UM 1827
Guidehouse Evaluation of PGE's Multifamily Water Heater Pilot Winter 2019-2020

Attachment A

Multifamily Residential Demand Response Water Heater Pilot Evaluation

Summer 2019 - Winter 2020 Report to the Oregon Public Utilities Commission

FINAL

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Table of Contents

Table of Figures ..... **ii**
Table of Tables ..... **iii**
List of Acronyms ..... **iii**
Disclaimer ..... **iv**
Executive Summary ..... **v**
Methodology v
Findings v
Process Evaluation Findings vi
Impact Evaluation Findings vii
1. Background **1**
1.1 Pilot Description 1
1.2 Pilot Objectives 1
1.3 Target Audience 2
1.3.1 Property Managers/Owners 2
1.3.2 Equipment Manufacturers 3
2. Evaluation Methodology **4**
2.1 In-Depth Interviews 4
2.2 Tenant Survey 4
2.3 Impact Analysis 5
2.3.1 Data Sources and Cleaning 5
2.3.2 Regression Modeling 5
3. Process Evaluation Findings **7**
3.1 Technologies and Data 7
3.1.1 Technology Selection, Integration, and Optimization 7
3.1.2 Data Tracking and Reporting 8
3.1.3 Dispatch Strategy Modifications 8
3.2 Recruitment, Enrollment, and Installation 9
3.2.1 Recruitment Strategies 9
3.2.2 Property Owner/Manager Participation Motivations 10
3.2.3 Enrollment and Installation 11
3.3 Property Manager Experience 12
3.3.1 Pilot Communications 12
3.3.2 Property Managers' Installation Experience 13
3.3.3 Property Managers' Communication with Tenants 13

3.3.4 Satisfaction and Word of Mouth 14
3.4 Tenant Experience 15
3.4.1 Awareness of Pilot Participation Status 15
3.4.2 Installation Notifications 16
3.4.3 Tenants' Installation Experience 17
3.4.4 Pilot Communications 18
3.4.5 Chinook Book 21
3.4.6 Hot Water Availability Issues 22
3.4.7 Overall Satisfaction 23
4. Impact Evaluation Findings 26
4.1 Summer 2019 Impact Results 26
4.1.1 Impact Results by Event Date 26
4.1.2 Device Statuses: Connectivity and Overrides 30
4.2 Winter 2019-20 Impact Results 31
4.2.1 Impact Results by Event Date 31
4.2.2 Device Statuses: Connectivity and Overrides 36
5. Conclusions 40
Appendix A. Winter 2019-20 Event Plots 43

Table of Figures

Figure 1. Summary of Recruitment and Installation Progress (March 2018 through March 2020) 9
Figure 2. Participating Units by Property Owner Group 10
Figure 3. Property Manager Satisfaction 15
Figure 4. Tenants' Residence Status and Awareness of Participation, by Month of Device Installation 16
Figure 5. Type of Installation Notifications Received 17
Figure 6. Satisfaction with Installation Process 18
Figure 7. Communication Received about the Pilot Operations 19
Figure 8. Participating Tenants' Awareness and Use of the Chinook Book Incentive 22
Figure 9. Overall Program Delight based on Receiving Communication about the Program 24
Figure 10. Program Delight by Hot Water Issue Status 24
Figure 11. Total kW Reduction and Percent Controlled per Event (Summer 2019) 27
Figure 12. Average kW Reduction per Controlled Device by Event (Summer 2019) 28
Figure 13. Total kW Impact: Guidehouse and Enbala Comparison (Summer 2019) 29
Figure 14. Average Snapback per Controlled Device by Event (Summer 2019) 30
Figure 15. Device Dispatch Status by Event (Summer 2019) 31
Figure 16. Total kW Reduction and Percent Controlled per Event (Winter 2019-20) 32
Figure 17. Average kW Reduction per Controlled Device by Event (Winter 2019-20) 33
Figure 18. Total kW Impact: Guidehouse and Enbala Comparison (Winter 2019-20) 34
Figure 19. Average Snapback per Controlled Device by Event (Winter 2019-20) 35

Figure 20. Average Hourly and Total Event Energy Impact....36
Figure 21. Device Dispatch Status by Event (Winter 2019-20)....37
Figure 22. Aquanta Device Dispatch Status by Event (Winter 2019-20) 38
Figure 23. Apricity Device Dispatch Status by Event (Winter 2019-20)....39

Table of Tables

Table 1. Impact Results by Season viii
Table 2. Summary of Process Evaluation Interviews....4
Table 3. Tenant Survey Sample Disposition....5
Table 4. How Property Managers were Persuaded to Participate 11
Table 5. Tenants' Understanding of Pilot Operations 20
Table 6. Summer 2019 Impacts per Event 26
Table 7. Winter 2019-20 Impacts per Event 32
Table 8. Winter 2019-20 Effects of Midseason Changes on Impact Results....34

List of Acronyms

AMI .... advanced metering infrastructure

ATE .... average treatment effect

DR .... demand response

DRMS....demand response management system

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

PGE.... Portland General Electric Company

Disclaimer

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Executive Summary

Portland General Electric Company's (PGE's) Multifamily Residential Demand Response Water Heater Pilot engages multifamily property managers and tenants 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 10,000 customers or up to 5 MW of Demand Response (DR) capacity by September 2020 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 incentives for property managers and tenants who 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 for the Summer 2019 and Winter 2019-20 DR seasons. Guidehouse serves as the independent evaluator for both the process and impact evaluations. This report to the OPUC is part of the deliverables provided by Guidehouse; prior deliverables include the 2018-19 evaluation report and a memo summarizing the impact evaluation of the Summer 2019 DR season.

Methodology

The process evaluation 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. Guidehouse 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 Summer 2019 DR season.

The impact evaluation used AMI data to estimate the average DR impacts for each event in the Summer 2019 and Winter 2019-20 DR season. Guidehouse submitted a data request to PGE to obtain participant tracking data, event data, and total household AMI interval data for all participating customers. To estimate event impacts, Guidehouse 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:

- **Many of the challenges identified in the previous evaluation have been resolved.** PGE, CLEAResult, and Enbala have developed a strong working relationship and completed the integration of a second switch manufacturer's technology much more quickly than the first integration. Recruitment strategies and installation processes have been streamlined and the program is meeting its targets for the number of installed units. Connectivity rates have improved, and average device curtailment savings increased as a result of deploying updated override algorithms across the installed device fleet.

- **Pilot staff are eager to explore the pilot's potential role in PGE's future demand response strategies.** After resolving many of the pilot's early technological and logistical challenges, pilot staff (including PGE staff and implementation staff) are starting to use the pilot to explore what this technology is capable of and how it might scale with increased enrollment. However, the short remaining timeline of the pilot and lack of insight into how PGE might want to use the water heater demand response resource leave pilot staff wondering what questions they should be seeking to answer at this stage. Pilot staff would benefit from additional communication from PGE Power Operations to understand what is needed to transfer the pilot into a full program.

- **Property managers and tenants 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 with the pilot overall was not as high as with the installation process, and satisfaction appears strongly correlated with whether or not tenants recall any communication about how the pilot works. Pilot staff have made several concerted efforts to assist property managers' communications with tenants since the evaluation team fielded its last survey in December 2019.

- **The COVID-19 pandemic impacted installations at additional properties as well as the ability to evaluate the effects of program improvements.** The pilot was unable to proceed with some scheduled installations in mid-March through June 2020 as a result of the stay-at-home orders, although the winter 2019-20 installations target was met, recruitment activities continued to build a large pipeline of future installations, and events at installed properties occurred as planned. At PGE's request, Guidehouse did not conduct planned interviews with participating property managers and surveys with participating tenants, to avoid bothering customers during this challenging period. As a result, Guidehouse was unable to assess the effectiveness of efforts made to improve property manager and tenant experiences, particularly related to program communications and awareness of the Chinook Book incentives.

Impact Evaluation Findings

- **Demand reductions from events in Summer 2019 and Winter 2019-20 increased in total and on a per device basis relative to the prior Winter 2018-19 season.** The Summer 2019 and Winter 2019-20 DR season events started and ended on the hour, making event impacts easier to detect in the AMI data. The program worked with Aquanta to update their firmware's water level threshold algorithm to extend event overrides longer relative to tank water hot water reserves, resulting in greater curtailment capacity per device by mid-Winter 2019-20. A second switch type, Apricity, that uses cell communication instead of Wi-Fi was added to the program for the Winter 2019-20 season. Enrollment, connectivity, and the percent of devices controlled all increased in the Summer 2019 and Winter 2019-20 seasons. These factors all contributed to improved curtailment savings over the first Winter season.

- **Snapback poses a potential risk to grid operations at scale as snapback demand increases following events are more than double the average hourly demand reductions during events.** When events conclude, most curtailed water heaters begin reheating simultaneously, causing large demand increases relative to the baseline. As the program scales in size, this ramp-up in demand may have implications for grid operations if not managed appropriately. This highlights the need to time events carefully and to consider strategies for mitigating or flattening snapback.

- **Connectivity and controllability rates improved significantly, with controllability rates increasing by 10 and 26 percentage points during Summer 2019 and Winter 2019-20 respectively.** By the Winter 2019-20 season, average connectivity (the percentage of devices able to receive the signal to curtail during events) reached 91%. This was a noticeable connectivity increase over the Summer 2019 season, which averaged 75%. Differences did exist between the two device types, with Aquanta averaging 89% connectivity and Apricity averaging 94% connectivity. The controllability rate (the average percentage of devices curtailed during an event) also differed between the two devices: Apricity averaged a 67% **controllability** rate and Aquanta averaged a 58% **controllability** rate. During the Summer 2019 season, Aquanta averaged a 46% **controllability** rate.

Table 1 summarizes the pilot's average per event impacts as well as the range for each of the evaluated DR seasons.

Table 1. Impact Results by Season

Metric	Winter 2018-19 Season Average (per Event)	Summer 2019 Season Average (per Event)	Winter 2019-20 Season Average (per Event)
Total Demand Reduction (kW)	-0.003	107	627
Enabled Devices	1,396	3,284	6,536
Devices Targeted per Event*	700	1,643	3,264
Devices Controlled per Event	263	765	2,043
Percent of Devices Connected	64%	75%	91%
Percent of Devices Controlled	36%	46%	62%
Impact per Controlled Device (kW)	0.135**	0.15	0.30
Snapback per Controlled Device (kW)	-	-0.48	-0.73

*The program targets 50% of devices (group A or B) per event.
**This is the" full hour" impact from the Winter 2018-19 analysis.
Source: Guidehouse analysis

1. Background

1.1 Pilot Description

The Multifamily Residential Demand Response Water Heater Pilot achieves peak demand reductions by directly 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. For the purposes of this report, "pilot staff" refers to the PGE program manager and the implementation team, including CLEAResult and Enbala. The pilot recruits property owners and managers of multifamily buildings to enroll their apartment units' water heaters in the pilot. Once a property is enrolled, the pilot installs switches on all eligible, accessible water heaters as well as Wi-Fi equipment, if necessary,[1] to enable the switches to receive signals to disrupt power to the water heater during events. The pilot uses water heater switches manufactured by Aquanta and Apricity. When events are called, any water heater that is actively heating and visible to Enbala's dispatch system Concerto is available for control. 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 30% of its capacity (Aquanta) or to detect if the top heating element turns on (Apricity). When the respective switches' algorithms determine that these conditions are met, the switch releases the tanks from the event and enters override until the tank is full, at which point it can return to the event. If the conditions are not met, 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 participating 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 or opt for a "light participation" mode with a higher override water threshold of 50% (Aquanta).

