qualtrics web surveying platform, first via a pretest to 100 randomly selected participants on March 12nd and then via a full launch to the remaining sample on March 20th. The pretest sample received two reminders and the full launch sample received one reminder. The survey was closed on March 31st. Participants who completed the full survey received a $10 Amazon gift card via email.

The survey achieved an overall response rate of 22%, as shown in Table 2. A total of 102 customers that were aware of their pilot participation completed the full survey. An additional 41 respondents were unaware of their participation in the pilot[3] and were screened out of the survey after the initial awareness questions.

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[3] Tenants may be unaware of their participation in the program if they moved in after the installation or if they simply do not recall the installation. The program gives the property managers information to pass along to new tenants, but they may not do so.

Table 2. Tenant Survey Sample Disposition

Emails sent	665
Bounced emails	12
Completed surveys	143
- *Aware of participation in pilot*	*102*
- *Not aware of participation in pilot*	*41*
Response Rate (completed surveys divided by valid emails sent)	22%

2.4 Impact Analysis

2.4.1 Data Sources and Cleaning

For the impact analysis, Navigant relied on the following data elements:

- Hourly AMI data for all enrolled units through February 28, 2019 (PGE)
- Event log containing event start and end times for each test group[4] as well as program-calculated impacts (Enbala)
- Program tracking data (CLEAResult)
- Water heater switch activity data (Aquanta)

Prior to the impact modeling, Navigant assembled and cleaned the data and <u>excluded</u> the following assets and AMI data:

- Assets (i.e., water heaters) with a missing or problematic VPP ID (the ID used to link the AMI data to the event log)
- Assets without a Participation Status of "Full Participation"
- Assets without an installation date (when an asset was installed at the premise[5]), activation date (when Aquanta officially adds the device to the PGE fleet, with field-collected initialization variables [e.g., tank size]), or enablement date (when an asset was connected to Enbala's system and available for dispatch)
- AMI data on or before the asset's activation or enablement date

2.4.2 Regression Modeling

To estimate event impacts, Navigant employed a fixed effects regression analysis using panel AMI data. A "fixed effect" controls for individual differences in demand driven by factors that do not change over time (e.g., apartment square footage, etc.), and panel data refers to the fact that the analysis was run across all participants to estimate the average impact of each pilot event.

As the pilot is designed for multifamily buildings, tenant turnover is an expected attribute in the data. Therefore, the analysis treats the premise as the unit of analysis and not the occupant. With the A/B design, the rate of turnover between the two groups should be equivalent and thus should not introduce bias into the evaluation.

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[4] The program uses an A/B design in which the population of enrolled customers is divided into two randomized test groups (A and B) who receive events on alternating weeks. When the A group is called for events, the B group serves as the control group, and vice versa. Navigant reviewed the balance of the A and B groups and provided PGE with rebalanced group assignments for the summer 2019 DR season.

[5] At this point, the asset will try to connect to Wi-Fi and the Aquanta cloud, and may start reporting device status, but may not yet be properly initialized and calibrated.

The impact evaluation model predicts hourly average demand as a function of various parameters. A set of DR event dummy variables captures the impact of load curtailment by time of day. The model treats the A/B test and control groups as separate dummy variables and includes time and weather variables to help control for load variation across event days. Due to the A/B design, only event day data is included in the model. Consequently, the event baseline is primarily informed by the group not subject to a DR event (the control group). However, if differences exist between the two groups during non-event hours on the event day, the model can correct for this.

The model outputs a set of DR impact estimates and their standard errors for each event. These impacts are a function of the predicted baseline generated by the model. The statistical significance (and resulting confidence interval) of an impact estimate is derived from the standard error. Formally, the model specification is as follows:

<div align="center">**Equation 1. Model Specification**</div>

$$kW_{it} = \alpha_i + \lambda_t + \beta_{1t}(T_{it} * Event_{it}) + \beta_{2t}(T_{it} * Snapback_{it}) + \gamma Weather_{it} + \varepsilon_{it}$$

Where:

kW_{it}	=	The average kW for premise i in time period t.
α_i	=	Premise-specific fixed effect.
λ_t	=	Time fixed effects (e.g., hour, day-of-week)
T_{it}	=	A dummy variable equal to 1 if premise i is in the treatment group (the curtailed group) during period t, and 0 otherwise.
$Event_{it}$	=	A dummy variable equal to 1 if time period t for premise i falls in the event period, and 0 otherwise.
$Snapback_{it}$	=	A dummy variable equal to 1 if time period t for premise i falls in the snapback period (the first hour following an event), and 0 otherwise.
$Weather_{it}$	=	A set of weather variables specific to customer i and time period t (e.g., temperature, THI, heat build-up).
β_{1t}	=	The coefficient to be estimated measuring the impact of the event during period t.
β_{2t}	=	The coefficient to be estimated measuring the post-event snapback impact during period t.

For the 2018/2019 DR season, Navigant estimated the average treatment effect (ATE) for each event. This is the average DR impact across all enrolled assets for a given event, regardless of whether the asset was online or fully controlled for an event.

3. PROCESS EVALUATION FINDINGS

3.1 Technology Selection, Integration, and Data Tracking

This section presents key learnings regarding the selection of switch technologies, the integration of hardware and software data systems, and data tracking and reporting. The findings in this section are based primarily on the interviews as well as informal conversations conducted with pilot staff and implementers.

3.1.1 Technology Selection

Vetting, selecting, and contracting with switch manufacturers is a critical task for the pilot and requires working with manufacturers in a small, nascent industry. CLEAResult indicated that they have had conversations with 17 manufacturers about their Wi-Fi capable switch technologies, the practicalities of installation, how their data systems work, how they prevent cold water events, whether they have a water temperature sensor, and even how the switches are labeled (so the pilot can reduce human errors as staff receive and install those switches). Most of these conversations occurred after the Winter 2018-2019 season evaluated in this report.

The pilot initially worked with three switch manufacturers in 2018. Two manufacturers had significant technical challenges that the pilot staff had to work through, described below:

- **Supply chain issues and faulty solder paste:** One switch manufacturer experienced significant technical challenges and the pilot eventually needed to remove those switches that had been installed in participating buildings. The manufacturer had delays at their Chinese manufacturing facility related to the global supply chain crisis for small electronics and decided to manufacture the switches in a U.S. facility instead. The U.S. facility had inadequate quality control procedures and produced switches that had faulty solder paste. This caused the switches to think that there were brown-outs and shut off power to the water heaters, as well as causing some switches to appear as being operational but not available for curtailment. After several of these switches caused water heaters to shut off spontaneously, the pilot had to quickly uninstall the switches so that the tenants would have a functional water heater. After a lengthy period of troubleshooting and testing, the pilot determined that they could not identify which switches were faulty and which were not, and thus made the decision to remove all of this manufacturer's switches and replace them with switches from the other manufacturer. These issues slowed the overall installation process and resulted in the first winter season of DR events only including switches from a single switch manufacturer.

- **Calibration issues and firmware bugs:** The pilot also had to work through some technical challenges with the switches that were used in the winter season events. The water temperature sensors on the switches had some calibration issues early in the season, which caused the switches to falsely detect that the water temperature was dropping, indicating inadequate supply for the end-user, and set the devices to override mode (i.e., remove the water heater from the event curtailment and allow it to begin heating again). In the early events, some water heaters were mistakenly put into override mode when they should have been available for curtailment, which reduced the potential demand reduction. The pilot team determined that the calibration issues were a result of seasonal variability in municipal water supply water temperature and that the algorithm that had worked well in the test events held in the summer no longer worked well in the winter. Midway through the winter season, the switch manufacturer added an operation to recalibrate the algorithm that detects changes in water temperature on a seasonal basis. Accordingly, this issue appears to have been resolved, although the pilot team continues to monitor the effectiveness of the algorithm. In addition to the calibration issue, these switches had a firmware bug whereby some devices remained in override mode permanently once they entered it. This caused the number of available water heaters to decline over the course of the winter season until a firmware fix was implemented in mid-February.

9

3.1.2 Technologies in the Exploratory Phase

Through the period covered by this evaluation, the pilot team has been focused primarily on the installation and integration of the Wi-Fi switches, but they are also pursuing other technologies that may improve pilot performance and cost-effectiveness in the future:

- **Cell-capable switches:** All of the switches installed to date rely on Wi-Fi technology (as opposed to cellular data) to receive the signal that an event is called and the water heater needs to be curtailed. The use of Wi-Fi required the pilot to install routers and repeaters throughout the participating buildings, and the equipment has required more troubleshooting and recurrent maintenance than initially expected. Even with this troubleshooting and recurrent maintenance/site visits, which is a big imposition to tenants, the pilot was only able to achieve approximately 60-70% Wi-Fi connectivity. The pilot is currently working on vetting and contracting with at least one manufacturer of cell-capable switches, which would eliminate the need for Wi-Fi equipment in tenants' units, and pilot staff are confident that the connectivity rate with these cell-capable switches will be much higher than the Wi-Fi technology can allow. Moving to cell-capable switches will also reduce equipment costs and installation time.

- **Lower cost water heaters with integrated communication technology:** The pilot has also worked to persuade water heater manufacturers to develop lower cost water heaters with integrated communication technology, which would reduce pilot installation costs by incentivizing new construction properties to install a fleet of these 'ready to install' water heaters. They include a port that an implementation team member can plug a communications module into, eliminating the requirement for electrician services on a retrofit. These communications modules currently rely on Wi-Fi, so implementation team members would still need to install routers. The pilot could also incentivize managers of existing multifamily properties to install these connected water heaters when they need to replace their existing water heaters. The pilot team successfully persuaded water heater manufacturer A.O. Smith to do a production run of these lower cost connected water heaters. PGE plans to offer a $70 instant rebate to cover the full incremental cost between a standard water heater and a connected water heater to properties that purchase them, based on pricing estimates from A. O. Smith's local distributor and manufacturer's rep.

3.1.3 Integration

One of the pilot's initial challenges was the length of time it took to select switch manufacturers and to integrate Enbala's system with the switch manufacturers' systems. Enbala was building out the software necessary to implement DR events in parallel to CLEAResult installing and testing equipment in the field. When it came time to integrate the two systems, the integration process was more complex than the pilot team had foreseen. A key issue was the necessity of the switches detecting when water heaters are about to run out of hot water, which is more complex than simply detecting the on/off status (as would be the case for an air conditioning direct load control program). The system needs to be able to put a device into override mode when the tank's water level is getting low. The switch manufacturers each have their own methodologies for determining the tank's water level.

The pilot also experienced issues with scaling up the number of assets included in Enbala's system. After the initial integration effort, the system was operating reliably with 400-500 assets, but when another large set of assets was added, the system became unstable again.

PGE and CLEAResult expressed some frustration with the length of the integration process and Enbala's approach to developing their API design document. This document went through nine iterations in which Enbala engaged different stakeholders (e.g., PGE, CLEAResult, EDM, switch vendors) at different stages of development. CLEAResult and Enbala worked through those challenges and both parties now describe their relationship as collaborative and effective, with frequent and candid communication. The lesson learned regarding the integration process was that the initial draft (and any subsequent drafts) of the

design documents need to be distributed to all the stakeholders at the same time so that they can review, provide feedback, and sign off on the same version.

The length of time required to complete the contracting and integration with the first switch manufacturer was one of the main causes for the pilot delaying its initial DR season to winter 2018-19 rather than summer 2018 as initially planned. Another key driver of the delay was the initial challenges in recruiting participating properties, discussed more in Section 3.2.1

3.1.4 Data Tracking and Reporting

The data systems needed to track and manage the pilot's installations, equipment, active participants, and events are complex and involve many different parties responsible for different aspects of the data flows. PGE and CLEAResult would like additional reporting capabilities from the Aquanta and Enbala systems to provide better insight into whether an event is achieving lower than expected load reductions, due to hot water being used during the event or due to connectivity or other technical issues. They indicated that the reporting has improved greatly over the course of the pilot but that additional improvements are still needed to improve QC processes and event management.