The pilot has conducted three demand response seasons:

- Winter 2018-19: December 12th, 2018 through February 28th, 2019.
- Summer 2019: June 3rd, 2019 through September 27th, 2019
- Winter 2019-20: December 2nd, 2019 through February 28th, 2019

In Winter 2018-19, events started at varying times of day, twice a day, and lasted for varying lengths of time. In Summer 2019, all events started at 4 PM and were four hours in length. During Winter 2019-20, events were called twice a day at 6 AM and 5 PM and were three hours in length. The pilot has flexibility to call multiple events up to eight hours each on all non-holiday weekdays.

1.2 Pilot Objectives

The Multifamily Residential Demand Response Water Heater Pilot staff identified several market barriers that the pilot design aims to address:

[1] Apricity devices use cellular technology rather than Wi-Fi.

- 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
- Determining the appropriate incentives for property managers and tenants who participate in a demand response program for water heaters
- Integrating and testing different technologies
- Implementing different demand response dispatch strategies

1.3 Target Audience

1.3.1 Property Managers/Owners

Pilot staff identified numerous target property management companies that the pilot seeks to enroll. 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 property owners are often 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 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.

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

1.3.2 Equipment Manufacturers

Secondary target audiences include manufacturers of water heaters, water heater switches, and communications modules. The pilot works directly with several switch manufacturers as vendors to identify switches with the capabilities they desire, integrate the switches' communications capabilities with the software necessary to call events, and ensure that override mechanisms work properly so that the pilot can achieve the targeted demand reductions without causing customers to run out of hot water. In addition to the retrofit water heater switches, PGE is targeting water heater manufacturers that can 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 In-Depth Interviews

Guidehouse conducted two rounds of interviews to inform this evaluation. The first round of interviews concerned feedback from participating property managers on their reasons for participation, installation experiences, and pilot-related communication with participating tenants. The second round of interviews with pilot staff focused on program evolution, achievements, lessons learned, and opportunities for improvement as the pilot integrated a second switch manufacturer and worked to increase connectivity rates and demand reductions from DR events.

Table 2. Summary of Process Evaluation Interviews

	Interviews Conducted in December 2019	Interviews Conducted in April-May 2020
CLEAResult project manager and implementation staff	-	5
Enbala project manager	-	1
Property managers	9	-

Source: Guidehouse

2.2 Tenant Survey

Guidehouse conducted two rounds of surveys with tenants at participating properties covering the topics of tenant satisfaction, installation experiences, and use of the Chinook Book incentive. Guidehouse programmed and fielded the survey through the Qualtrics web surveying platform. Tenants who completed the full survey received a $10 Amazon gift card via email. Table 3 outlines the survey sample disposition of each round.

The first round of surveys was conducted with winter 2018-19 tenants between March 12th and March 31st, 2019. The sample frame for this round 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. This first round of surveys achieved a 22% response rate, reaching 102 customers who were aware of their pilot participation and completed the full survey.

The second round of tenant surveying was fielded between December 9th and December 23rd, 2019. The sample frame included all tenants at participating properties who had devices installed and activated on or before August 30th, 2019, and therefore would have experienced at least one month of events during the Summer 2019 DR season which ended on September 27th. The sample received two reminders. The survey achieved an overall response rate of 24%, as shown in the following table. A total of 195 aware tenants completed the full survey. An additional 113 respondents were unaware of their participation in the program and were screened out of the survey after the initial awareness questions.

Table 3. Tenant Survey Sample Disposition

Month of survey	March 2019	December 2019
Emails sent	665	1,299
Bounced emails	12	26
Completed surveys	143	308
- *Aware of participation in pilot*	*102*	*195*
- *Not aware of participation in pilot*	*41*	*113*
Response Rate (completed surveys divided by valid emails sent)	22%	24%

Source: Guidehouse

2.3 Impact Analysis

2.3.1 Data Sources and Cleaning

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

- Hourly AMI data for all enabled units through February 29, 2020 (PGE)
- Event log containing event start and end times for each test group[3] as well as program-calculated impacts (Enbala)
- Program tracking data (CLEAResult)
- Water heater switch activity data (Aquanta and Apricity)

Prior to the impact modeling, Guidehouse assembled and cleaned the data and excluded the following assets and AMI data:

- Assets without a Participation Status of "Full Participation"
- Assets without an installation date (when an asset was installed at the premise[4]), 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

2.3.2 Regression Modeling

To estimate event impacts, Guidehouse 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

[3] 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.

[4] 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.

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.

The impact evaluation model predicts total household 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:

Equation 1. Model Specification

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

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} (the	=	A dummy variable equal to 1 if premise *i* is in the treatment group 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.
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 2019-20 DR seasons, Guidehouse estimated the ATE for each event. This is the average DR impact across all assets targeted for dispatch for a given event (group A or group B), regardless of whether the asset was online or fully controlled for an event. Assets must be enabled in Enbala's system to be targeted for dispatch.

3. Process Evaluation Findings

3.1 Technologies and Data

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, unless otherwise noted.

3.1.1 Technology Selection, Integration, and Optimization

A considerable amount of pilot staff effort has gone into vetting, selecting, and contracting with switch manufacturers for this pilot. The pool of possible manufacturers is relatively small and there are many questions about equipment capabilities (particularly detection of water levels) and installation practicalities that need to be addressed, as well as challenges of integrating new switches into the software systems already built to support this pilot. At the time of this report, the pilot has installed and enabled switches by two manufacturers: Aquanta and Apricity. Aquanta switches operate on Wi-Fi networks, while Apricity devices are cell-capable. At the beginning of the pilot, there were no cell-capable switches that had all of the desired features, like water level detection; some pilot staff believe that the pilot has played a role in transforming the market to develop these cell-capable options by working with manufacturers who wanted to develop products to meet the program needs.

Pilot staff observed that the integration process for the Apricity switches went much more quickly and smoothly than the integration for Aquanta switches, which they attribute to lessons learned in the Aquanta integration as well as a prior working relationship between Enbala and Apricity so the two entities already understood each other's systems well.

Early in the first season that Apricity switches were used (Winter 2019-20), pilot staff observed that these Apricity devices were achieving significantly higher demand reduction than the Aquanta devices. This discovery prompted pilot staff and Aquanta staff to explore opportunities to increase the demand reductions. As a result, Aquanta identified and corrected an error in how its algorithm calculated the estimated tank water level in early December 2019, and pilot staff decided to shift the threshold water level at which devices go into override mode from 50% to 30%. These changes resulted in higher per-unit demand reductions for Aquanta devices. Although few customers have complained about running out of hot water, when that does occur, they are put back to the 50% threshold or moved up to an 80% threshold.

Maintaining connectivity of the Wi-Fi networks necessary to use the Aquanta devices has been a challenge for pilot staff, though they have learned many lessons in how to set up and maintain these networks and achieved progressively higher connectivity rates in each season. See Sections 4.1.2 and 4.2.2 for more discussion of connectivity in the Summer 2019 and Winter 2019-20 seasons, respectively.

Apricity and Aquanta devices use different methods to detect when it's time to put the device into override mode and begin heating again. Rather than detecting the tank's water level, Apricity's devices rely on detecting when the upper heating element turns on, and pilot staff have found that in a very small percentage (~1%) of cases, the override is triggered too late and customers run out of hot water. Since Apricity switches don't have the ability to change the

threshold the way that Aquanta switches can, those customers were put into “sleep” mode in which they did not receive any events for the remainder of the season.

3.1.2 Data Tracking and Reporting

In the previous evaluation report, Guidehouse noted that pilot staff were interested in building out better data tracking and reporting tools. Since then, the implementation team has invested significant effort in improving the tools available to track and manage the pilot’s installations, equipment, active participants, and events. The implementation team has developed a suite of Tableau reports focused on event capacity results and PowerBI tools to assist in installation and maintenance scheduling and to track key performance indicators and the recruitment pipeline. They plan to share these tools with PGE in the future.

A few areas for improvement remain:

- **Connectivity and device status:** Staff have identified that deeper analytics on device connectivity data and reasons for devices not dispatching could be useful for troubleshooting and potentially improving fleet capacity. The implementation team has direct access to the Apricity connectivity data, but that direct access is not yet available for Aquanta.

- **Data syncing:** The process for syncing up PGE customer data with CLEAResult participant data is relatively manual. This syncing process is done weekly to capture move-in and move-out data. As participation grows, this manual process could become increasingly difficult. While most pilot parties use SPID as the customer identifier, Enbala uses the switch DSN, which creates opportunities for errors. Additionally, the format of addresses from property managers differs from PGE’s records. Efforts to standardize the collection of address data would smooth the process of syncing records between parties.

- **Asset count discrepancies throughout the DR seasons:** Enbala estimates of available assets in Tableau for each event did not always reconcile with the total number of enrolled and available assets on a given event day based on program tracking data.

3.1.3 Dispatch Strategy Modifications

Pilot staff have raised questions about how real-time impacts will be estimated if the pilot moves to a full program and the alternating A/B dispatch design is phased out. During the Summer 2020 season, the pilot will begin testing an “all-call” dispatch strategy whereby all enrolled and enabled devices are targeted for an event. A key barrier to a full “all-call” dispatch strategy is the CBL. The CBL has rigid requirements for non-control days within a lookback window and these requirements may not be met under a full “all-call” scenario. As program begins to test alternative dispatch strategies, alternative CBL methodologies should also be explored. Pilot staff have expressed concerns about a lack of ownership of the CBL development process and who should lead future revisions or modifications.

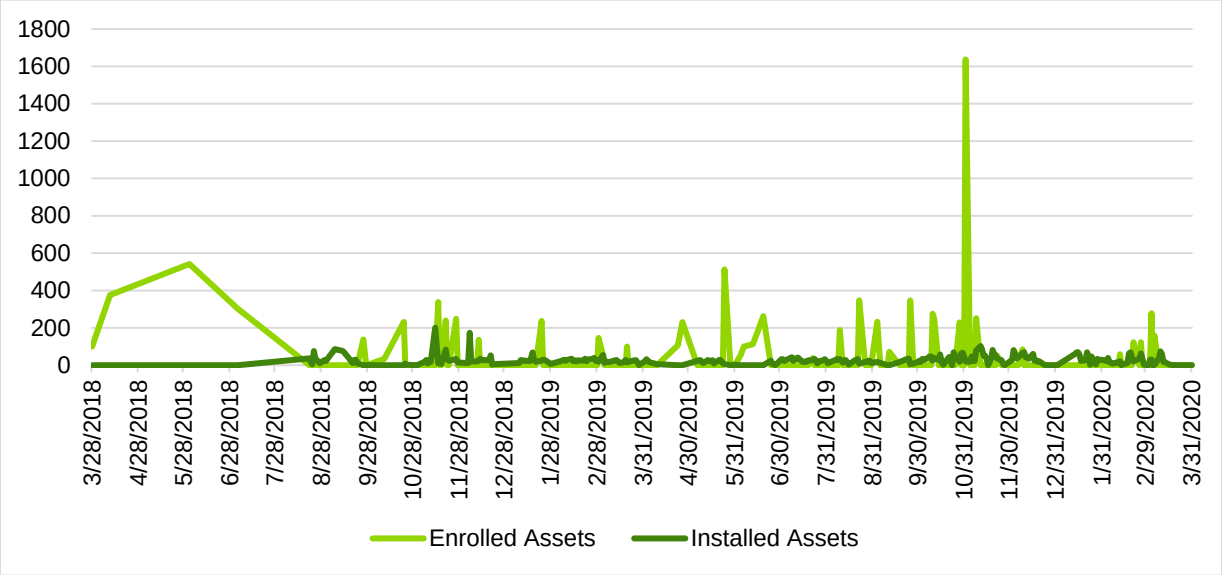
Pilot staff anticipate the need to develop snapback mitigation strategies as the pilot scales and moves towards a full program. As snapback demand impacts increase, so does the need to stagger the release of devices from the event so tank re-heating does not occur all at once. Staff recognize that the lack of 15-minute AMI interval data hampers their ability to do the type

of snapback mitigation strategies that they were experimenting with during the first Winter 2018-19 DR season. See also sections 4.1.1 and 4.2.1 for snapback impact results by season.