CLEAResult also expressed a desire for better real-time reporting from Aquanta during the installation phase, so that installers can more easily verify that a device is activated and connected before they leave the property. This improvement would reduce the need for costly follow-up site visits and reduce the impact of the pilot on tenants.

Many data tracking and reporting issues were discovered as a result of the impact evaluation activities. These issues are summarized below:

- **Fluctuating event results in Enbala's Tableau report:** The PGE pilot manager maintains an Excel-based event log detailing each dispatched event. This includes the start and end time of each event for each sub-group, the number of assets controlled, and the resulting demand reduction for each sub-group. These event details are copied into Excel from a Tableau-based reporting dashboard managed by Enbala. On numerous occasions, the pilot manager found that a given event result changed throughout the season, making it difficult to keep an accurate log of event results.

- **Discrepancies between the PGE and Enbala event logs:** During the impact modeling efforts, Navigant discovered several disagreements between PGE's event log containing event results and Enbala's event log. Start and end times weren't always in alignment, and some events existed in one log but not the other.

- **Incorrect VPP IDs in program tracking data:** During the first iteration of impact modeling, Navigant discovered that some assets in the program tracking data had VPP IDs that did not agree with the asset's higher level DR group (e.g., VPP ID "1B" but DR group "A").

- **Asset count discrepancies throughout the winter DR season:** Until the very end of the evaluation, Navigant's estimates of available assets for each event were consistently lower than those reported by Enbala. After a significant investigation, a discrepancy was discovered between the program tracking data and Enbala's system. Some assets in the program tracking data had not been designated as available for dispatch despite being available in Enbala's system.

These issues have been resolved for the evaluation of the winter 2018-2019 season, and three improvements to the data tracking and reporting could prevent some of these issues from reemerging going forward. All these improvements could enable better QC and faster identification of issues for pilot managers, as well as more expeditious impact evaluation:

- **Asset level participation records for each event** (e.g., full participant, partial participant, override, offline, etc.), with clear criteria for what defines each status. This would provide a clear record of all assets that were available to the pilot on each event day and to what level each asset participated.

- An **exportable full-season event log** from the Tableau report would reduce the risk of discrepancies between the PGE and Enbala logs. Ideally, this log would have event date, start time, end time, VPP, number of assets in each participation status, and estimated impacts for all events.

- **Clear definitions for asset participation statuses** in the CLEAResult program tracking data (e.g., Enrolled, Enrolled + Installed, Full Participation, Opt-Out) **and clear dates for when an asset reached each level of participation**. Currently, several date fields (e.g., installation, enablement, and activation) determine when an asset was fully participating in the pilot, which contributed to asset count discrepancies throughout the winter 2018-2019 season. Providing a single date field for full participation would simplify the process of identifying available assets.

3.2 Recruitment, Enrollment, and Installation

Figure 1 summarizes the number of assets that the pilot has enrolled (i.e., contracted with the pilot), installed, and enabled (i.e., available for events) over time. The remainder of this section discusses the key learnings related to the recruitment, enrollment, and installation processes. The findings in this section are primarily based on the pilot staff and implementer interviews, and also include findings from the property manager interviews when relevant.

Figure 1. Summary of Recruitment and Installation Progress (March 2018 through April 2019)

Source: Navigant analysis of CLEAResult program tracking data.

3.2.1 Recruitment Strategies

Initial recruitment was a significant challenge, requiring a lengthy sales cycle and a high volume of communication between the pilot and potential participants, sometimes requiring up to 70 email, phone, and in-person contacts over the course of 6-8 months before persuading a property to commit to the pilot. The length of time necessary for recruiting a new participating property has decreased significantly as

PGE and CLEAResult refined their marketing approach, expanded their presence at industry events, and built positive word of mouth about the pilot.

The pilot team has seen a lot of success with in-person attendance at industry events, such as the Spectrum event, when they had a chance to interact face-to-face with an engaged audience of property managers and make a memorable impression with a photo booth and rubber ducky giveaway. The team's enthusiasm for the pilot concept is palpable and contagious, and their visible presence at events such as Spectrum and the Multifamily Northwest group's breakfast events helps raise the profile of the pilot and make recruitment easier. One CLEAResult team member noted, *"Last year, we were coming in cold, and now over time that people are seeing my face at events and we have all these materials, they have some kind of association of me with PGE and this program. They'll say, 'I've heard of you.' They have some measure of trust. Before, I would spend weeks, months, an entire year trying to get someone to believe I'm not full of it."*

Pilot staff have learned that educating potential participants on the concept and purpose of demand response is ineffective in getting property managers' and owners' attention; it is much more effective to lead with the benefits of participation, discussed in the next section. Since property managers are frequently the initial point of contact but not the sole decision-maker, it is important that the initial message be concise and appealing so that property managers can easily and accurately relay it to their property owners and maintenance managers.

Once one property manager has a positive experience with the pilot, it becomes significantly easier to recruit other properties owned by the same company. A CLEAResult team member observed, *"Now it's like an automatic referral system – if you do well at a property, they'll tell their colleagues."*

3.2.2 Property Owner/Manager Participation Motivations

Pilot staff observed that some property managers were tentatively interested but **unwilling to be the "early adopters"** and wanted to wait to see how other property managers react to the pilot's implementation before they will agree to participate.

Some property managers are very motivated by the per-unit **financial incentives** that they receive for participating; they appreciate the opportunity to have some breathing room in their budget to buy a new golf cart for the maintenance staff or replace a sprinkler. Pilot staff report that other property managers have directly told them the financial incentives are too small to mean anything to them. The interviewed property managers generally said that they appreciated the financial incentive but they weren't necessarily a strong motivation. Several property managers emphasized their desire to participate in energy-saving programs and to be perceived as environmentally conscious organizations.

Some of the interviewed property managers mentioned that they were very interested in the pilot's **potential ability to help them detect water leaks** or other water heater maintenance issues; however, the pilot has not yet built out this capability.

3.2.3 Enrollment and Installation

PGE and CLEAResult both feel the **enrollment process is working smoothly** and efficiently with no need for improvement. After a property agrees to participate, they follow a series of standardized steps:

1. First, the property manager provides a list of apartments/addresses that are to be enrolled, and CLEAResult verifies that they are PGE addresses.

2. Then there is a physical inspection to confirm that the water heaters are the right size, type, and in an accessible location.

3. Finally, CLEAResult schedules the installation and completes the work.

CLEAResult staff report that, after an initial learning curve, there has been a **steady decrease in the time required to complete the installations**, from one hour to approximately 15 minutes per switch. Pilot staff also report a significant reduction in the time needed to plan and prepare for installation, which will help allow for greater flexibility moving forward if there are unexpected schedule changes.

CLEAResult described a **positive working relationship with the electricians** who install the switches. They noted that they had some "attitude issues" with one of the companies early on, but they successfully resolved those issues by allowing that company to focus on the installations at new construction properties, where they do not have to interact with tenants and can start work earlier in the morning as they prefer.

One challenge with the installation process is the **need to meet permitting requirements** in a variety of city and county jurisdictions throughout PGE territory. Navigating the web of requirements is time consuming for the pilot staff. In some cases, the municipality requires a post-installation inspection, which can be an inconvenience for property managers and tenants. However, property managers and tenants report high overall satisfaction with the installation process; see sections 3.3.2 and 3.4.3, respectively, for more details on their installation experiences.

3.3 Property Manager Experience

This section discusses the property managers' experiences with the pilot. The findings in this section are based primarily on interviews conducted with property managers in fall 2018 and spring 2019 unless otherwise noted.

3.3.1 Pilot Communications

The interviewed property managers consistently praised the pilot for how well the pilot was explained to them. In particular, they noted that CLEAResult field staff was knowledgeable, helpful, and responsive. One property manager explained their enthusiasm for the pilot's communication as follows:

- *"The great thing was that [CLEAResult field staffer] was in communication with us pretty much every day before and during the installation. He was on top of his team, ahead of time he sent out a schedule for week 1, week 2, and calendar reminders with which buildings would be done on which days, so we were able to notify the tenants…It was extremely successful staying in such close contact with Kyle…I loved the way that they went above and beyond."*

One property manager experienced a situation in which the rebate check was initially sent to the wrong address but noted that CLEAResult stayed in close communication as they helped resolve the issue and the property manager did not appear to have any lingering dissatisfaction with the situation.

One property manager noted that they wished they had known ahead of time that a city inspection involving two visits would be required. They felt that the inspections would be too intrusive to tenants who had just had installers in their homes, so they negotiated to limit the inspections to vacant units. CLEAResult staff noted that they have learned that the requirements for inspections vary significantly by both city and county jurisdiction, and they are learning how to implement those requirements while minimizing tenant disruptions.

3.3.2 Property Managers' Installation Experience

The interviewed property managers had very positive things to say about the installation process, particularly the timeliness of installers, the speed with which the installations were finished, and the ease and flexibility of scheduling the installations around tenants' schedules and preferences. Some example comments from property managers on the installation experience include:

- *"Scheduling and communication was great…they did a great job of following up on scheduling."*

- *"I think it went really well. No one complained about the technicians, the time it took. Usually I have one or two complaints, but I didn't even have that… Very satisfied with the timeliness of the installers – they were here at 9 am every day like they said they would be and usually finished earlier than they anticipated throughout the day."*

- *"The installers were actually amazing. No complaints. Knowledgeable, polite, quick, they were great. No issue with any of them."*

One interviewed property manager noted that there were a few minor issues with the installers leaving doors unlocked or lights on but observed that three or four issues out of 338 units is not bad. That same property manager noted the installers were very professional and adhered faithfully to the planned schedule.

3.3.3 Property Managers' Communication with Tenants

The pilot relies on the property managers as the primary point of contact with tenants, including installation notifications, explanation of the pilot, fielding initial complaints about the pilot, and encouraging tenants to not opt out, since the property manager has a direct financial incentive to keep tenants in the pilot.

The property managers report that they have received minimal complaints from tenants about the pilot. One complaint that some property managers have received is about the flashing light on the devices, but they noted that the problem is easily resolved by placing a piece of electrical tape over the light. Some property managers noted that some of the equipment had to be placed in fairly conspicuous positions and were concerned about both the aesthetics and the potential for the equipment getting bumped; one said, *"Cosmetics are a big part of our industry. They were in a very awkward position."*

One property manager feels that the pilot should create a simplified brochure with a basic explanation of the pilot for tenants, noting, *"Many people don't read it [the current brochure]. It would be better with a photo and 3 bullet points. Many people didn't see the instruction that they could opt out – need to make this clearer."*

When asked if they discussed the pilot's environmental benefits with current or prospective tenants, most property managers said they did not discuss those benefits with tenants beyond what was communicated directly from the pilot, but one property manager observed, *"From what I understand, limiting the amount of power plants that we have is a good thing. I talked to a lot of people about the goals of the program – really positive response…it shows that we're trying to be environmentally conscious."* Another property manager said that they believe the environmental benefits of the pilot helps them stand out in the rental market, and stated, *"I don't know if it's necessarily a tipping point, but it's something that's memorable to [prospective tenants], especially here in the Portland area as we become more environmentally friendly…it does create a little bit of a wow factor."*

3.3.4 Satisfaction and Word of Mouth

Pilot staff have repeatedly emphasized the importance of property managers having a positive experience with the pilot, acknowledging that one disgruntled property manager could significantly disrupt the positive word of mouth about the pilot that they have been building. The interviewed property managers all expressed very high satisfaction with the pilot and had few—if any—negative comments about any aspect of the pilot. The following quotes illustrate the property managers' overall positive experience with the pilot:

- *"The whole team of people that has been involved—customer service is excellent, follow-through excellent. Everything was overall very well put together."*

- *"I can't stress enough how smooth the installation went, and the program making the time to come out and sit down and explain why they're doing it, because then I was able to educate our residents, and know the history of what they're doing this for. I think they're a great team and have a good thing going here."*

When asked if they had discussed the pilot with other property managers (within their company or at other companies), the interviewed property managers responded as follows:

- *"Our company is very large and word travels fast so I have spoken about it with other property managers. Response is very positive. 99% of interactions I've had have been positive. The other one percent, you could give some people a plate of gold bars and they still won't be happy. Takes a special person to find fault."*

- *"The whole program is working well. Will recommend to sister properties."*

The interviewed property managers also universally stated that their experience with this pilot made them more willing to consider participating in other demand response programs in the future.

Overall, the interviews with participating property managers indicate that the pilot is doing a very good job at communicating with property managers, scheduling installations, and minimizing the potential for disruptions caused by the pilot at the participating properties.

3.4 Tenant Experience

This section discusses the experiences of tenants in the participating properties. The findings in this section are based on the tenant survey conducted in March 2019 unless otherwise noted.

3.4.1 Awareness of Pilot Participation Status

One-third (32.9%) of tenant survey respondents recognized the pilot name and confirmed that their household was participating. Another 38.5% of respondents did not recognize the pilot name or were unsure if their household was participating but did recall someone coming into their home to install something on their water heater. **Altogether, 71% of survey respondents were able to confirm that they were participants in the pilot.**

Awareness of their participation status varied significantly by the month that the pilot installation took place at their property and correlates closely with whether or not the participant lived at the property at the time of installation. Of participants who had devices installed in August 2018, just 58% were living at the participating property at that time and only 36% were aware that they were in the pilot. In contrast, 100% of the respondents with installations in December or January had lived at the property at the time of installation and the awareness of their participation status was much higher, as shown in the graph below.

Figure 2. Participants' Residence Status and Awareness of Participation, by Month of Device Installation
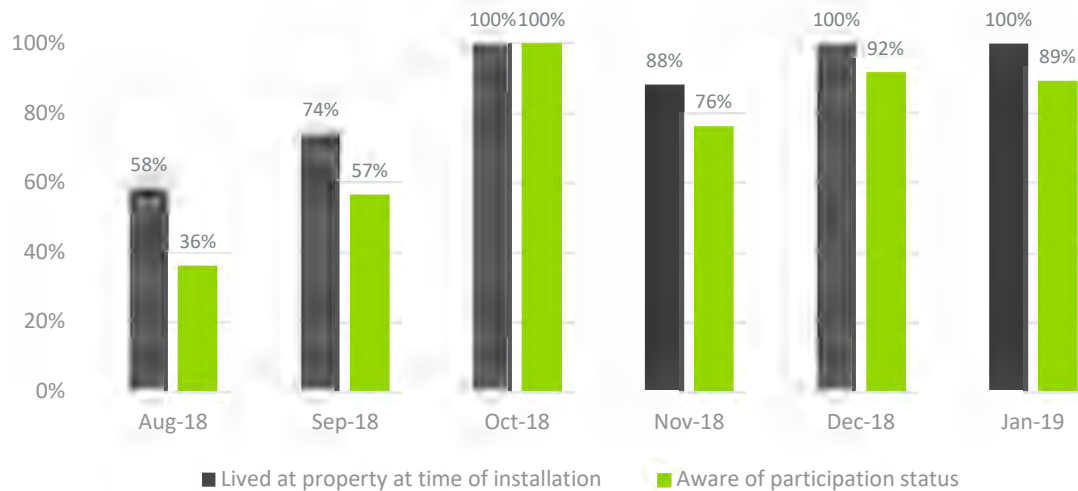
Source: Navigant survey of residents at participating properties (n=139).

Of the 21 surveyed participants who did not live at the participating property at the time of installation, only four (19%) had ever heard of the Connected Water Heaters program[6] and just one person was able to confirm their household's participation in the pilot. These findings suggest that **tenants who move into participating properties *after* the water heater devices are installed may not be given adequate information about the pilot.**

The remainder of this section presents the results of survey questions that were asked only of participants who were aware of their participation status (i.e., they either directly confirmed that they participated in the pilot or they recalled the installation).

3.4.2 Installation Notifications

Property managers are responsible for notifying their tenants about the installation, with guidance and example letters provided by the pilot. Tenants were highly satisfied with the advance notification about the installation, with an average satisfaction rating of 4.6 on a 5-point scale. Most tenants (61%) learned about the installation via a letter from their property manager; 39% received an email from their property manager and 27% received a notification left on their door (Figure 3). Just one tenant (1%) indicated that they did not receive advance notice of the installation.

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[6] Note that Connected Water Heaters is the consumer-facing program name for the Multifamily Residential Demand Response Water Heater Pilot.

Figure 3. Type of Installation Notifications Received
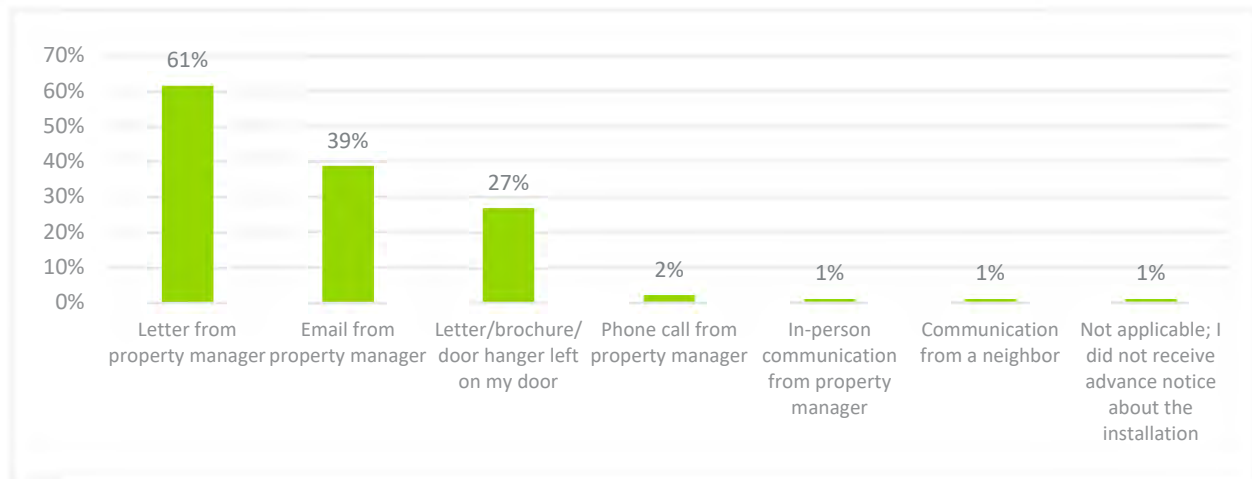
Source: Navigant survey of aware participants who lived in the home at the time of installation (n=101). Respondents were able to provide more than one response to this question.

When asked if the advance notification about the installation could have been improved in any way, most tenants did not suggest any improvements. Seven tenants offered ideas for specific improvements that fell into three categories:

- More advance notice (mentioned by four tenants)
  - *"Maybe given more time before they come to install? I think 24/48 hours may be too short for some. A week's notice would be nice."*
  - *"I was only informed a couple days ahead of time."*
  - *"More advance notice"*
  - *"More time between notice and install"*
- More specificity in the time of installation (mentioned by two tenants)
  - *"Clear exact time of installation"*
  - *"I was told my apartment would be done on day 1, but it was not until day 2. I then had to crate my dog for two days instead of just one."*
- Notification via text message (mentioned by one tenant)
  - *"Text is best"*

3.4.3 Tenants' Installation Experience

Overall, tenants are highly satisfied with the installation process. Ninety percent of tenants rated their satisfaction with the overall process as a 4 or 5 on a 5-point satisfaction scale, and very few tenants could name any specific improvements to the process that they would like to see. Figure 4 shows the average satisfaction ratings for various aspects of the installation process.

Figure 4. Satisfaction with Installation Process
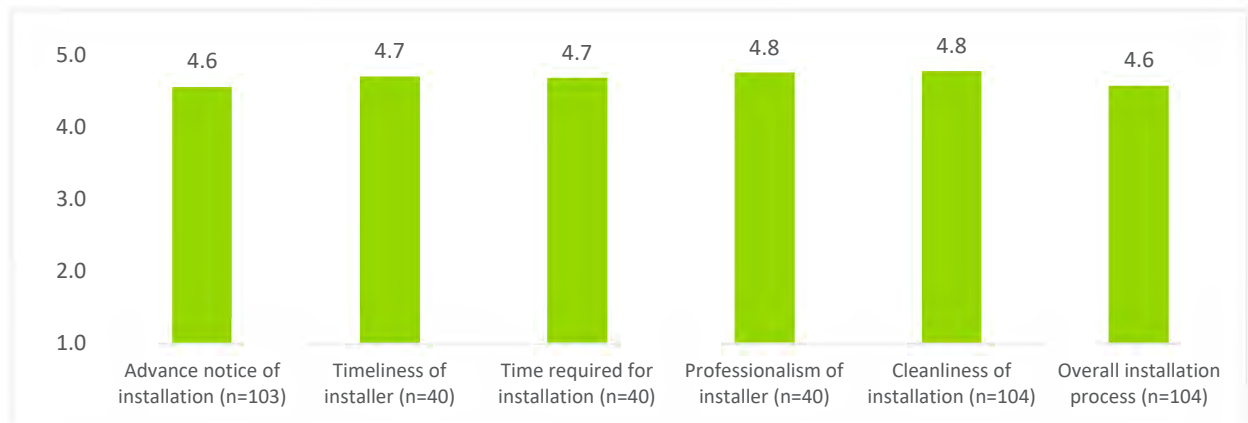
Source: Navigant survey of aware participants who lived at the participating property at the time of installation (n=101).

Note that **the majority (62%) of tenants were not home during the installation** itself; those tenants were not asked to rate their satisfaction with the timeliness of the installer, the time required for installation, and the professionalism of the installer.

Very few tenants offered specific suggestions for improvements to the installation process when asked. No tenants said that any improvements were necessary to the installers' professionalism. The only suggestions for improving the cleanliness of the installation were tying the cables behind the equipment and vacuuming under spots where holes were drilled in the wall (both mentioned by one tenant only).

Several tenants mentioned their annoyance with the flashing green light on the device, and property managers have indicated that they tell tenants who complain to put a piece of electrical tape over the light; to head off this complaint, installers could simply put the tape over the light during installation.[7] Interviews with property managers confirmed that they get complaints from tenants about the flashing green light. Pilot staff indicate that future participants will be receiving switches from a different manufacturer that do not have a visible light, so this suggestion may be moot going forward.

3.4.4 Pilot Communications

The tenant survey explored whether the tenants received verbal or written communication about how the pilot worked.[8] Less than half (45%) of tenants reported receiving any communication about how the pilot works. Most often, tenants who received communication about the pilot received written communication from the property management company (25%) or PGE (23%). Three tenants visited the PGE website and one person called PGE to learn more about the pilot.

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[7] Note that the light only flashes when it is trying to find a network to connect to, and therefore may not have been flashing when the installer was there.

[8] Note that PGE provides high-level information on the pilot to the property managers to provide to their tenants at the time of installation and, at their discretion, when new tenants move in after the pilot equipment has been installed. The responsibility for communication about the pilot lies with the property managers.