3.2 Recruitment, Enrollment, and Installation

Figure 1 summarizes the number of assets that the pilot has enrolled (i.e., residential units in properties that have committed to participating) and installed over time. By the end of the Winter 2019-20 DR season, the program had enrolled and installed more than 8,000 switches on participating water heaters. 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 March 2020)



Source: Guidehouse analysis of CLEAResult program tracking data.

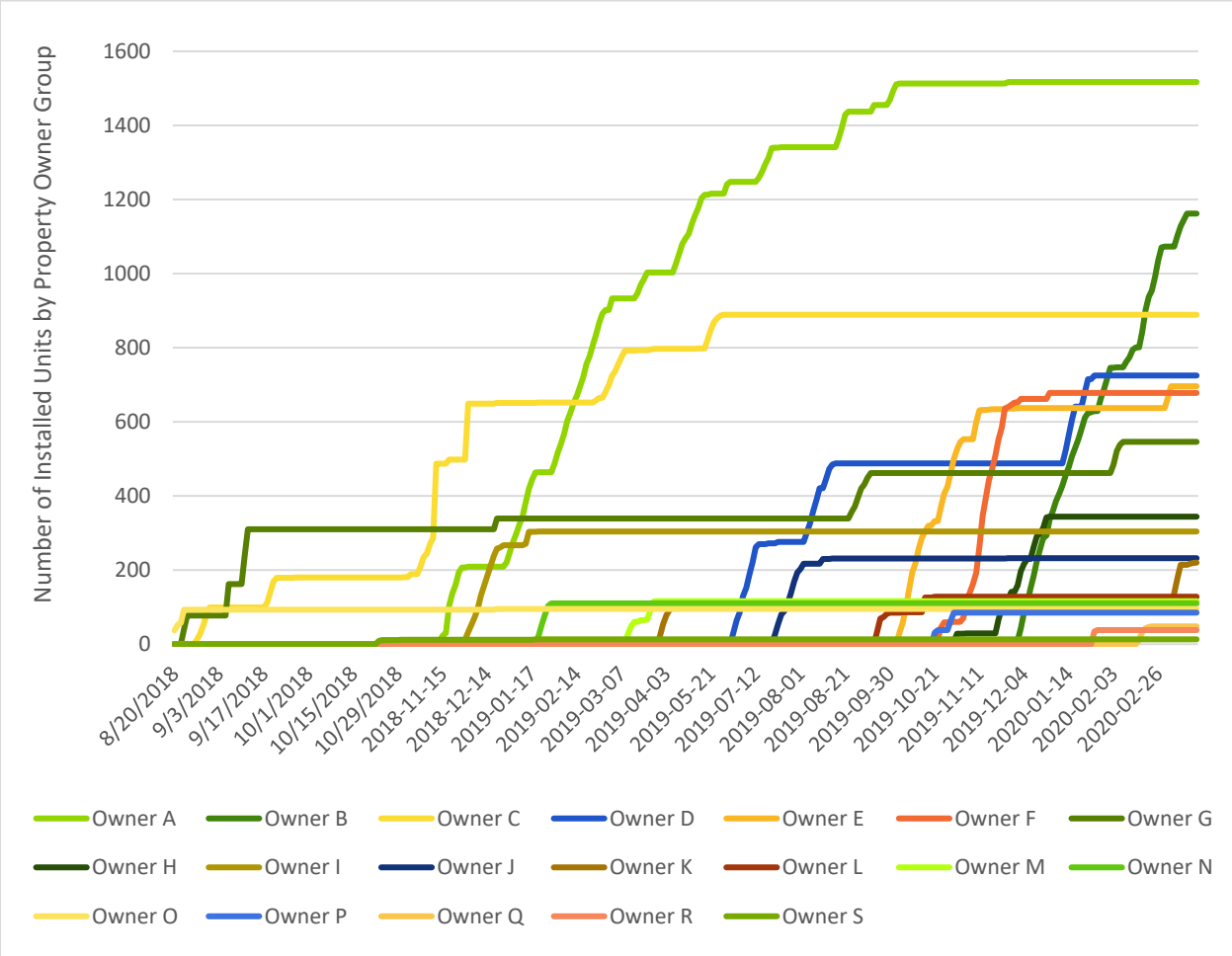
3.2.1 Recruitment Strategies

The pilot team has continued to refine their marketing approach, expanded their presence at industry events, and built positive word of mouth about the pilot. Pilot staff working on recruitment report that they have been well supported by PGE's program and marketing staff, particularly with regards to coordinating attendance at industry events and developing new communications materials (handouts and presentations) for property managers.

Pilot staff emphasized the importance of impeccable customer service in working with property managers because the most effective recruiting tool they have is positive word of mouth. Thus, a considerable amount of effort is put into anticipating challenges that property managers might encounter, providing written information to answer frequently asked questions, and maintaining the relationship built in the recruitment phase through the enrollment, installation, and post-installation phases. Pilot staff have developed a list of references of enthusiastically satisfied property managers to aid in recruitment.

One of the challenges in recruitment is that the property managers on site are often not the final decision-makers for participation in the pilot; the decision to participate is generally made by the property owner, who can be harder to reach. While this dynamic can complicate the initial communications and increase the length of time necessary to persuade a given property to participate, a positive experience with the program at one property can make it much easier to persuade a property owner to decide to expand participation to its other qualifying properties. These intracompany referrals are evident in the participation records, as shown by the number of companies that have expanded their participation over the course of the pilot in Figure 2. Eleven out of the 19 participating property owner groups have multiple properties participating in the pilot.

Figure 2. Participating Units by Property Owner Group



Source: Guidehouse analysis of program tracking data

3.2.2 Property Owner/Manager Participation Motivations

The interviews with property managers explored their initial motivations for participation in the pilot. Property managers were persuaded to participate in the program for a variety of reasons, as shown in the table below. Several property managers noted that the decision was not made

by them, and they may or may not have had insight into why the property owner or previous property manager chose to participate. The incentives offered to participating properties were cited as a motivation by two property managers, and an equal number cited the desire to distinguish their property as "cutting edge" or "sustainable" as the primary motivation.

Table 4. How Property Managers were Persuaded to Participate

Response Theme	Percentage	Example Comments
Owner wanted to do it	22% (2)	*"Owner told me to do it. I wasn't given a choice."* *"I have to obey [the owner's] wishes."*
Incentive	22% (2)	*"The owner likes the idea of incentives. The incentive got their attention."* *"Something involving a discount."*
Cost savings	11% (1)	*"We have older buildings and utilities are not lovely. Saving power and cutting cost is something we're always trying to do."*
Trying to be cutting edge, beneficial for marketing	11% (1)	*"When PGE was approaching the former property manager, they were trying to be cutting edge."*
Sustainability benefits aligned with company's values	11% (1)	*"We own and operate an Ecovillage—a sustainably driven and ecologically driven apartment community. This was an easy thing to do that aligned with our values."*
Not sure/no response given	22% (2)	

Source: Guidehouse interview of property managers (n=9).

A few property managers brought up the possibility of the pilot offering insight into the health of their water heater fleet through leak detection or other monitoring capabilities. This is a potential benefit of the pilot that property managers find very attractive, but the pilot has not yet fully built out this capability.

3.2.3 Enrollment and Installation

The implementation staff member responsible for recruitment remains involved with the property manager relationship through the enrollment and installation, starting with an on-site assessment to confirm that water heaters are appropriately sized and positioned in such a way that the switches can be installed.

Implementation staff noted that one minor area for improvement might be streamlining the legal agreements participating properties must sign with both PGE and CLEAResult. The existence of two similar agreements can be overwhelming for customers and lead to confusion and questions, further complicated by the fact that property managers often coordinate with their corporate offices to get the agreements signed. An effort to streamline and consolidate these agreements may be worthwhile.

The pilot team reports that installation practices are streamlined and the installers that they're working with are motivated, self-sufficient, and capable of answering most tenant questions that arise during the installation without requiring help from the pilot staff.

The pilot team has also made efforts to improve post-installation communications by developing a frequently asked questions (FAQ) document to leave behind with property managers, as well as door hangers for current tenants and handouts to provide to future tenants who move in after the installation is complete. Pilot staff in charge of installations report that the FAQ document has decreased the number of calls from property managers.

Installations at new properties were paused due to the COVID-19 pandemic, and the implementation team has been working with property managers to develop policies and procedures for safe installations consistent with public health guidelines when installations resume. These procedures include details such as how to get keys from property managers, open doors, maintain distance from customers, and disinfect surfaces. The implementation team anticipates more tenants will refuse entry into their units at first as installations resume.

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 nine property managers in December 2019 unless otherwise noted.

3.3.1 Pilot Communications

One-third of the nine interviewed property managers first heard about PGE's Connected Water Heaters program from their property owner or portfolio manager. Three people (33%) first heard about the program from a PGE representative who reached out or a PGE partner at an industry event. Two property managers (22%) started working at their properties recently and did not know where their property first heard of the program. **Most property managers (67%) thought the program was explained well to them.** One third said the program was explained to them not well or not at all. Below are quotes from the property managers that did not feel they had received a good explanation of the program:

- *"The only thing explained was the device going onto the water heaters to gauge when people use it and when to heat up the water heater. [PGE] did not explain how routers are being used, if blinking [lights] means it's not connected and to watch out for it, and that there's a yearly service. Needed to know that to let residents know."*[5]
- *"We had people use routers for personal use, connected their modems into it. [PGE] had to go through every unit and document. [I had to] communicate to residents that they can't use those routers and had to buy their own. Last time they brought little stickers to put on the routers and that helped."*

[5] The "yearly service" referenced by this property manager refers to program staff returning to properties to maintain the Wi-Fi network equipment.

- *"Tenants ask me all the time, what is that for? It would be nice to answer that question. When asked, I tell them it made it a smart water heater… I'm still confused as to what it was."*
- *"It wasn't explained, I don't really know much about it."*

Although there wasn't a question specifically about the site visits, several property managers spontaneously noted that the pre-installation site visits were helpful opportunities to ask questions and resolve concerns about the installation process, even though there was not a question specific to that topic.

3.3.2 Property Managers' Installation Experience

All interviewed property managers had a positive experience with the installation process. Out of nine interviewed property managers, four had great experiences and were very satisfied with the installation process overall. Five other property managers were satisfied but also offered some constructive feedback about their experiences with the installation process.

Two of the property managers noted the installations took longer than they expected, and another actually noted the installations were faster than expected and was completed in two days while they had told their tenants to expect that it would take three days. One noted that daytime installations were difficult for tenants who work night shifts and sleep during the day.

Some feedback related to the logistics of installation when units had varying layouts or sizes of water heaters. One property manager was surprised to learn that some units had water heaters that were smaller than allowed by the program; another had certain units in which the water heaters were not accessible without moving the clothes washers and dryers, which wasn't possible because the property managers did not have enough staff on hand. Program staff make site visits prior to installation to prepare for these types of installation logistics, but might need to make additional efforts to visit a variety of units to identify situations in which some water heaters may be inaccessible or ineligible for the program to avoid surprises for the property managers.

3.3.3 Property Managers' Communication with Tenants

Most property managers (five) have not received any tenant complaints about the program, despite their role as the go-to person for tenant complaints**.** Four property managers did mention specific complaints from their tenants, including: a delay getting hot water to their sink, cold water issues, devices getting hot and tripping the breaker,[6] and PGE entry and re-entry into apartments. However, almost all property managers stated they did not have any current issues or concerns about the program that PGE should know about, suggesting they had already successfully resolved any issues or concerns with PGE. Property managers do not often receive positive feedback from their tenants, and this program was no exception; few property managers report hearing any positive feedback about the program from their tenants. However, one property manager heard from a tenant who thought she saved a lot of money through the program.

[6] The property manager mentioned that 2-3 PGE devices smoked and tripped the breaker for the entire building so it was without electricity. PGE sent out electricians to inspect the unit and install new devices. These incidents were random but the property manager is fearful more devices might catch fire.

Blinking lights on the devices are a nuisance to program tenants and property managers who have to figure out solutions. Three property managers specifically mentioned their tenants complained about blinking lights on the devices.

- *"Didn't know the routers would be blinking. The installers should have said [during the installation] that they're all blinking. A few months later in the summer, the installers had to come back to review the blinking."*
- *"The only [issue] I've had is the blinking light and that was explained to me and I haven't heard anything since."*

Most property managers communicated with their tenants during installation, but only one property manager maintains regular communication with their tenants post-installation. Five of the nine interviewed property managers describe the program to new tenants who move in after installation during the walk-through tour (four) and/or by providing program materials in the move-in packet (two). Three property managers specifically mentioned handing out PGE program flyers to their tenants. Just over **half (five) of the property managers would appreciate additional program materials** to assist them in their communication with tenants. Since these interviews were conducted, program staff have developed new materials for property managers to give their tenants.

3.3.4 Satisfaction and Word of Mouth

Property managers are generally likely to recommend the program to other property owners or managers, with an average rating of 7.3 (on a 0-10 scale) and a mode of 10. Of the property managers who rated their likelihood above a 5, most (five out of six) have discussed the program with someone else. The response from other property owners or managers was often excited and interested, though one property manager said the response was skeptical.

Property managers rated their overall satisfaction with the program on average 7.9 (on a 0-10 scale), with a mode of 10, as displayed in Figure 3.

Figure 3. Property Manager Satisfaction

Source: Guidehouse interview of property managers (n=9).

Property managers who were motivated by saving money and those who had a great installation process tended to be more satisfied with PGE overall. Property managers who were very satisfied with PGE overall (9-10 on a 0-10 scale) participated in the program because of the incentive or cost savings, whereas property managers with lower satisfaction (less than 7) participated at the instruction of the property owner. There is also a correlation between satisfaction with PGE overall and satisfaction with the installation process, which is expected considering that the installation process is the part of the process that will require the most action from property managers. The program will likely see higher satisfaction from property managers over time as they've implemented efforts to reduce the time necessary for installation, as well as the adoption of cell-capable switches which require less maintenance than Wi-Fi networks.

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 December 2019 unless otherwise noted.

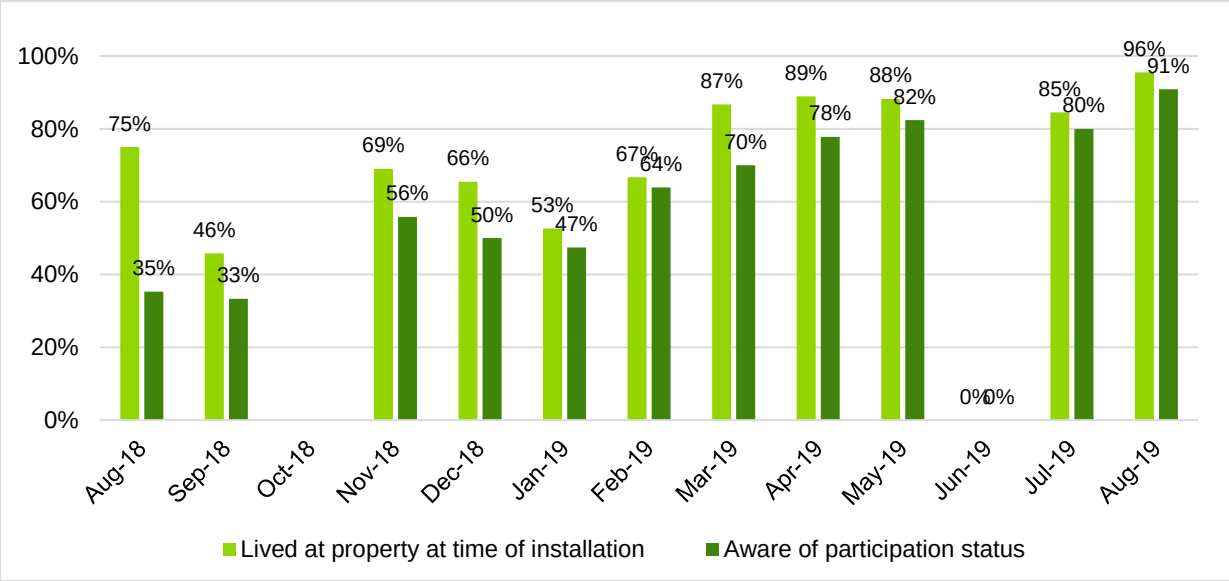
3.4.1 Awareness of Pilot Participation Status

Approximately one-fifth (22%) of survey respondents recognized the Connected Water Heater program name and confirmed that their household was participating. This is a significant decline from the March 2019 survey conducted after the winter 2018-19 season, which found that one-third of tenants recognized the program name and confirmed participation by name. Another 42% of respondents did not recognize the program 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, 63% of survey respondents were able to confirm that they were tenants in the program.**

Tenants' awareness of their participation status varied significantly by the month that the switch device installation took place at their property and correlates with whether or not the

tenant lived at the property at the time of installation, as shown in Figure 4. Tenants whose devices were installed in August or September 2018 had much lower awareness (33-35%) of their participation status compared to those who entered the program in Summer 2019, with awareness of 80-91%, as shown in the graph below. The previous survey of 2018-2019 winter season tenants observed similar patterns.

Figure 4. Tenants' Residence Status and Awareness of Participation, by Month of Device Installation



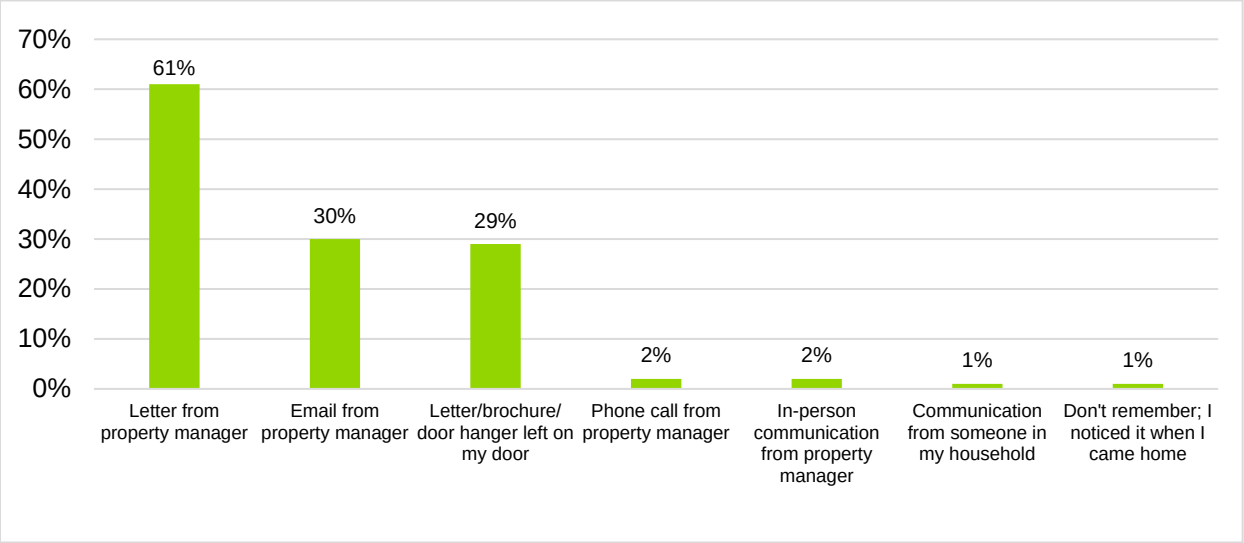
Source: Guidehouse survey of tenants at participating properties (n=308). No survey respondents had the water heater device installed in October 2018. One person who had their water heater device installed in June 2019 was not aware of participation in the program (0%).

Of the 79 surveyed tenants who did not live at the participating property at the time of installation, only nine (11%) had ever heard of the Connected Water Heater program and six (8%) were able to confirm their household's participation in the program. These findings suggest that surveyed tenants who move into participating properties *after* the water heater devices are installed were not given adequate information about the program. However, since this survey was conducted, PGE and CLEAResult have implemented additional efforts to encourage property managers to communicate to new tenants about the program, including a new marketing handout that can be included in tenants' welcome packages.

3.4.2 Installation Notifications

Tenants were highly satisfied with the advance notification about the device installation, with an average satisfaction rating of 9.0 on a 0-10-point scale. Property managers are responsible for notifying tenants about the installation, with guidance and example letters provided by the program. As shown in Figure 5, the majority of tenants (61%) learned about the installation via a letter from their property manager; 30% received an email from their property manager and 29% received a notification left on their door. Just two tenants (1%) indicated that they did not remember any communication or simply noticed the installation when they came home.

Figure 5. Type of Installation Notifications Received



Source: Guidehouse survey of aware tenants who lived in the home at the time of installation (n=189). 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, the majority of tenants did not suggest any improvements. Twelve tenants offered relevant ideas for specific improvements that fell into four categories:

- More advanced notice (mentioned by seven tenants)
  - *"More notice than 24 hours."*
  - *"Giving us at least a week longer. Had to schedule time off work."*
  - *"It takes me more than 24 hours sometimes to get someone to watch my dogs."*
- Offer other communication modes (mentioned by three tenants)
  - *"Email, phone call or text message would have been nice."*
  - *"More lead time and email or text notification would have been more effective."*
- Options for installation days/times and more accurate scheduling (mentioned by two tenants)
  - *"Maybe more choices of times for installations. Later in the day would have been better for me since I work nights."*
  - *"Day given was two days long and we were given the wrong day."*
- More detailed program information (mentioned by two tenants)
  - *"More time and explanation would have been nice."*
  - *"Give an explanation as to why this installation was being done."*

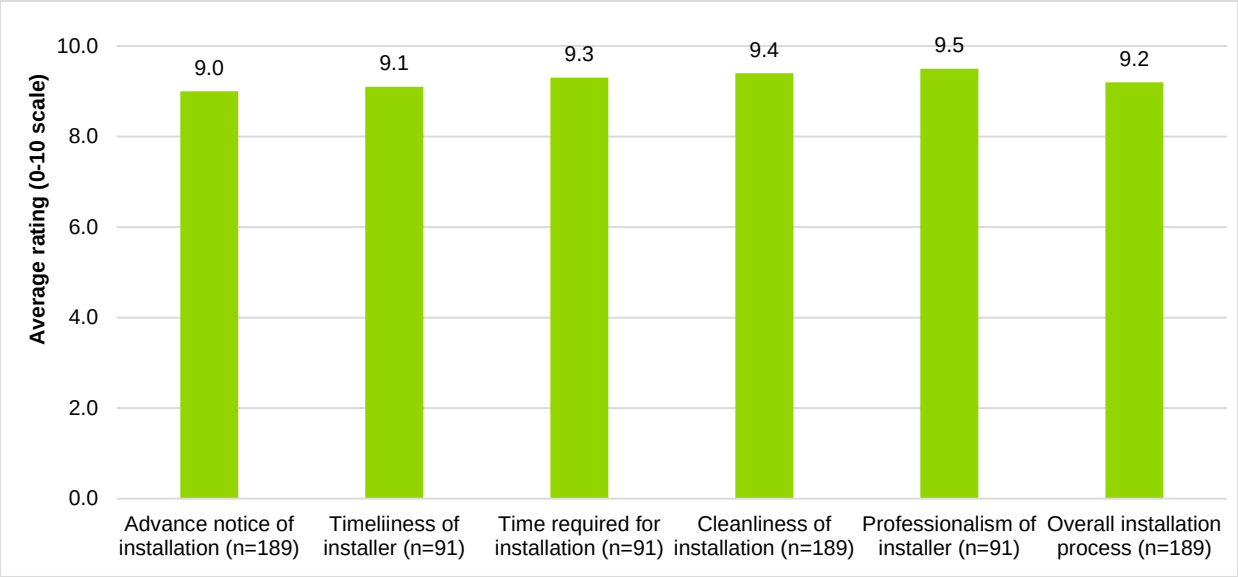
3.4.3 Tenants' Installation Experience

The findings in this section are based only on survey responses from the tenants who lived in their current home at the time of installation and who were aware of their participation in the program (n=189).