Figure 5. Communication Received about the Pilot Operations
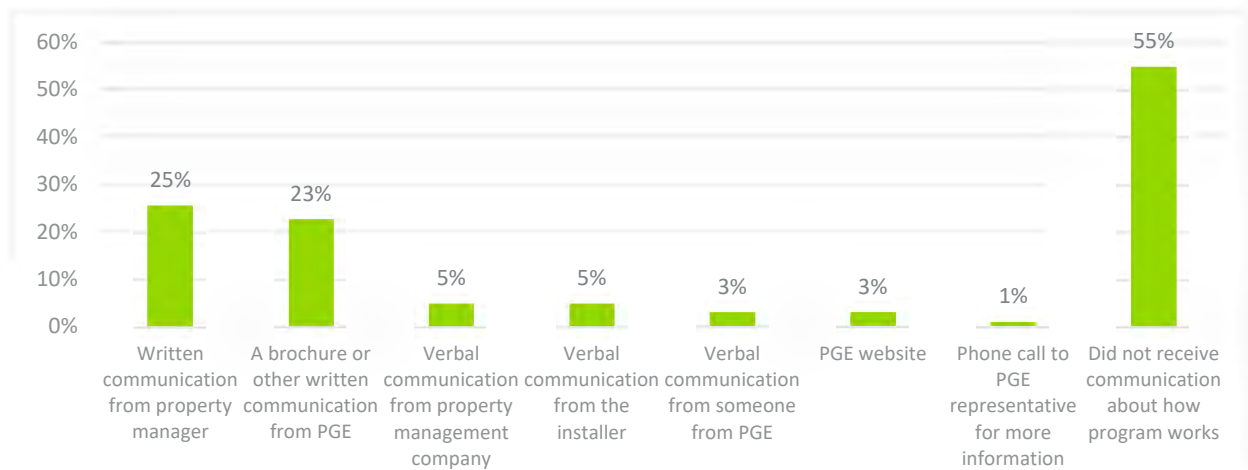
Source: Navigant survey of aware participants (n=102). Respondents were able to provide more than one response to the question about what type of communication they received.

The tenants who received communication about how the pilot works were generally satisfied with the communication, with an average satisfaction rating of 4.0 on a 5-point scale. When asked to explain their understanding of how the pilot works, there were a variety of responses, as shown in the following table. Relatively few tenants connected the pilot to the concept of peak demand or off-hours. Nearly a quarter of tenants mistakenly attribute more intelligence to the switch device than it really has; these tenants believe that the device learns when their household uses the most hot water and heats more during those times and less during other times.

Table 3. Tenants' Understanding of Pilot Operations

Response Theme	Percentage*	Example Comments
Stops heating water during peak demand times or "off hours" or "when energy savings are needed most"	15%	"The device allows the water heater to…save energy by heating water during off hours instead of during peak energy usage times, without affecting your access to hot water."
Saves me money	9%	"It saves me money."
Improved efficiency or energy savings (no reference to cost savings or time of usage)	9%	"More efficient use of hot water."
Coupons	2%	"Free coupon book."
Stops heating water when rates are high	7%	"Heating of the hot water occurs when the rates are lowest."
Monitors hot water usage	9%	"Big brother is watching."
Limits hot water	4%	"I believe it controls the amount of hot water during the times I use it most."
Heats water faster	2%	"I assume it provides hot water faster."
Learns when household does not use hot water and avoids heating during those times	22%	"The system tracks when hot water is used most and heats more when it is more likely to be used and runs less when it's not likely to be used."
Don't know/don't remember	22%	"I cannot remember."

* Includes only those respondents who recalled receiving some communication about how the pilot works.

When asked if communications about the pilot could be improved, two-thirds of tenants said that no improvements were needed or they were not sure how the communications could be improved. The remaining one-third of tenants offered suggestions related to the format and content of pilot communications. Most comments centered on the desire for more information about how the pilot works and its benefit to tenants. Some tenants expressed confusion about whether there were any actions they needed to take as part of the pilot. The following bullets summarize the main themes and some example comments from tenants.

- **Preference for email communication**
  - *"A follow-up email about the program would have been nice."*
- **More information about how the pilot impacts tenants:**
  - *"Give more of a timeline when I can see how this machine will be limiting [my] water heater."*
  - *"Need to understand what the program is all about and what we can do so our previous volume of hot water is the same."*
- **More information about how the pilot benefits tenants**
  - *"Maybe a reminder of what the program is doing for us?"*
- **More information about whether tenants need to take action**
  - *"I need more detail about how it works, and especially if there is anything I can or should do as a result."*
  - *"It was unclear whether we should try and change our behavior to be more energy efficient, or if the smart monitor just does it for us."*
- **Better information about ability to opt out**
  - *"Mainly, I think the opt-out option should be front and center. The fact that it isn't shows that the program isn't being communicated in a way that the customer sees a benefit."*

3.4.5 Chinook Book

Tenants receive access to the Chinook Book online coupon book as an incentive for participation in the pilot. Just one-third of the aware participants were able to confirm that they received the Chinook Book access email from PGE. **Nearly half (46%) believe they have not received the Chinook Book email**, and another 19% are not sure. Just 14% have accessed the Chinook Book website or app and only 4% have actually redeemed a coupon. Some tenants indicated that the tenant survey was the first that they had heard about the Chinook Book and they would like to receive one.

Figure 6. Participating Tenants' Awareness and Use of the Chinook Book Incentive
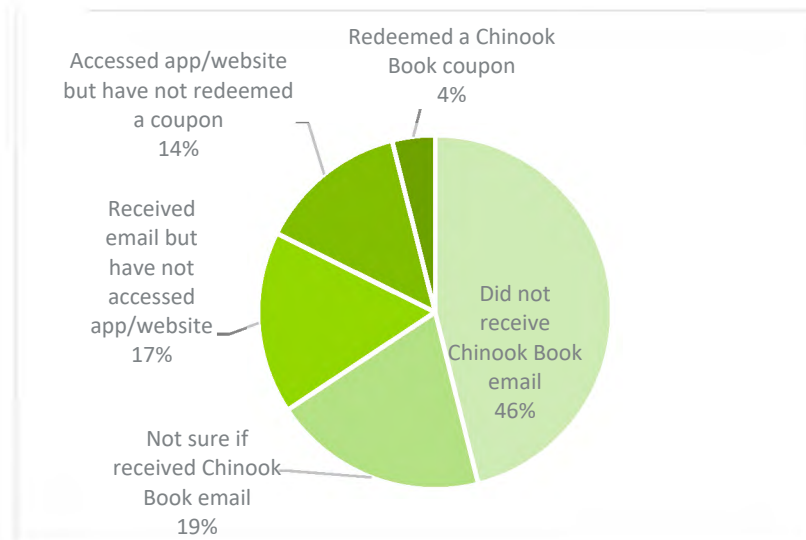
Source: Navigant survey of aware participants (n=102).

3.4.6 Hot Water Availability Issues

Tenants answered a question about whether they thought their hot water usage patterns had changed since participating in this pilot. The question was designed to elicit insights into whether tenants believe that the pilot is causing them to run out of hot water without creating a misconception that the pilot is likely to cause tenants to run out of hot water if they were not already experiencing that. By this point in the survey, some tenants had already volunteered information about their belief that the pilot was limiting their hot water availability in earlier open-ended questions on unrelated topics, so Navigant reviewed all open-ended questions for complaints about hot water availability. **Altogether, ten tenants (10% of 102 pilot-aware participants) believe that they are running out of hot water more often** since participating in the pilot. Some of the comments about hot water availability included:

- *"The hot water will only be good for one person, the next person will be getting cold water."*

- *"There is less hot water available so I am taking shorter showers."*

- *"I have noticed our hot water seems to run out much quicker than before. Is the hot water being regulated or is this just my imagination?"*

As indicated in the last comment, it is possible that some of these tenants are simply imagining that they are running out of hot water more quickly than they were before the device was installed. Multifamily properties experience high tenant turnover, so tenants may not have lived in the home long enough before the device was installed to have a good sense of how much hot water they normally get.[9] The ten participants who reported hot water issues were concentrated in four of the ten properties included in the survey, suggesting that there may be a tangible cause for these issues related to the water heaters themselves or some aspect of the pilot's installation.

One of the technical issues experienced early in the pilot was a data entry error that led to incorrect water heater tank volume values recorded for some participants. This may have caused the algorithm monitoring hot water usage to allow the tank to drain below 50% of available hot water before entering override, or caused it to enter override before reaching the 50% hot water threshold, depending on if the value entered for the tank volume was larger or smaller than the actual tank size. Over one-quarter (27%) of the participants who had tank volume errors reported hot water issues, compared to 8% of people who did not have the tank volume errors. These errors were corrected on February 20th, which was nearly the end of the winter 2018-19 demand response season, so affected tenants would have experienced very few events after the error was corrected.

All of the interviewed property managers indicated that they have not been receiving complaints from tenants about hot water issues. Furthermore, CLEAResult keeps a log of all hot water issues that are reported by phone calls or emails from tenants or property managers. Out of 1,560 participants in the winter 2018-19 DR season, CLEAResult received a total of 23 calls and emails regarding hot water availability problems, and four of those instances were linked to water heater maintenance or usage issues unrelated to the pilot. Pilot-related issues included installation issues (4 instances), faulty device issues (8 instances), or issues with undetermined causes (7 instances); all of these issues were resolved by replacing the switch or changing the participant's participation status or dispatch schedule.

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[9] The survey results provide some support for this hypothesis: 50% of the people who reported hot water issues had lived in their house for less than a year at the time of the survey, compared to 36% of people who did not report hot water issues. However, the sample size of participants reporting hot water issues is very small (10). The next tenant survey (slated for October 2019 after the summer DR season) will survey a larger sample of participants to support a more definitive analysis.

3.4.7 Overall Satisfaction

Overall tenant satisfaction with the pilot was lower than satisfaction with the installation process and pilot communications. The average satisfaction rating was 3.7 and the mode was 3 on the 1-5 scale. Open-ended comments suggest that the relatively neutral satisfaction scores relate more to a general lack of understanding of what the pilot is doing as opposed to an active dissatisfaction with any specific aspect of their participation, although some tenants did complain that the pilot seems to offer them little benefit. The average satisfaction with the overall pilot was significantly higher for tenants who recalled receiving communication about how the pilot works (3.91 on the 1-5 scale vs. 3.46 among people who do not recall such communication).

As shown in the following graphic, tenants who believe the pilot is limiting their hot water availability have lower satisfaction with every aspect of the pilot; the average satisfaction with the overall pilot was 3.9 among those who did not report any hot water issues and just 2.0 with the ten tenants who experienced such issues.

Figure 7. Overall Pilot Satisfaction
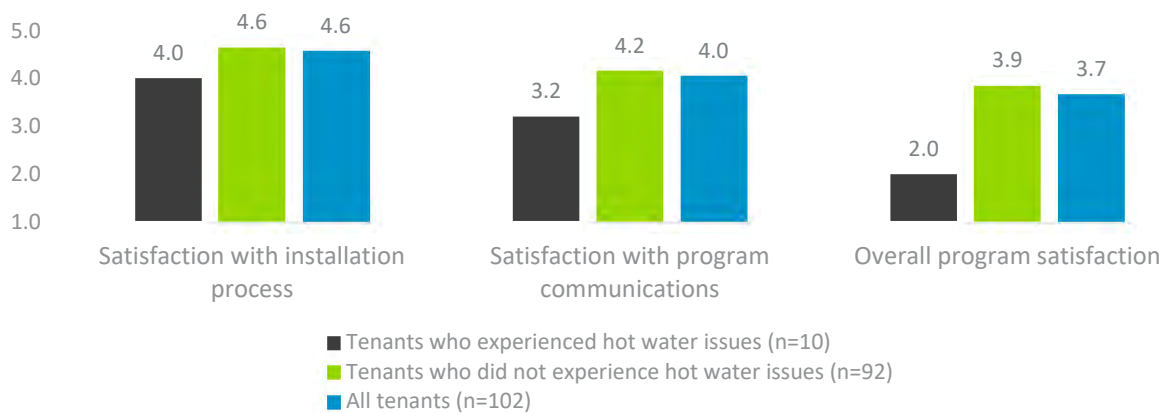
Source: Navigant survey of aware participants (n=102). Note that the question about satisfaction with pilot communications was limited to the tenants who said they received communications about how the pilot works (n=46).