Overall, tenants are highly satisfied with the installation process. Eighty-two percent of tenants rated their satisfaction with the overall process as a 9 or 10 on a 0-10-point satisfaction

scale. Figure 6 shows the average satisfaction ratings for various aspects of the installation process.

Figure 6. Satisfaction with Installation Process



Source: Guidehouse survey of aware tenants who lived at the participating property at the time of installation (n=189).

Note that **about half (52%) 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.

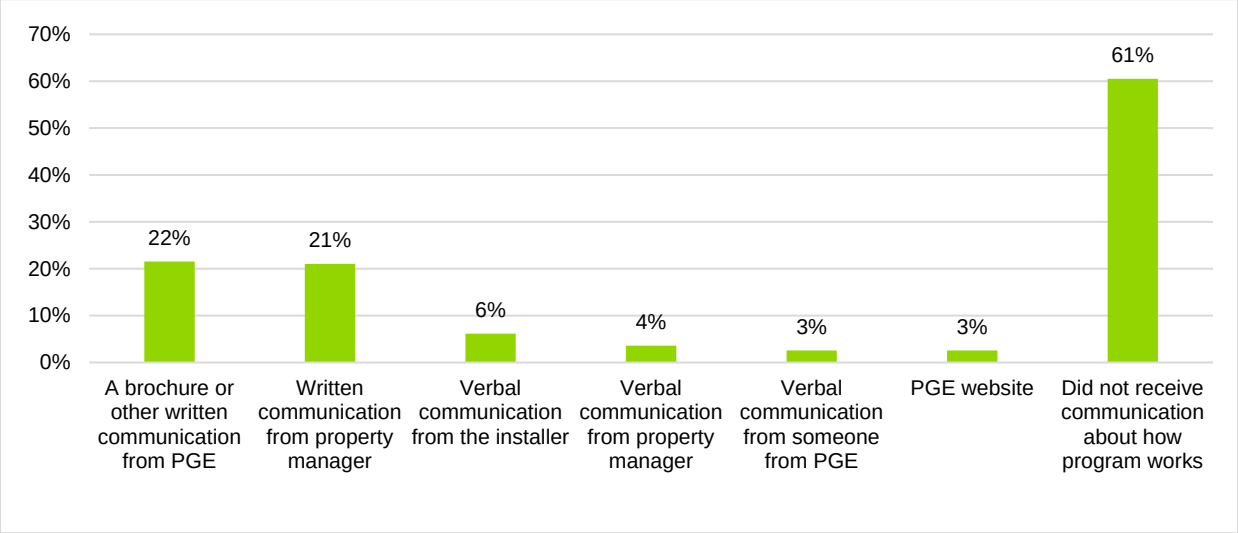
Very few tenants offered specific suggestions for improvements to the installation process when asked. The installers' professionalism could be improved by waiting longer between knocking on the door and entering the apartment; two tenants mentioned entry was too fast. Suggestions for improving the cleanliness of the installation included not leaving behind garbage or spare parts and cleaning the floor of debris (mentioned by seven tenants).

3.4.4 Pilot Communications

The tenant survey explored whether the tenants received verbal or written communication about how the pilot worked, as shown in Figure 7.[7] **Less than half (40%) of tenants reported receiving any communication about how the program works**, 5% less than the surveyed 2018-2019 winter season tenants. Most often, tenants who received communication about the program received written communication from PGE (55%) or the property management company (53%). Twelve tenants spoke with the person who installed the device on their water heater, seven spoke to their property management company, five talked to someone from PGE, and five visited the PGE website.

[7] 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. Since this survey was fielded, PGE and CLEAResult staff have developed additional materials for property managers to pass along to their customers regarding how the program works, but Guidehouse has not yet had an opportunity to explore the impacts of those efforts on customer awareness.

Figure 7. Communication Received about the Pilot Operations



Source: Guidehouse survey of aware tenants (n=195). 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 8.4 on a 0-10 scale. When asked to explain their understanding of how the pilot works, there were a variety of responses, as shown in Table 5. Though fewer than one-third (29%) connected the pilot to the concept of peak demand or off-hours, this was an increase from the winter 2018-19 season survey in which just 15% referenced off-peak hours. Another 16% connected the program to a vague sense of efficiency or energy savings. Ten percent of tenants (down from 22 percent in the 2018-19 winter season) mistakenly believed that the device learns when their household uses the most hot water and heats more during those times and less during other times. Though understanding of how the program works remains low, it appears to be trending in the right direction relative to the previous survey.

Table 5. 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"	29%	*"Monitors water usage to establish peak times and offer savings for using hot water in staggered intervals."* *"It creates hot water at times it's cheaper."* *"Hot water heater turns off on high demand times and you save a few dollars."* *"PGE monitors your energy usage to better plan for power spikes."*
Improved efficiency or energy savings (no reference to cost savings or time of usage)	16%	*"It reduces the amount of time the hot water heater is running."* *"It's supposed to save energy somehow."* *"Helps to control the temperature of the water heater when not in use to help conserve energy."*
Monitors hot water usage	12%	*"I'm unsure? I think they're watching exactly how much water we use so that the manager can charge us more for our use. If we use more than others in building, they now charge us more."* *"Tracks how much hot water I'm using."*
"Smart" hot water heater learns when household does not use hot water and avoids heating during those times	10%	*"It allows the hot water heater to be smarter about how much hot water is used, based on historical usage."* *"I believe it's an on-demand system."* *"It tracks when you use hot water. Doesn't keep the water hot all the time only the times when you are using it."*
Improved efficiency or energy savings for cost savings (no reference to time of usage)	6%	*"Uses energy more efficiently to keep costs low and affordable."* *"Using hot water during certain times saves money."*
Saves me money	4%	*"It's supposed to save on the hot water heater bill."*
Don't know/don't remember	18%	*"I cannot!"*

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

When asked if communications about the program could be improved, more than three-fifths of tenants said that no improvements were necessary, or they were not sure how the communications could be improved. The remaining almost two-fifths of tenants offered suggestions related to the format and content of program communications. Generally, most comments centered on the desire for more information about how the program works, its benefit

to tenants, and troubleshooting issues (e.g., a blinking light). Some tenants misplaced flyers with program information and asked for follow-up information with program details via email, mail, or online to refresh their memory. The following bullets summarize the main themes and some example comments from tenants.

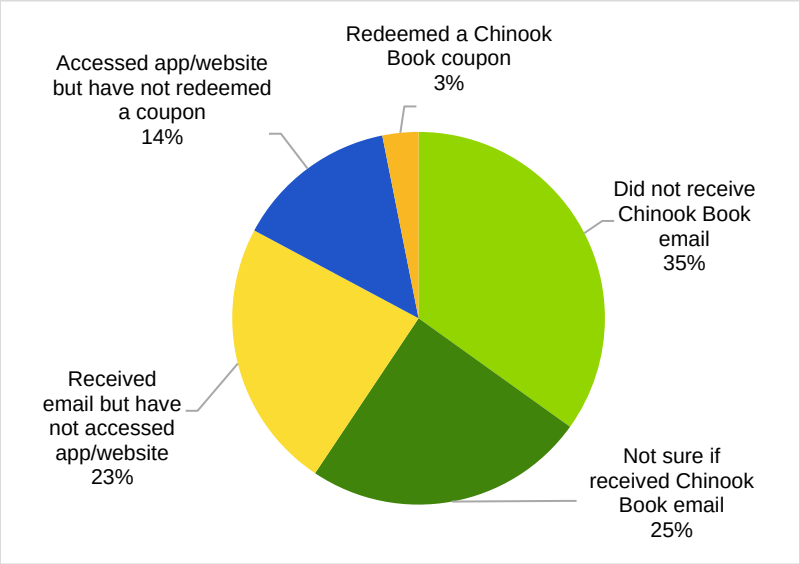
- **More program information, including benefits for tenants and troubleshooting**
  - *"Actually outline what is going on, why, and the purpose of the study. Information given was very vague."*
  - *"What is the green light for, what does it blink on occasion and why is the light red in the middle of the night on rare occasions."*
  - *"Become more informative of the benefits there in for the customer and the apartment dweller utilizing it."*
  - *"Why it's needed. How it works. Visuals/pictographs would be better than written explanations."*
  - *"Easier in a simple to understand document. Email preferred or/and email linking to short page on a website."*
- **More detailed information about cost savings**
  - *"Yes, maybe quarterly statements on savings."*
  - *"Exactly how does this work in lowering my monthly bill."*
- **Follow-up and refresher information for tenants**
  - *"An email follow up with instruction because I lost the paper instantly."*
  - *"Perhaps more follow up information could be provided a few months after implementing the program just for a reminder. I was given the information once, but lost it and don't really remember what it's for."*
  - *"Maybe a refresher mailer?"*

3.4.5 Chinook Book

Tenants receive access to the Chinook Book online coupon book as an incentive for participation in the pilot. As shown in Figure 8, more than one-third (42%) of the aware tenants were able to confirm that they received the Chinook Book access email from PGE, which is the tenant incentive for participation in the program. This is an improvement relative to the March 2019 survey in which 33% of 2018-2019 winter season tenants could confirm receipt of the Chinook Book email. **One-third (35%) believed they had not received the Chinook Book email**, and another 25% were not sure.[8] Only 17% had accessed the Chinook Book website or app, and only 3% had actually redeemed a coupon.

[8] Note that at the time of the survey, customers who had moved into their home after the device installation would not have received a Chinook Book email; just five survey respondents fell into that category. PGE has since modified its Chinook Book processes so that new customers who move into participating units are sent the Chinook Books.

Figure 8. Participating Tenants' Awareness and Use of the Chinook Book Incentive



Source: Guidehouse survey of aware tenants (n=195)

Since this survey was fielded, PGE has implemented several changes to increase tenant awareness of the Chinook Book, including the addition of a reminder email and a doorhanger left behind on tenants' doors after installation which highlights the Chinook Book offering and instructs tenants how to ensure that they'll receive the Chinook Book emails.

3.4.6 Hot Water Availability Issues

The survey reminded tenants of the common household activities which use hot water and asked them what time of day they think they use the most hot water. Tenants then answered a question about whether they thought their hot water usage patterns had changed since participating in this program. The question was designed to elicit insights into whether tenants believe that the program is causing them to run out of hot water without creating a misconception that the program is likely to cause tenants to run out of hot water if they were not already experiencing that.

At this point in the survey, some tenants had already volunteered information about their belief that the program was limiting their hot water availability in earlier open-ended questions on unrelated topics, so Guidehouse reviewed all open-ended questions for complaints about hot water availability.

Altogether, **eleven tenants (6% of 195 aware tenants**, less than the 10% of 102 2018-2019 winter tenants**) had complaints about their hot water availability. Six of those people mentioned their hot water availability has changed over time**, suggesting their hot water issues are attributable to the program. Some of the comments about hot water availability included:

- *"Since installing, there has been multiple times when the shower does not get hot at all which can be frustrating. Always in the evenings."*
- *"Have noticed decreased temp in the shower."*
- *"Water isn't as hot and doesn't seem to last as long."*

- *“Hot water seems to run out quicker than it used to.”*
- *"However, it seems like since the device was installed we run out of hot water faster than we did before. It could be coincidence, but it definitely seems to have a negative impact on hot water availability, while not actually seeming to provide much of a drop in energy usage.”*

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.

Five of the eleven tenants who reported hot water issues and were aware of their participation in the program did not directly attribute their hot water issues to the program. They did not specifically mention their hot water issues had developed over time or since participating in the program, they simply noted issues with hot water availability. Some of the comments about hot water availability include:

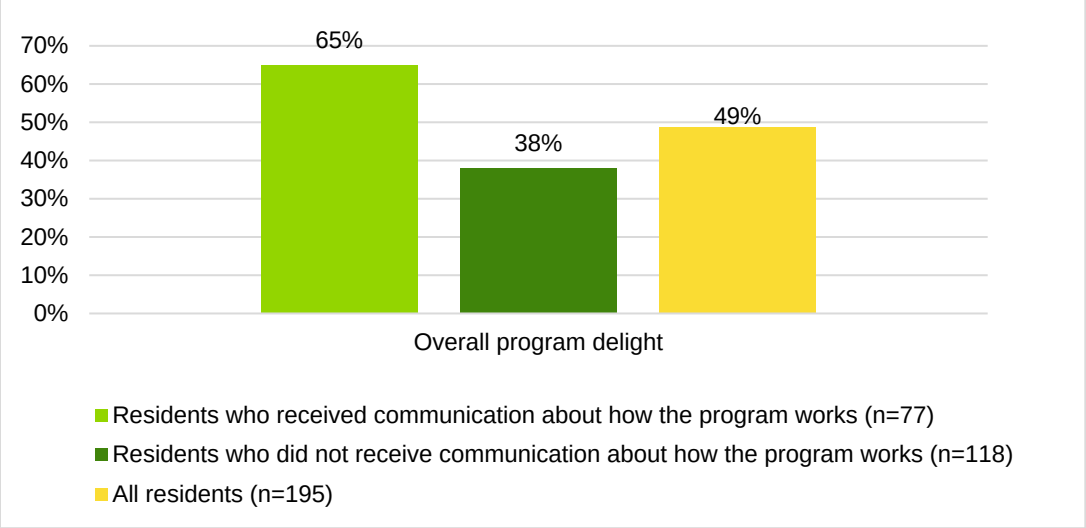
- *“Water never stays hot enough to fill a bathtub.”*
- *“Hot water longevity is short lived. Doesn't stay hot for more than 10 minutes before becoming cold. Not happy.”*

3.4.7 Overall Satisfaction

Tenant satisfaction with the overall program was lower than satisfaction with the installation process, program communications, and PGE. The average satisfaction rating was 7.7 on the 0-10 scale. Half (49%) of aware tenants were delighted with the program overall (9 or 10 on a 0-10 scale). Less than 6% rated their satisfaction lower than a 5 on the 0-10 scale. Open-ended comments suggest that the relatively neutral satisfaction scores relate more to a general lack of understanding of what the program is doing as opposed to an active dissatisfaction with any specific aspect of their participation, although some tenants did complain about bright blinking lights on the router and that the program seems to offer them little benefit.

Delight with the program overall was significantly higher for tenants who recalled receiving communication about how the program works (65% of respondents who received communication about how the program works were delighted with the program overall, compared to 38% of people who did not recall such communication), as shown in Figure 9. This finding highlights the importance of ensuring that tenants receive clear, useful explanations of the program, how it works, and why it benefits PGE customers.

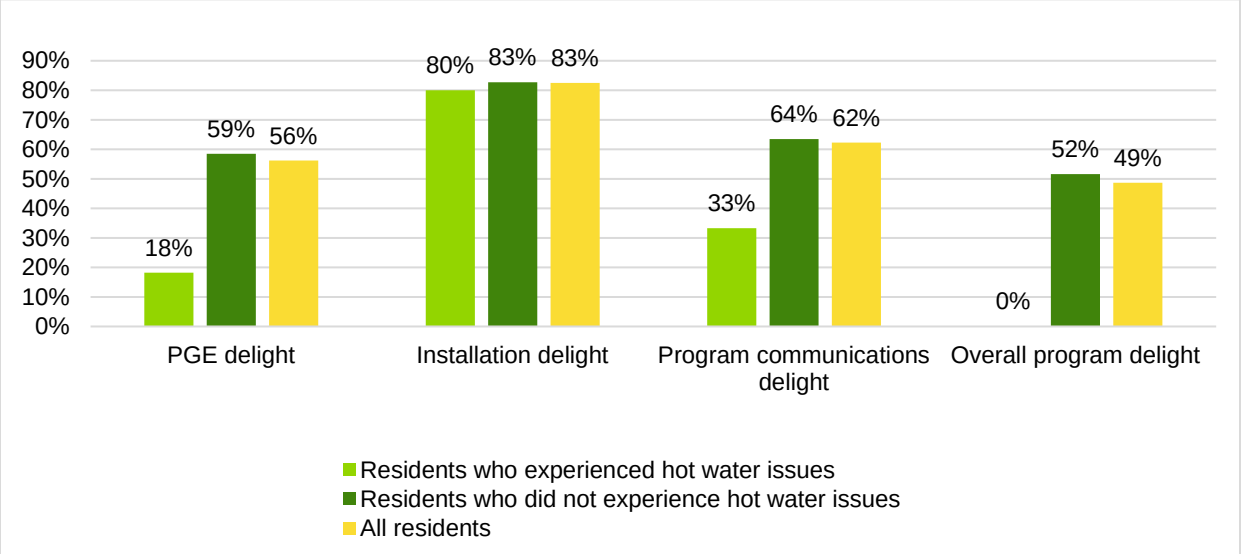
Figure 9. Overall Program Delight based on Receiving Communication about the Program



Source: Guidehouse survey of aware tenants (n=195). Delight is the percentage of respondents who rated their satisfaction a 9 or 10 on a 0-10 scale.

As shown in Figure 10, tenants who believe the program is limiting their hot water availability have substantially lower satisfaction with every aspect of the program *except* the installation process; none of the eleven aware tenants who experienced such issues rated their overall satisfaction with the program as a 9 or 10 on the 0-10 scale.

Figure 10. Program Delight by Hot Water Issue Status



Source: Guidehouse survey of aware tenants (n=195). Delight is the percentage of respondents who rated their satisfaction a 9 or 10 on a 0-10 scale. Note that the question about satisfaction with program communications was limited to the tenants who said they received communications about how the program works (n=77) and the question about satisfaction with installation was limited to tenants who lived at the participating property (n=189).

Tenants who are aware of their participation in the program are more likely to be satisfied with PGE overall. More than half (58%) of tenants who were aware of their participation were delighted with PGE, while only 42% of tenants who were not aware of their participation were delighted with PGE.

The survey did not include a question on satisfaction with the Chinook Book as an incentive, but the very small percentage of respondents who reported actually making use of the coupons suggests that it does not contribute to high program delight. Two respondents did not like using the Chinook Book.

Some other sources of dissatisfaction may be easy for the program to address. Tenant communications could be improved to make it clear that tenants do not have to take any actions as part of their participation in the program. Several tenants mentioned their annoyance with the blinking green light on the device, and some property managers indicated they do not understand why this happens or how to troubleshoot. Program staff report that they the installers have started placing tape over the blinking lights, but it appears that that may be occurring inconsistently. Tenant and property owner communications could include a more thorough description of the device and how to block the blinking lights without interfering with the device's function.

Tenants' generally neutral view of the program is reflected in the 55% of tenants who said their program experience had no influence on their willingness to participate in other PGE programs. Just 5% said the program made them somewhat or much less likely to participate in other programs.

4. Impact Evaluation Findings

This section discusses the findings from Guidehouse's impact evaluation of the Summer 2019 and Winter 2019-20 DR seasons.

4.1 Summer 2019 Impact Results

This section discusses the findings from Guidehouse's impact evaluation of the Summer 2019 DR season, which lasted from June 3, 2019 through September 30, 2019. Section 4.1.1 presents the results of the regression analysis on an event-by-event basis and Section 4.1.2 presents the analysis of device connectivity and override data

4.1.1 Impact Results by Event Date

Table 6 summarizes the key metrics for the Summer 2019 DR events, including the season average and the minimum and maximum values by event.

Table 6. Summer 2019 Impacts per Event

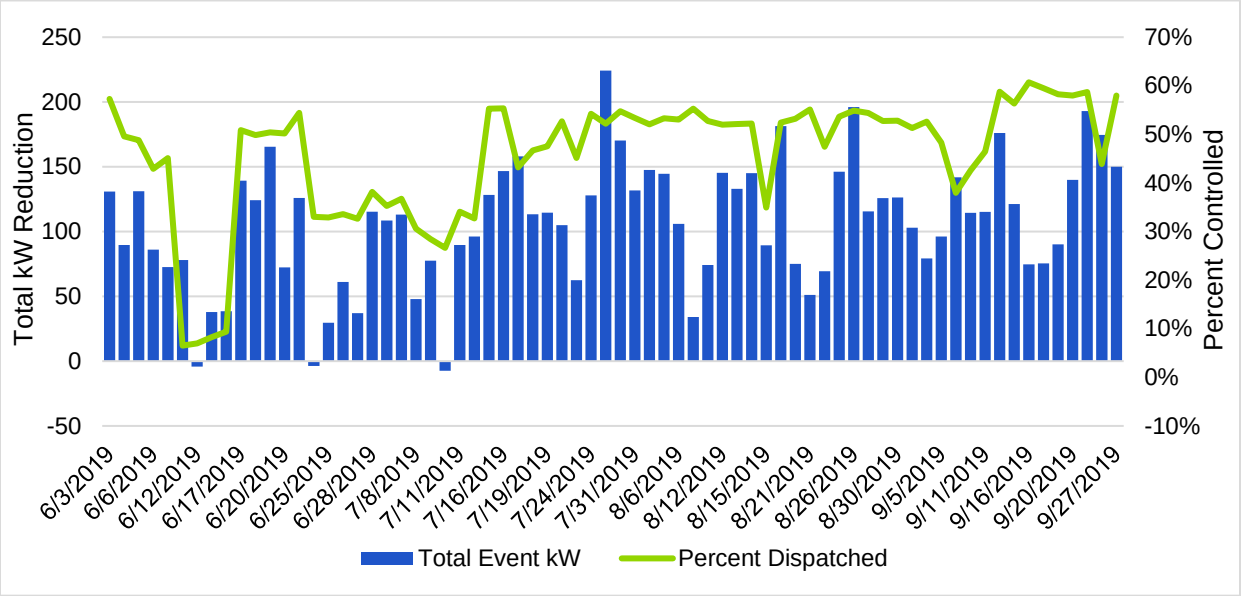
Metric	Season Average (per Event)	Minimum	Maximum
Total Demand Reduction (kW)	107	-7	224
Percent of Devices Controlled	46%	7%	61%
Impact per Controlled Device (kW)	0.15	-0.04	0.80
Snapback per Controlled Device (kW)	-0.48	-0.76	0.35

Source: Guidehouse analysis

The program called a total of 70 events during the Summer 2019 season. The **total demand reduction per event** averaged 107 kW. As shown in the grey bars in Figure 11, impacts varied from event to event, with a range of -7 kW to 224 kW. Some of the variation in impacts is due to the variation in percent of devices that were successfully controlled (shown as the light green line in Figure 1), as well as an increase in the overall number of devices participating as installations were completed through the season. The **percent of devices controlled** ranged from 7% to 61%, and the total number of enrolled devices increased 40% from 2,995 at the beginning of the season to 4,192 at the end of the season.[9]

[9] Note that due to the A/B design of the program, roughly half of all participating devices were eligible for each event. On weeks that the A group received events, the B group served as the control group, and vice versa.