The survey did not include a question on satisfaction with the Chinook Book as an incentive, but the very small percentage of tenants who reported use of the coupons suggests that it is unlikely to contribute to high pilot satisfaction. The pilot may want to consider an alternative incentive to secure additional good will with participating tenants.

Tenants' generally neutral view of the pilot is reflected in the 52% of tenants who said their pilot experience had no influence on their willingness to participate in other PGE programs. Another 39% said the experience made them somewhat or much more likely to participate in other programs, and 9% said they are now less likely to participate in other programs.

4. IMPACT EVALUATION FINDINGS

This section discusses the findings from Navigant's impact evaluation of the winter 2018-19 DR season, which spanned from December 12, 2018 to February 28, 2019. The impact evaluation, based on regression analysis of AMI data, found that only a few events generated demand reductions that are statistically different from zero. However, this does not mean that the pilot is not generating demand savings; the per-device impact may be too small for this type of analysis to pick up in the overall noise of whole house AMI data. Section 4.2 discusses alternative impact evaluation methodologies that PGE and Navigant may consider for the evaluation of future DR seasons.

4.1 Impact Results

This section summarizes the winter 2018-19 DR season's impact results by event date (Section 4.1.1), for full hours only (Section 4.1.2), and across the entire season (Section 4.1.3). Section 4.1.3 provides analysis of device statuses that provide context for the impact results, and Section 4.1.5 discusses some limitations of the AMI analysis methodology for assessing this pilot's impacts. See also Section 2.4 for details on the impact evaluation methodology.

4.1.1 Impact Results by Event Date

Navigant estimated DR event impacts on an event-by-event basis using hourly AMI data for all enrolled assets. For each event, either group A or group B was targeted for the event dispatch, but not all assets in each group were dispatched and controlled, for reasons discussed subsequently. The non-targeted group served as the control group for each event. The impact estimation relied on the control group to form the event baseline.

Total pilot per-event impacts are presented in Figure 8. Event impacts that are statistically significant are highlighted in green. Of the 56 events called during the winter season, only seven (highlighted in green) had average impacts that were statistically significant at the 90 percent level (statistically different from zero). Of those seven, three were negative impacts, meaning the model estimated a statistically significant increase in load as a result of the event.

Figure 8. Total Pilot Impact per Event
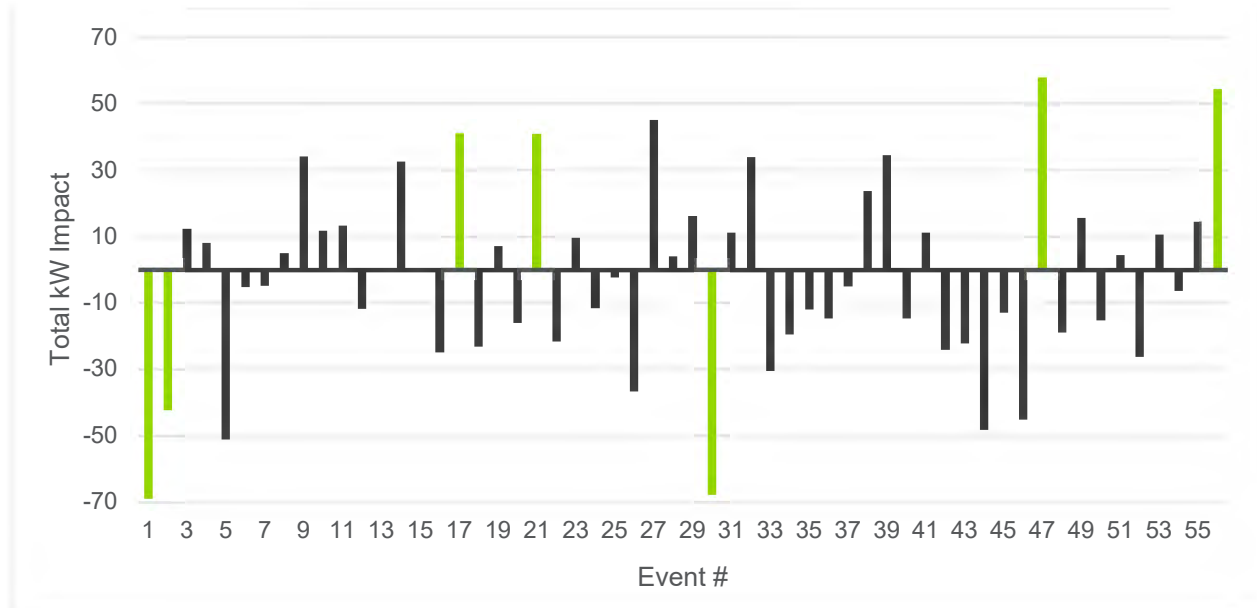
Source: Navigant analysis

Per-event results from the impact analysis are detailed in Figure 9. These impacts are the event average treatment effect (ATE), which is the average impact of the pilot across all devices in the treatment group (A or B) and all event hours. The impacts presented in this figure include all devices, regardless of connectivity or override status (see Section 4.1.3 for more discussion of connectivity and overrides).

Figure 9. Average Treatment Effect per Event
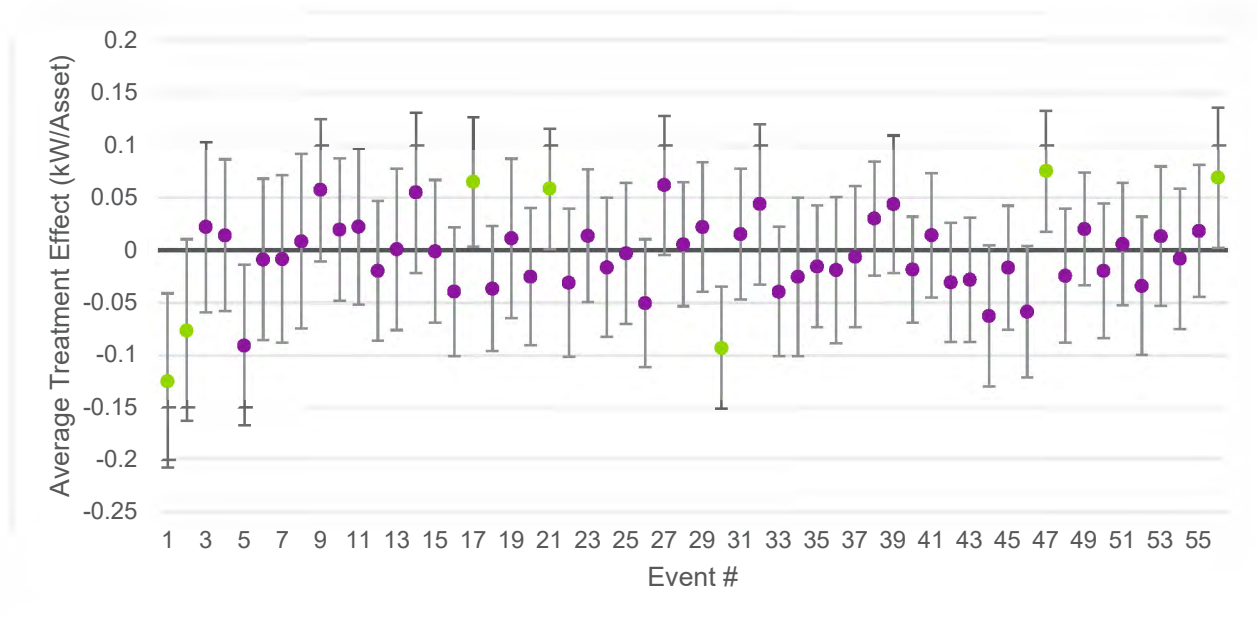
Note: the error bars represent the 90 percent confidence interval for each impact estimate.
Source: Navigant analysis

Figure 9 above shows the average treatment effect (ATE) per event, which is the average impact across all enrolled assets. However, not all assets are dispatched and controlled for each event (see Section 4.1.4 for more discussion). The average impact per *controlled* asset, also known as the average treatment effect on the treated (ATT), is shown below in Figure 10. This is the total pilot impact divided by the number of controlled assets. The ATT is a useful metric to understand how the pilot impact might scale if the proportion of controlled assets increased, while the ATE reflect the impact per installed asset (a cost from the pilot perspective).

Figure 10. Average Treatment Effect vs. Treatment Effect on the Treatment
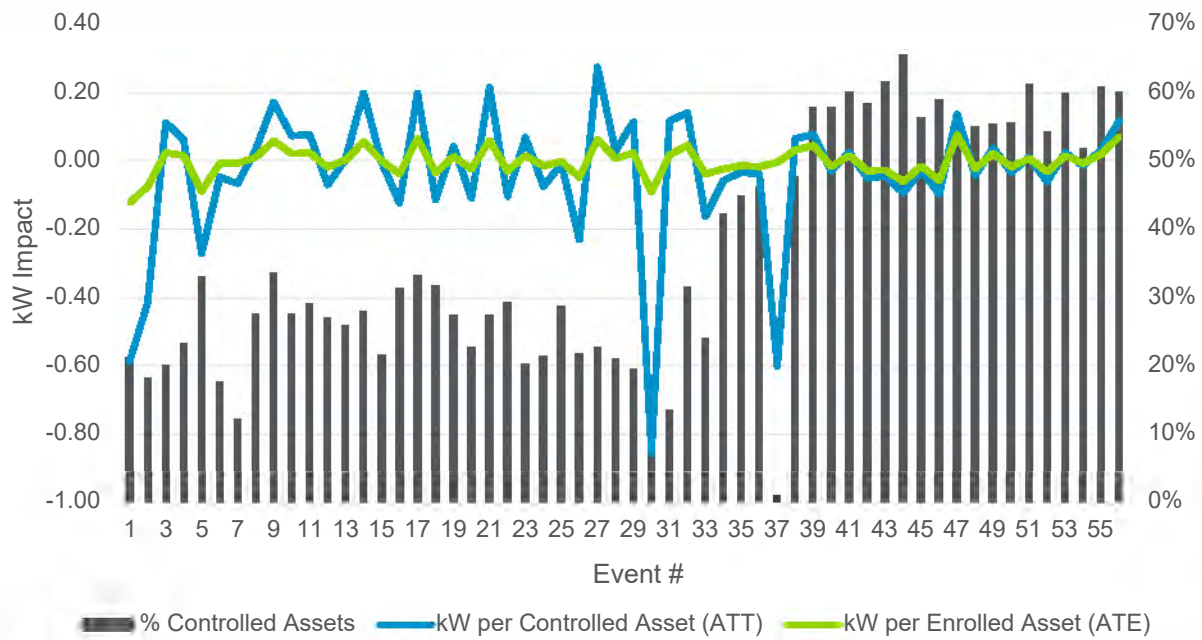
Source: Navigant analysis of AMI and Aquanta data

The pilot's DRMS provider, Enbala, also provided an impact estimate for each event, as shown in Figure 11. This vendor estimate used a different baseline methodology than Navigant. While Navigant's analysis used a control group baseline, Enbala used an asset-specific baseline, relying on non-event day asset power draw data derived from the asset telemetry, during a 90-day lookback period. For each event, the asset baseline was calculated using the previous five same weekdays that were non-events. The asset baseline served as the reference load for each event, and the event impact was calculated by differencing the reference load and the actual asset load during the event period. Navigant did not conduct an independent verification of the asset baseline methodology or results. Enbala's event results went through several iterations over the course of the winter season as issues were uncovered with the baseline calculations and the total number of available assets. The results below reflect their current estimate of winter event savings.