Figure 11. Total kW Reduction and Percent Controlled per Event (Summer 2019)



Source: Guidehouse analysis

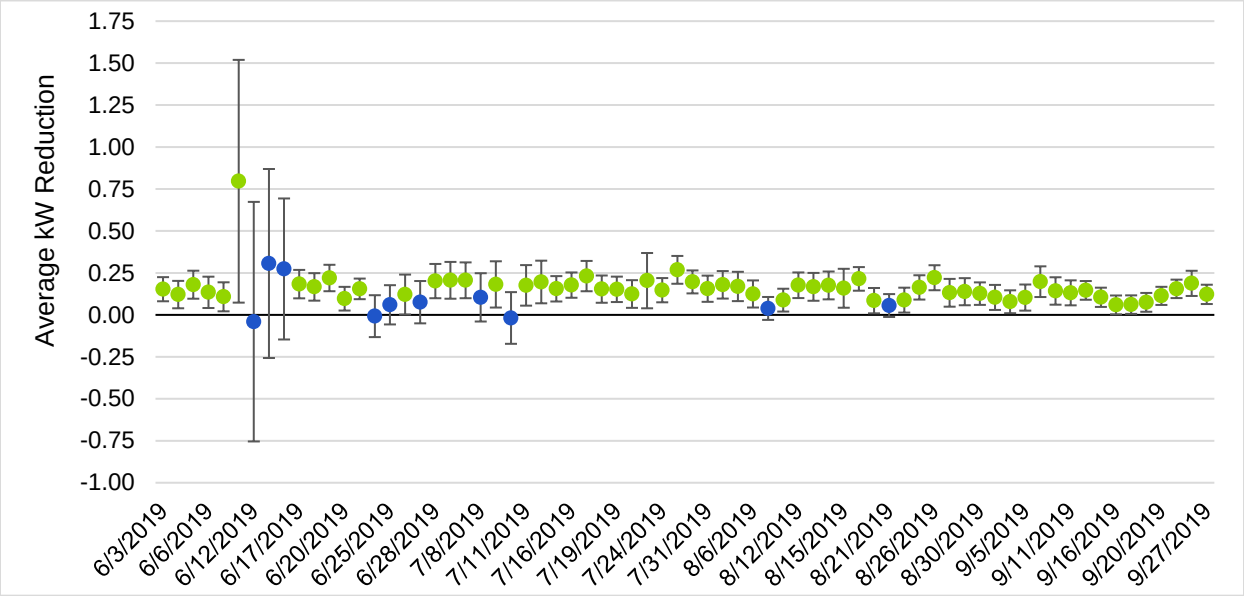
Figure 12 presents the **average impact per controlled device** for each event. These averages are calculated by dividing the total event impact (shown in the previous graphic) by the number of controlled devices[10] for that event, which is a function of water heater connectivity, heating status, and tank level[11]. The average impact is 0.15 kW per controlled device, with a range of -0.04 to 0.80 kW[12]. The impact estimates were statistically significant (i.e., statistically different from zero) for 60 out of the 70 events; statistically significant estimates are represented with grey dots in the graph, and the range around each dot represents the margin of error in the estimate.

[10] Guidehouse calculated controlled device counts using Aquanta's control records retrieved through the Aquanta API by CLEAResult.

[11] Water heaters are controllable only when heating and not in override mode due to low water levels.

[12] The event at the upper end of this range could be considered an outlier. Only a small number of devices were controlled, therefore the confidence interval on this estimate is large.

Figure 12. Average kW Reduction per Controlled Device by Event (Summer 2019)

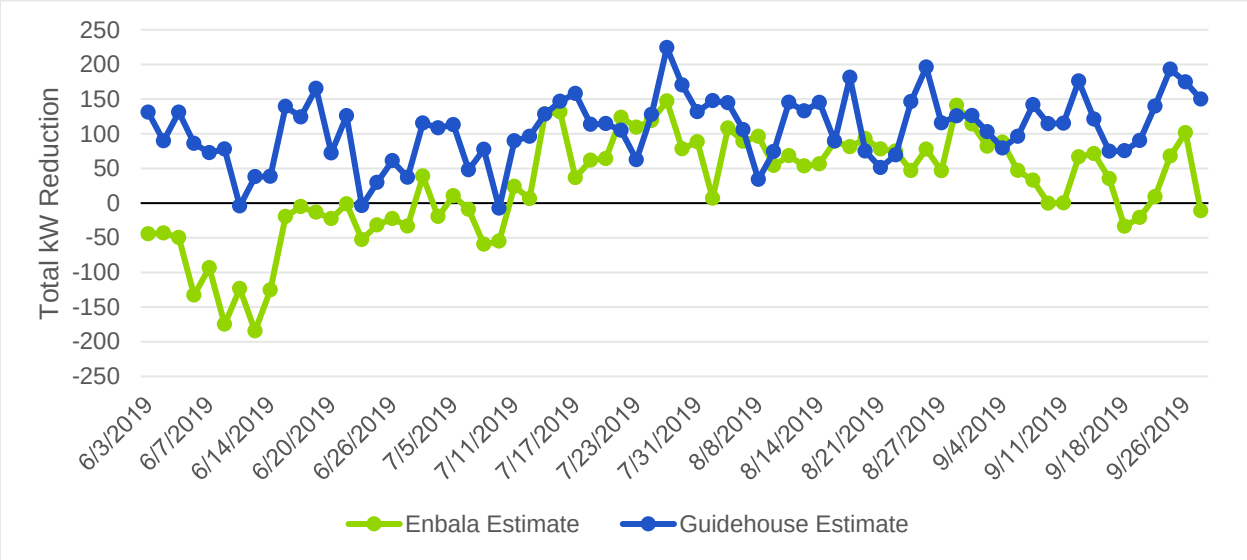


Note: green dots signify kW reduction estimates that are statistically different than zero. The narrower the error bands around each dot, the higher the confidence in accuracy of the point estimate.

Source: Guidehouse analysis

Figure 13 presents a **comparison to impact estimates from Enbala**, the demand response management system vendor. Note that Guidehouse and Enbala use different methodologies: Guidehouse's analysis is conducted using regression analysis on hourly household electricity consumption and uses a control group for the baseline (i.e., the amount of energy that controlled devices would have been using if not controlled). Enbala's analysis uses 15-minute water heater telemetry data to estimate a customer-specific baseline from each household's past water heater usage. For 61 out of the 70 events, Guidehouse's estimates are higher than Enbala's estimates, suggesting that Enbala may have used conservative baseline assumptions in their Summer 2019 analysis.

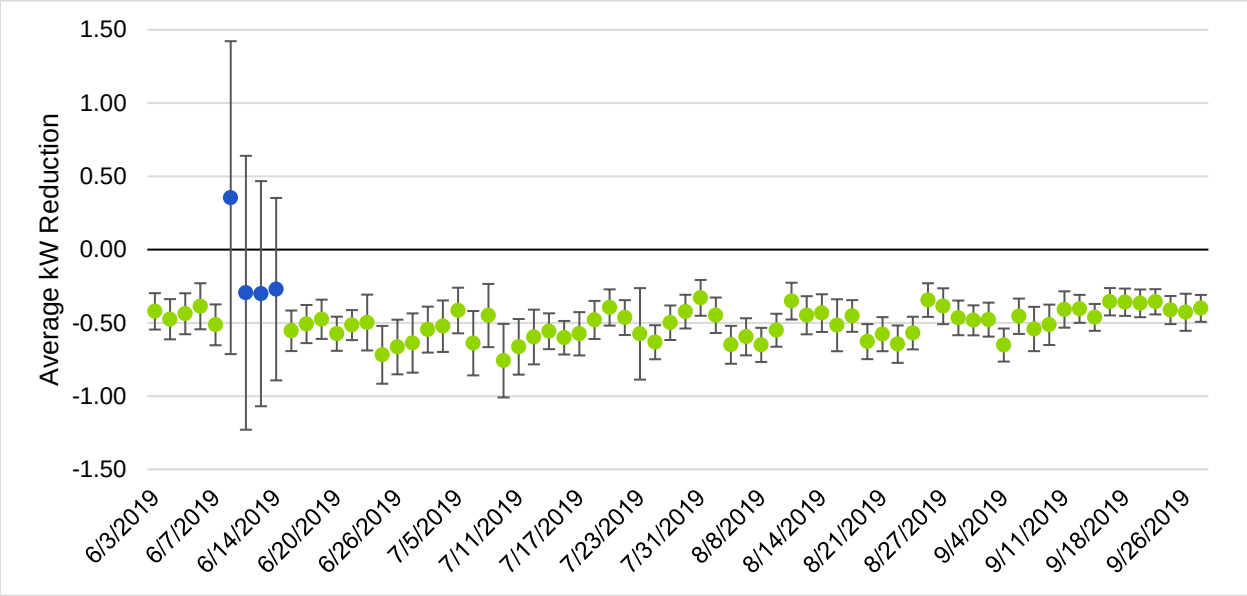
Figure 13. Total kW Impact: Guidehouse and Enbala Comparison (Summer 2019)



Source: Guidehouse analysis, Enbala Performance Summary from 10/24/2019

Figure 14 presents the average **snapback per controlled device**. Snapback is the increase in overall electricity demand that occurs in the one hour after a device has been controlled for a DR event; for this program, snapback occurs when the water heaters start heating again after the event. The average snapback per controlled device was -0.48 kW, meaning that on average the participating households were using 0.48 kW *more* than the control group households during the period after the events. Per-device snapback ranged from -0.76 kW to 0.35 kW.

Figure 14. Average Snapback per Controlled Device by Event (Summer 2019)



Note: grey dots signify kW snapback estimates that are statistically different than zero. The narrower the error bands around each dot, the higher the confidence in accuracy of the point estimate.