Figure 11. Vendor-Estimated Impacts per Enrolled Asset

4.1.2 Full Event Hour Impact Results

In Figure 9 and Figure 10, each point on the graph is the average load impact per device across all hours of the event. However, this doesn't necessarily capture the true impact of the pilot. The pilot often scheduled the DR events to begin and end at the half or quarter hour. Further, the A and B groups were divided into four sub-groups (e.g., A, 1A, 2A, 3A), with each group often having a different end time to the event, to prevent large-scale snapback. An example group dispatch schedule is displayed in Figure 12. Note that sub-group A has three times as many assets as sub-groups 1A, 2A, and 3A.

Figure 12. Example Event Dispatch Schedule

With events not starting and ending on the hour and the sub-groups phasing out of the event to minimize snapback, many hours included in the impact modeling were only partially controlled. Figure 13 illustrates the percent of each hour controlled for the event schedule in Figure 12. With all sub-groups dispatched at

7:45 AM, only 25 percent of the hour ending 8:00 AM load is controlled. Additionally, the hours ending at 12:00 PM and 1:00 PM are not fully controlled due to the sub-group phase-out beginning at 11:45 AM.

Figure 13. Example Hourly Load Curtailment
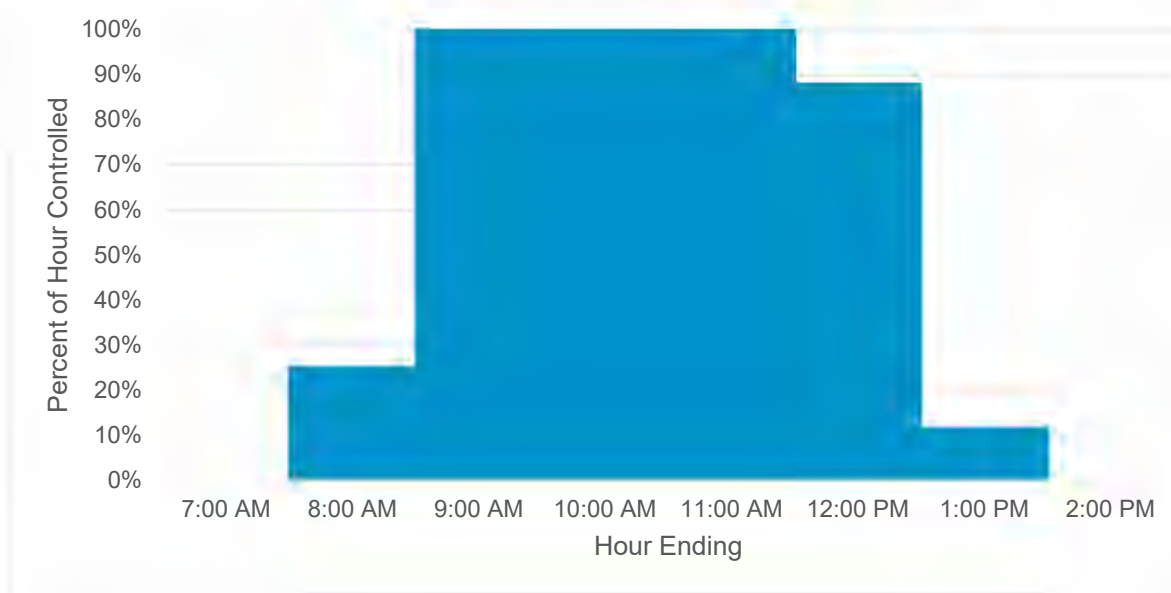
Source: Navigant

Figure 14 below shows a comparison between the estimated event impact using all curtailable hours of the event (in green) and the average "full hour" impact (in blue), averaging impacts from only the fully curtailable hours of the event. By excluding the partial hours from the average, the impacts are notably higher.

Figure 14. Full Hour Event Impact Comparison

Source: Navigant analysis

In future impact evaluations, partial event hours should present less of an issue for impacts measurement. Beginning with the summer 2019 DR season, the pilot has changed its event deployment strategy to start and end almost all events on the hour and dispatch all devices for the same time and duration (i.e., there are no longer sub-groups with staggered event end times).

4.1.3 Summary of Winter Season Impacts

A summary of the winter season impacts is presented in Table 4. The pilot per device impact ranged from -0.124 kW per device to 0.075 kW per device, averaging at -0.004 kW. Full hour impacts had a higher average and maximum across the season, as partially controlled hours were excluded from that calculation. Full hour impacts per controlled device were even higher, averaging 0.135 kW per device. Total pilot event impacts peaked at 0.058 MW for the season, but averaged -0.003 MW. The evaluation did not attempt to quantify post-event snapback as part of this evaluation due to overlapping event and snapback hours. Snapback will be quantified for the Summer 2019 evaluation.

Table 4. Winter 2018-2019 Impacts per Event

Metric	Season Average	Minimum	Maximum
Per Device **kW** Impact (ATE)	-0.004	-0.124	0.075
Per Device Full Hour **kW** Impact	0.039	-0.031	0.132
Per Controlled Device **kW** Impact (ATT)	-0.037	-0.856	0.272
Per Controlled Device Full Hour **kW** Impact	0.135	-0.140	1.069
Total Pilot Event **MW** Impact	-0.003	-0.069	0.058

Source: Navigant analysis

A summary of the Enbala-estimated winter season impacts is presented in Table 5. The Enbala-estimated per device impact ranged from -0.385 kW per device to 0.211 kW per device, averaging at 0.070 kW. As stated previously, these are results provided by the pilot's DRMS provider and were not independently verified by Navigant. The vendor estimates used a different baseline methodology than Navigant. While Navigant's analysis used a control group baseline, Enbala used an asset-specific baseline, relying on non-event day asset power draw data derived from the asset telemetry (in lieu of AMI data) during a 90-day lookback period. For each event, the asset baseline was calculated using the previous five same weekdays that were non-events. The asset baseline served as the reference load for each event, and the event impact was calculated by differencing the reference load and the actual asset load during the event period. Navigant did not conduct an independent verification of the asset baseline methodology or results. Enbala's event results went through several iterations over the course of the winter season as issues were uncovered with the baseline calculations and the total number of available assets. The results below reflect their current estimate of winter event savings.

Table 5. Winter 2018-2019 Enbala-Estimated Impacts per Event

Metric	Season Average	Minimum	Maximum
Per Device **kW** Impact (ATE)	0.070	-0.385	0.211
Per Device Full Hour **kW** Impact	0.095	-0.006	0.228
Per Controlled Device **kW** Impact (ATT)	0.179	-1.729	1.221
Per Controlled Device Full Hour **kW** Impact	0.272	-0.035	1.329
Total Pilot Event **MW** Impact	0.054	-0.289	0.167

Source: Navigant analysis of Enbala-estimated impacts

4.1.4 Device Statuses: Connectivity and Overrides

When an event was called, not every enrolled device was dispatched and controlled during the event period, and not every dispatched device was controlled for the entire event period. This is evident in Figure 10, which shows the percent of controlled assets on a per-event basis. Throughout the winter season, the percent of assets controlled per event ranged from one percent up to 65 percent. The number of assets controlled is largely determined by three factors: devices not heating, devices without connectivity, and devices in override.

To quantify the extent to which these categories impacted the number of devices controlled during each winter season event, Navigant analyzed the event dispatch data and categorized devices into one of six dispatch statuses:

- **No Connectivity[10]:** a device that was not actively connected to Wi-Fi and could not receive a dispatch signal

- **Not Heating:** a device that was not actively heating and thus had no load to curtail

- **Heating, Not Dispatched[11]:** a device that was actively heating, but was not dispatched

- **Override, Not Dispatched:** a device in override mode[12] that was not dispatched for any part of the event

- **Override, Partial Dispatch:** a device that was actively heating and was dispatched for the event, but was in override mode for part of the event

- **Dispatched:** a device that was actively heating and was dispatched for the entire event

Figure 15 shows the breakdown of enrolled devices across the six categories for each event. Similar to Figure 10, the share of devices dispatched increases in the last third of the season. Although a small

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[10] The "Connectivity" status that Aquanta provides to Enbala via their API is not 100% reliable. There are instances where assets report heating and dispatch activity, but also report as "Not Connected". As data can only be reported when there is connectivity, the combination of these statuses is not possible. This is an ongoing issue impacting a small number of devices. The program is in discussions with Aquanta to better quantify the issue and resolve it.

[11] These are a small number of cases, but this status should not occur. The program will continue exploring these cases during the Summer 2019 evaluation.

[12] A device enters override mode when its tank drains more than 50 percent and cannot be curtailed until the tank refills; in addition, a firmware bug (fixed in February 2019) caused some devices to remain in override status once they entered it.

share of the overall device count, fewer devices appeared in the "Override, Not Dispatched" category at the end of the season, which could be due to the firmware fix in February 2019.

Connectivity issues plagued the pilot throughout the entire winter season, with the share of connected devices ranging from 53 to 69 percent (the share of connected devices is expected to increase when the program moves to cell communication in September 2019). Surprisingly, devices not heating experienced the most notable decrease by the end of the season and appear to be the biggest contributor to the increase in controlled devices.

Figure 15. Dispatch Status by Event
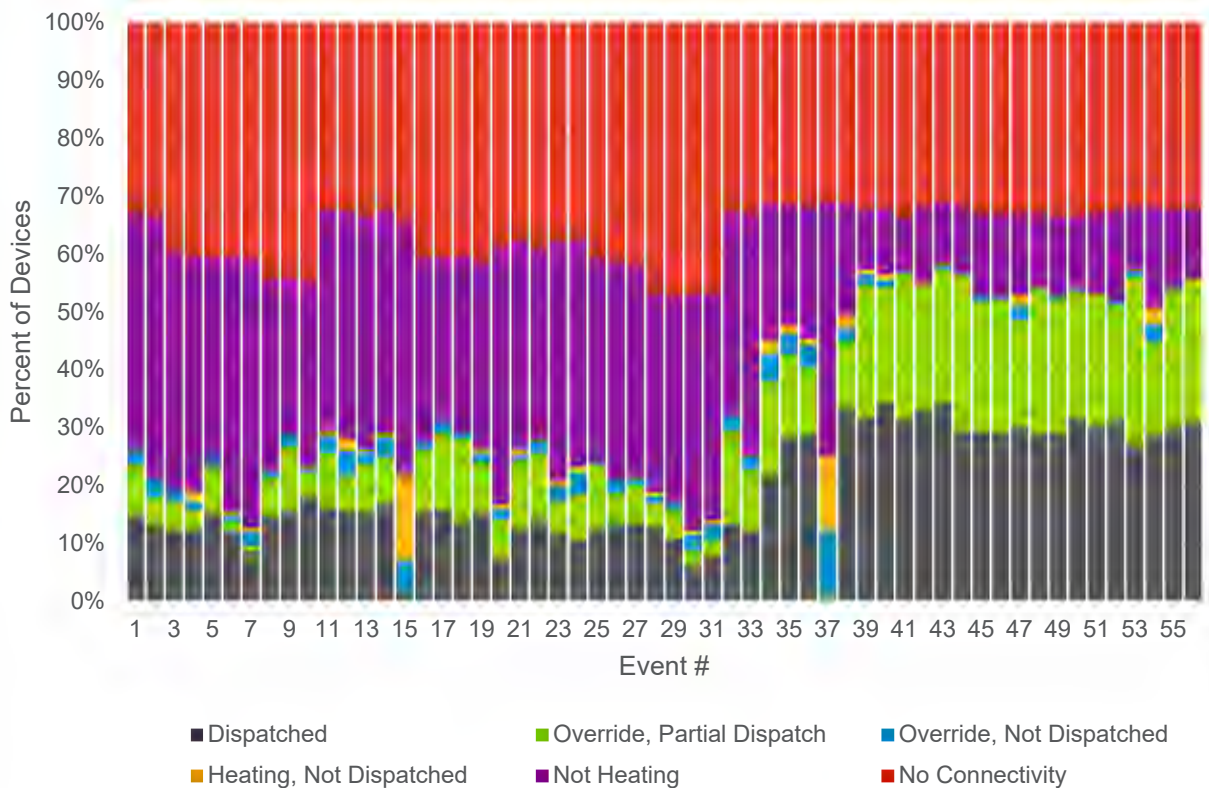
Source: Navigant analysis of CLEAResult event dispatch data

Note that CLEAResult pilot staff are analyzing the frequency of overrides in the summer 2019 DR season.

4.1.5 Limitations of AMI Data Analysis

Several factors limited the effectiveness of the AMI data analysis for evaluating this first season of DR events. These factors may or may not persist in the evaluation of later DR seasons; see Section 4.2 for more discussion of alternative impact evaluation methodologies that PGE and Navigant may pursue in the future. The following bullets summarize these issues.

- **Small population:** The total number of assets that could be called in any given event in the winter season did not exceed 800 for any event and totaled less than 600 for the earliest events. These numbers represent the maximum number of assets that could theoretically be called for an event. The number of assets that actually generate demand reductions is even smaller than the number of installed assets for the following reasons:

- The pilot experienced persistent **device connectivity issues** due to the limitations of the Wi-Fi technology; if the Wi-Fi signal does not reach the switch, the water heater will not be curtailed and no demand reduction will be generated.

- By design of the pilot, the switches stop curtailment and go into "override mode" when the water heater tank drains to 50 percent[13], so any household actively using hot water during the event would not be generating demand reductions after entering override mode.

- Once devices enter override mode (i.e., not curtailing), they are supposed to remain in that mode until the water heater tank refills, then they can be curtailed again. However, **due to a switch firmware bug, some devices remained in override mode permanently** once they entered it; this issue was not corrected until mid-February 2019. Thus, the number of available assets declined over the course of the season until the firmware fix was implemented.

- Water heaters can only be curtailed if they're actively heating, so any water heater that is not actively heating does not generate demand reductions. The amount of time that a water heater is actively heating during an event will vary based on the household's usage of hot water prior to the event as well as the efficiency and insulation of the water heater.

- **Hourly AMI data:** PGE only collects hourly AMI data for the majority of participating households, but most events did not start and end on the hour as discussed above. Thus, even if a water heater is curtailed for the entire event, its impact may be diluted in the AMI data during the partial hours that the event was active due to the parts of the hour in which the water heater was not being curtailed. As discussed above, partial hour events will be not be a problem in future DR seasons. Furthermore, water heaters may be curtailed during only part of an hour and then go back into active heating mode due to hot water usage during the event.

- **Small signal:** Water heaters are a relatively small percentage of a home's electricity consumption, and AMI measures whole home electricity consumption. The AMI data analysis is trying to detect small reductions in overall home electricity consumption in aggregate across a relatively small population in which only some water heaters were curtailed during parts of the hours being measured. This small signal can easily be masked by other home end uses or imbalances between the A and B groups given the small pilot population. As the pilot population grows, this signal will be easier to detect.

4.2 Alternative Impact Evaluation Methodologies

PGE and Navigant may change the evaluation scope to utilize alternative methodologies to estimate pilot impacts in future DR seasons. This section outlines two alternative methods under consideration.

4.2.1 Regression Analysis with Asset Telemetry Data

If the AMI data continues to obfuscate DR impacts due to its various limitations, Navigant proposes that PGE consider a regression impact analysis using asset telemetry data. From an implementation standpoint, nothing would change. The pilot would still employ an A/B design and continue to dispatch DR groups as one unit. The level of effort on the evaluation end may increase slightly: the telemetry data may require additional formatting and cleaning in preparation for modeling. However, the increase in data processing would be a small drawback to the increased accuracy in pilot impact estimates.

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[13] Note that the program is considering a lower threshold for override mode to increase the kW impact per controlled device and plans to test this lower threshold in late 2019.

As discussed in Section 4.1.5, there are several limitations to the AMI data analysis that are inhibiting the regression model from estimating accurate event impacts. These limitations become evident when visually examining the DR group loads on event days. For precise impact estimates, DR events should be easily detectable through a graphical analysis of the AMI data.

Upon graphing the event day whole home loads for households with potentially curtailable assets, not all events were evident in the data. Figure 16 below displays the average hourly household load for two event days from the winter 2018-2019 season: February 13th and February 19th. The pilot dispatched two events for group A on the former date and two events for group B on the latter date. The visual evidence for both morning events is stronger. There are small, but clear reductions for the curtailed group relative to the control group at the beginning of both events. As assets are released from curtailment towards the end of each event (i.e., turned back on), the curtailed group displays a spike in usage.

The evening events are much harder to detect. For the February 13th event, the curtailed group has lower usage relative to the control group, but that pattern existed prior to the beginning of the event. At the end of the event, there is no visible spike in usage indicating assets re-entering heating mode. Curtailed and control group usage are practically identical in the February 19th evening event. One might conclude an event had not occurred except for a hardly discernable increase in usage for the curtailed group near the end of the event period.

Figure 16. Example AMI Events
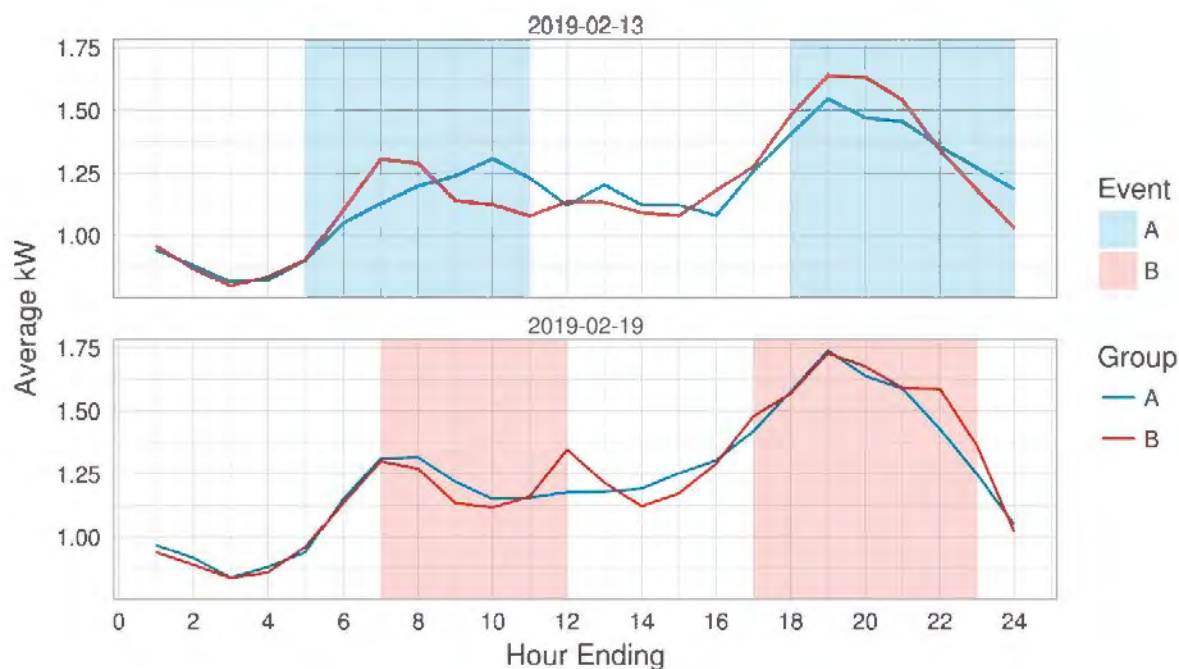
Source: Navigant analysis

As a point of comparison, the implementation team did a graphical analysis of the asset telemetry data available through the water heater switch API. This telemetry data reports asset-level power consumption at a sub-hourly level. Once aggregated, the telemetry data shows the water heating load for all online and available pilot assets. Figure 17 displays the aggregate quarter-hourly load for the same two event days: February 13th and February 19th (note, this is different from the average load displayed in the previous figure). At first glance, the evidence of curtailment is stronger with the telemetry data. Unlike the AMI data, the water heating load is isolated instead of mixed with other household end-uses. Clear differences between the curtailed group and control group can be attributed to the DR event. Due to limitations in the evaluation scope and timeline, the evaluation team was not able to replicate this analysis or do further

investigation into the available telemetry data. However, this preliminary evidence suggests that PGE should explore the use of telemetry data for the summer 2019 DR season evaluation.

Figure 17. Example Telemetry Events

ControlGroupA, Event
ControlGroupA, Hourly KW
ControlGroupB, Event
ControlGroupB, Hourly KW
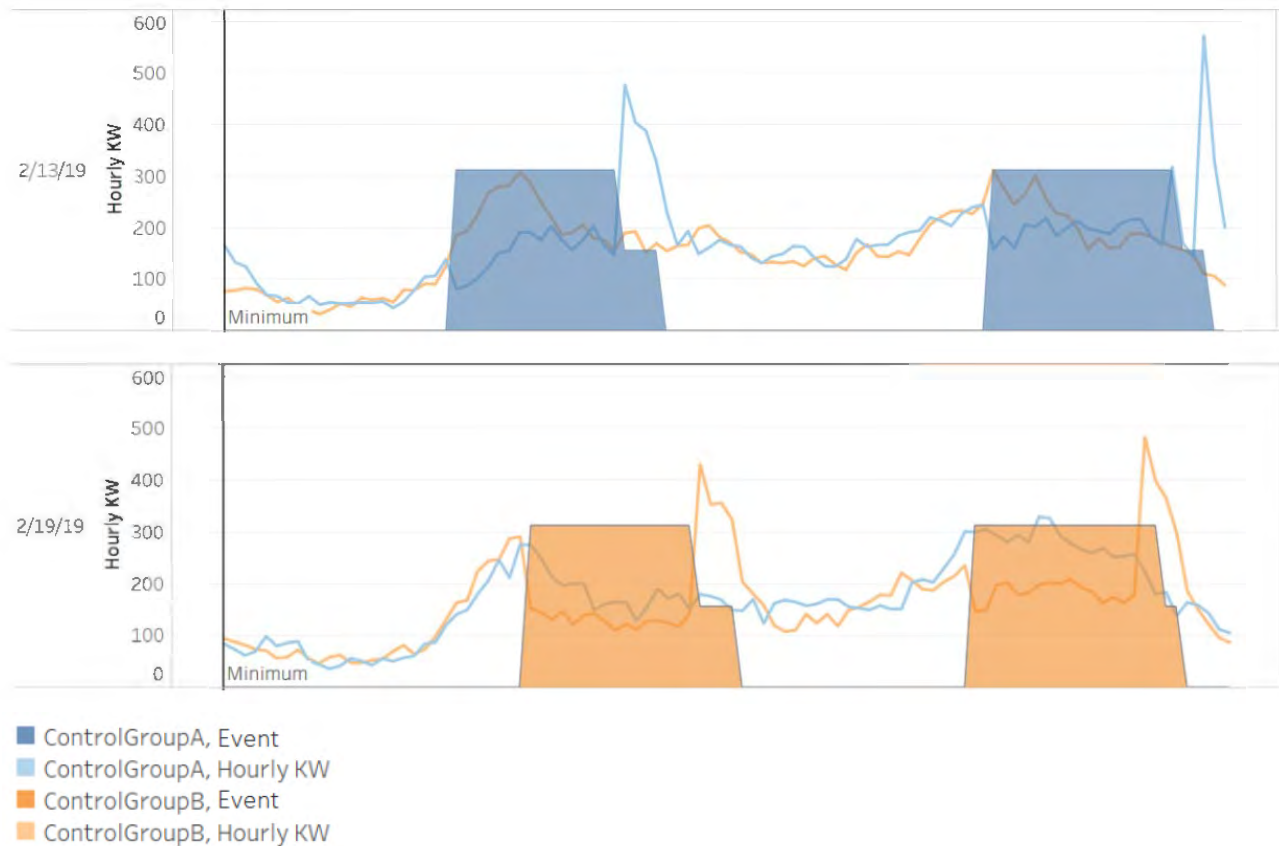
Source: CLEAResult analysis

4.2.2 Regression Analysis with Non-Participant Matching

The pilot asset sample size is another limitation of the current pilot design. With enrolled assets split into A and B groups, only half the assets can be dispatched for a given event (with the other half serving as the control group). An alternative to a traditional control group is a matched control group, a form of quasi-experimental design. If a sufficient number of similar non-participants exist outside of the pilot, a non-participant comparison group can be created through load profile matching. With a matched control group methodology, all enrolled assets can be dispatched for each event, effectively doubling the potential load impacts for a given event.

A matched control group methodology has two main requirements:

- A large non-participant population (30-40k customers) with similar characteristics to participants. In the case of this pilot, multifamily non-participants.

- Several non-event days (non-holiday weekdays) within a given DR season. These days are used as the load profile matching period.

To form the matched control group, non-participants are matched participants based on hourly load during the matching period. For a given participant, the non-participant whose average hourly consumption patterns have the smallest Euclidean distance from the participant is selected as that

participant's match. Matching is done with replacement, meaning a non-participant can serve as a match for more than one participant. Once the matched control group is formed, the analysis proceeds with a regression model similar to the one used in the current analysis.

A matched control group maximizes the pilot sample size and consequently the total pilot impacts. An increased sample size will improve the precision of the impact estimates. Larger total pilot impacts will help the pilot towards its demand curtailment goals.

Before abandoning the A/B methodology, Navigant recommends PGE explore a matched control group methodology within the current parameters of the pilot. If matching yields a robust comparison group for the summer 2019 season, PGE can begin deploying all assets for the winter 2019-2020 season.

5. CONCLUSIONS

This section presents key findings of the evaluation and their associated recommendations for improvements to pilot implementation or future research. As the pilot team has demonstrated a collaborative, problem-solving ethos throughout this evaluation process, some of those recommendations are already in the process of being implemented, but they are documented here nonetheless.

Finding #1: Technology integration and recruitment challenges delayed the pilot timeline.
Integrating the hardware and software necessary to implement this pilot proved to be a more challenging and time-consuming task than initially expected, and the pilot was unable to conduct large-scale non-testing events in summer 2018 as originally planned. However, PGE, CLEAResult, and Enbala have developed a strong working relationship that focuses on solving problems quickly, and they have worked through many technical challenges together over the course of the pilot to date.

> **Recommendation #1:** Continue to apply the lessons learned from the first integration to future integrations with other switch manufacturers.

Finding #2: Pilot staff learned that the most persuasive recruiting message is not about demand response. Property managers respond most enthusiastically to succinct, benefits-focused messages and testimonials from other property managers who have had positive experiences with the pilot; education about demand response was not useful in persuading property managers to participate.

> **Recommendation #2:** Continue efforts to build word of mouth and amplify positive stories about the pilot through industry events, publications, and the PGE website.

Finding #3: Property managers and customers are highly satisfied with the installation process, with a few suggestions for minor improvements. Interviewed property managers praised the pilot's communications and the ease of the installation process, and tenants were also highly satisfied with the installers' timeliness and professionalism. Tenants and property managers both mentioned complaints about the blinking light on the Wi-Fi equipment, and one property manager felt that the second visit for a city-required inspection wasn't adequately communicated ahead of time.

> **Recommendation #3a:** Consider having the installers place black electrical tape over the blinking light during the installation, rather than waiting for the tenant to complain to the property manager and then the property manager tell them to place tape over it. Note that the pilot is now installing a different type of switch that does not have a blinking light, so this recommendation may no longer be relevant moving forward.

> **Recommendation #3b:** Prioritize researching the local city and state requirements for inspections earlier in the enrollment process so that the property managers can know how many pilot-related visits they can expect to their properties and communicate that information to their tenants.

Finding #4: Tenant satisfaction could be improved with additional communication. Tenant ratings of overall pilot satisfaction averaged 3.7 on a 1-5 scale. Satisfaction is significantly higher among the tenants who recalled receiving communication about how the pilot works than those who did not recall such communication; however, less than half recalled receiving any communication about how the pilot works. Furthermore, nearly one-third of participating tenants were unaware of their own participation status. One property manager thought that tenants would benefit from a short, simple explanation of how the pilot works and what tenants need to know.

> **Recommendation #4a:** Create a simple, streamlined explanation of the pilot from the tenant perspective. PGE should consider mailing this simple document to all participating households on an annual basis to ensure that tenants that moved into the apartment after the installation took place are aware of the pilot and how it works.

Recommendation #4b: Provide periodic reminders to property managers about the pilot-related materials that they should share with their tenants.

Finding #5: Few tenants are aware of the Chinook Book incentive. Just 4% of all aware participants have actually used a coupon from it and two-thirds either have not received the email inviting them to access the Chinook Book or are not sure if they have received the email.

Recommendation #5: Consider alternative incentives to reward tenants for their participation in the pilot. At a minimum, explore methods for ensuring that tenants receive the Chinook Book email. The leave-behind material could suggest that tenants add the email address that the Chinook Book comes from to their email address book to prevent it from getting caught in spam filters. Sending multiple emails to remind tenants about the opportunity to get access to a Chinook Book may also be helpful.

Finding #6: Some tenants believe that they are experiencing hot water issues as a result of the pilot. Of surveyed tenants that are aware that they're participating in the pilot, 10% believe that the pilot is causing them to run out of hot water. Note that the sample size for the tenant survey was relatively small due to the limited population of participants, so 10% equaled just ten people, and none of the interviewed property managers indicated that they had ever received this complaint. That said, one of the pilot objectives is to cause no negative impacts on tenants, so this is a concern that should be monitored closely as pilot participation expands and new switch manufacturers are brought on board.

Recommendation #6: Pilot staff should continue to listen for any complaints about hot water availability from property managers or tenants, and Navigant will increase the sample size of the tenant survey to be fielded after the summer 2019 season to have more confidence in survey findings on this topic.

Finding #7: Improved data tracking and reporting would improve pilot management and evaluation. PGE and CLEAResult staff both expressed a desire for better reporting from Enbala and Aquanta, to enable faster diagnostics of connectivity issues and better insight into event performance. The impact evaluation uncovered some inefficiencies and errors in data tracking procedures that—if improved—could enable better QC and faster identification of issues for pilot managers, as well as easier impact evaluation.

Recommendation #7a: Define asset-level participation statuses for each event, such as full participant, partial participant, override, offline, etc., and document the criteria for assigning each status.

Recommendation #7b: Develop an exportable event log (event date, start time, end time, VPP, number of assets in each participation status, and estimated impacts for all events) in Tableau to remove the need for human error-prone copying and pasting from the browser into the PGE manager's event log.

Recommendation #7c: Provide a clear date in the pilot asset tracking data that identifies when an asset was available to the pilot for dispatch.

Finding #8: Only a few events produced statistically significant demand reductions that are measurable in the AMI data. Of the 56 events called during the winter season, only four had average demand reduction impacts that were positive and statistically different from zero in the AMI data analysis. The analysis was complicated by the fact that most AMI data is hourly, but events often started and ended on the quarter or half hours, thereby diluting the measurable impact in partial event hours. A "full hour" analysis revealed higher average savings relative to the full event result. In addition to the partial hour issue, several other factors limited the effectiveness of the AMI data analysis for evaluating this first season of DR events, including a small population of participants and connectivity issues. These factors may or may not persist in the evaluation of later DR seasons.

Recommendation #8a: For at least some events each season, start and end curtailment for all sub-groups on the hour (e.g., at 8:00 AM, not 8:15 AM) to avoid the issue of impacts in partial event-hours getting lost in the hourly AMI data.

Recommendation #8b: Consider converting AMI meters at participating premises to collect data at 15-minute intervals.[14] This will allow for granular estimates of event impacts and flexibility in event scheduling.

Recommendation #8c: Consider alternative evaluation methodologies, such as regression analysis of telemetry data or a matched control group, as discussed in Section 4.2.

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[14] The program explored moving to 15-minute interval data collection for the Winter 2018-2019 season, but PGE resource constraints made this conversion unfeasible.

APPENDIX A. PILOT LOGIC MODEL

The following page presents a visual diagram of how the pilot's inputs set into motion a chain of activities, outputs, and outcomes that enable the pilot to meet its goals. Note that the logic model is intended to be a living document that evolves as pilot staff incorporate new learnings into their pilot implementation approach. This logic model represents the pilot design as of the finalization of Navigant's logic model memo in April 2019.

Figure 18. Pilot Logic Model

PGE Multifamily Water Heating Demand Response Pilot Program

Target Audiences: Property owners/managers/maintenance managers/tenants of 25+ unit buildings; water heater manufacturers

Inputs: PGE funds, PGE staff time, CLEAResult staff time, Enbala staff time, staff time of CLEAResult subcontractors (Apricity Code, EDM, Aquanta, SkyCentrics, Emerson)

Barriers

- Water heating is a major contributor to residential energy consumption yet a low innovation product category
- Water heaters are the lowest engagement household appliance
- Water heater switches and communications modules are relatively new, expensive, and minimally tested
- Manufacturers assume that target audience for connected water heaters are single family households
- Cost of water heater upgrades falls on landlords, but are not valued enough by tenants to justify charging higher rent

Activities

Recruitment | Installation | Customer Experience (Managers & Tenants) | DR Retrofit Equipment Selection | Event Management | Software Development | Account Management for PMCs | Water Heater Manufacturer Engagement

Outputs

- Marketing and outreach materials produced and distributed; contacts made with property managers and owners
- Installers recruited and trained
- Systems set up to field calls and process rewards; materials & website developed to educate managers and tenants
- Equipment acquired
- Load profiles and dispatch strategies developed
- Platform created to dispatch events for multiple manufacturers
- PMC incentive process developed
- Water heater issues reporting process developed
- Negotiations with manufacturers

Short-term Outcomes (Winter 2018-19)

- Property managers and owners become aware of the program and understand the benefits of participation
- Property managers agree to participate in program, have equipment installed and connected, and inform tenants about program
- Tenants gain awareness of program and don't immediately drop out
- Events are implemented reliably and do not cause hot water issues
- Annual incentives are distributed to property managers
- Property managers gain knowledge of their water heaters' performance and potential issues
- Water heater manufacturers are persuaded to adopt the cost-effective communications protocol necessary to support program

Intermediate Outcomes (March – August 2019)

- Some tenants become program proponents and influence neighbors and other property managers
- Tenants remain unaware of events occurring and don't drop out of program; are satisfied
- Influential property managers promote program through word of mouth, making other property managers/owners easier to persuade to participate
- Property managers remain satisfied and expand participation to other buildings
- Property owners and managers see the financial value of participation
- Property managers see that participation reduces operating costs and liability due to water damage issues
- New, low-cost connected water heaters (no switches) are installed in new construction and fleet replacement scenarios

Long-term Outcomes (September – December 2019)

- Tenants are more likely to participate in (other) DR programs
- Market concept proven; OPUC approves full program
- Program achieves MW targets; program implementation costs have decreased
- PMCs are more likely to participate in other DR programs

Program Goals: Proof of hardware, software, and communications technologies; total MW targets achieved in 2019 (4 MW), program implementation costs decrease in 2019; satisfied customers with no negative impact; proof of market concept; PUC program approval

Source: Navigant analysis