Source: Guidehouse analysis

4.1.2 Device Statuses: Connectivity and Overrides

Figure 15 shows the breakdown of device dispatch status by event across the summer season. Device participation is broken down into one of six categories:

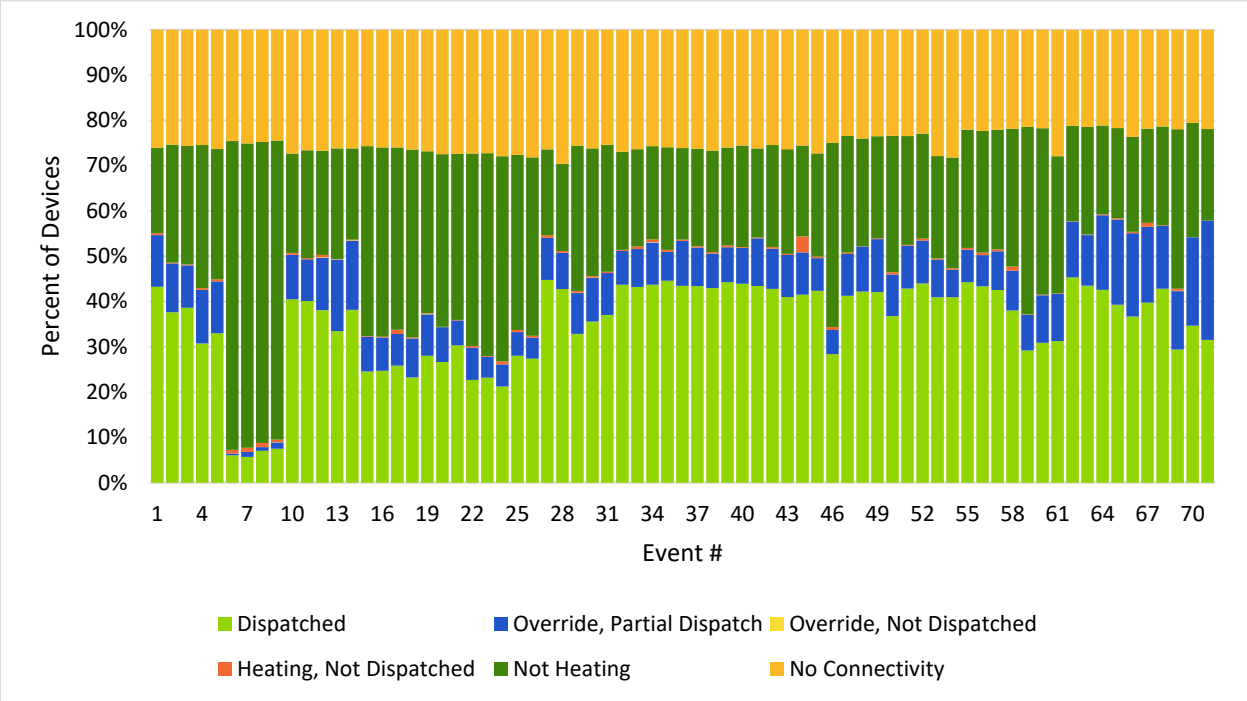
- **No Connectivity:** a device that was not actively connected to Wi-Fi and could not receive a dispatch signal
- **Not Heating:** a device that was not actively heating and thus had no load to curtail
- **Heating, Not Dispatched**[13]**:** a device that was actively heating, but was not dispatched
- **Override, Not Dispatched:** a device that entered override mode[14] during the event and 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. Devices can enter and exit override mode during an event if override conditions are no longer met.
- **Dispatched:** a device that was actively heating at the time of dispatch and was controlled for the entire event

[13] These are a small number of cases, but this status should not occur.

[14] Aquanta devices enter override mode when its tank drains more than 30 percent and cannot be curtailed until the tank refills.

During Summer 2019, connectivity rates were higher than the previous winter, at 70% or higher for all events throughout the season, averaging 75%. As noted previously, the percent of devices controlled (dispatched) varied from event to event, averaging 46% (an increase over the Winter 2018-2019 season's 36%).

Figure 15. Device Dispatch Status by Event (Summer 2019)



Source: Guidehouse analysis of CLEAResult data

4.2 Winter 2019-20 Impact Results

This section discusses the findings from Guidehouse's impact evaluation of the Winter 2019-20 DR season, which lasted from December 2, 2019 through February 27, 2020. Section 4.2.1 presents the results of the regression analysis on an event-by-event basis and Section 4.2.2 presents the analysis of device connectivity and override data.

4.2.1 Impact Results by Event Date

Table 7 summarizes the key metrics for the Winter 2019-20 DR events, including the season average and the minimum and maximum values by event.

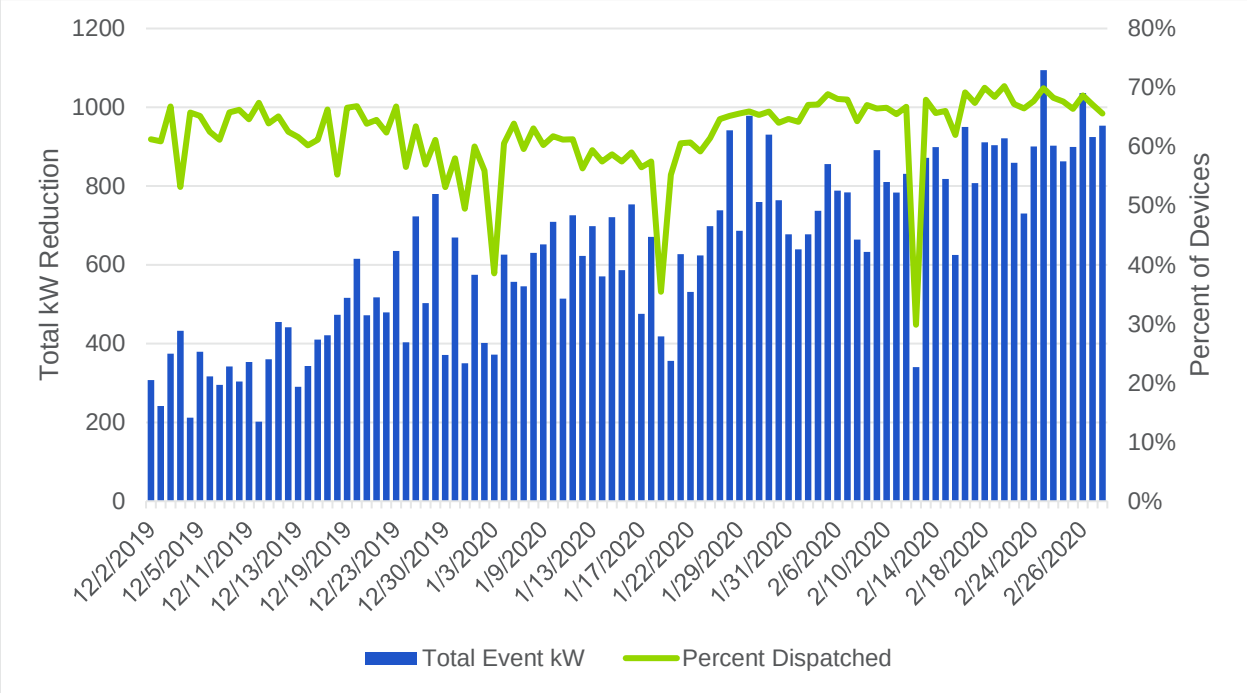
Table 7. Winter 2019-20 Impacts per Event

Metric	Season Average (per Event)	Minimum	Maximum
Total Demand Reduction (kW)	627	202	1,094
Percent of Devices Controlled	62%	30%	70%
Impact per Controlled Device (kW)	0.30	0.10	0.46
Snapback per Controlled Device (kW)	-0.73	-1.00	-0.32

Source: Guidehouse analysis

The program called a total of 98 events during the Winter 2019-20 season. The **total demand reduction per event** averaged 627 kW. As shown in the grey bars in Figure 16, impacts varied from event to event, with a range of 202 kW to 1,094 kW. Some of the variation in impacts is due to the variation in percent of devices that were successfully controlled (shown as the light green line in Figure 1), as well as an increase in the overall number of devices participating as installations were completed through the season. The **percent of devices controlled** ranged from 30% to 70%, and the total number of enrolled devices increased 33% from 5,562 at the beginning of the season to 7,388 at the end of the season.[15]

Figure 16. Total kW Reduction and Percent Controlled per Event (Winter 2019-20)

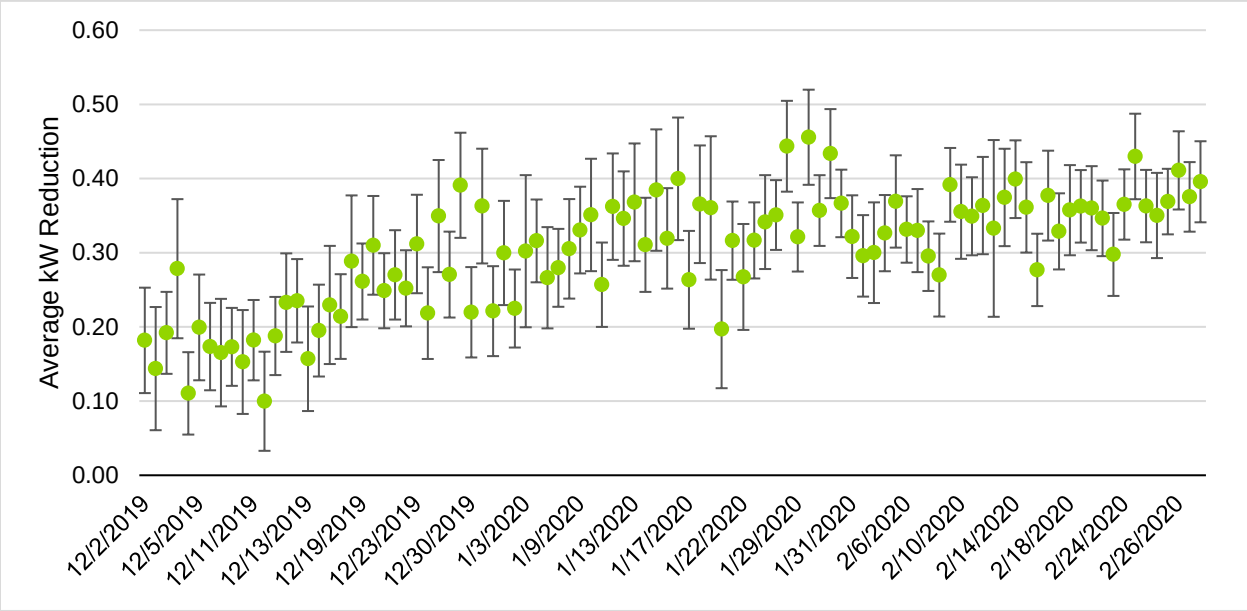


Source: Guidehouse analysis

[15] Note that due to the A/B design of the program, roughly half of all participating devices were eligible for each event. On weeks that the A group received events, the B group served as the control group, and vice versa.

The **average impact per controlled device** was 0.30 kW per controlled device (shown in Figure 17), with a range of 0.10 to 0.46 kW. The impact estimates were statistically significant (i.e., statistically different from zero) for all events. These averages are calculated by dividing the total event impact (shown in the previous graphic) by the number of controlled devices[16] for that event, which is a function of water heater connectivity, heating status, and tank level.[17] The range around each dot in the figure represents the margin of error in the estimate.

Figure 17. Average kW Reduction per Controlled Device by Event (Winter 2019-20)



Source: Guidehouse analysis

Average event impacts increased over the course of the season, stabilizing in mid-January. To illustrate the improvement in impact results, the average impacts before and after January 15th are presented in Table 8. Although the average percent of devices controlled only increased from 61% to 64%, the average impact per controlled device increased more markedly, from 0.25 kW to 0.35 kW per device. This increase may be partially attributable to the change in water level detection and override thresholds for Aquanta devices (implemented in mid-December through mid-January), in which the firmware was updated to let the tanks drain to 30% before moving into override mode. This enabled devices to participate in events for longer periods of time and achieve higher impacts.[18]

[16] Guidehouse calculated controlled device counts using Aquanta's and Apricity's control records retrieved by CLEAResult.

[17] Water heaters are controllable only when heating and not in override mode due to low water levels.

[18] In previous DR seasons, Aquanta devices entered override mode when the tanks were 50% drained.

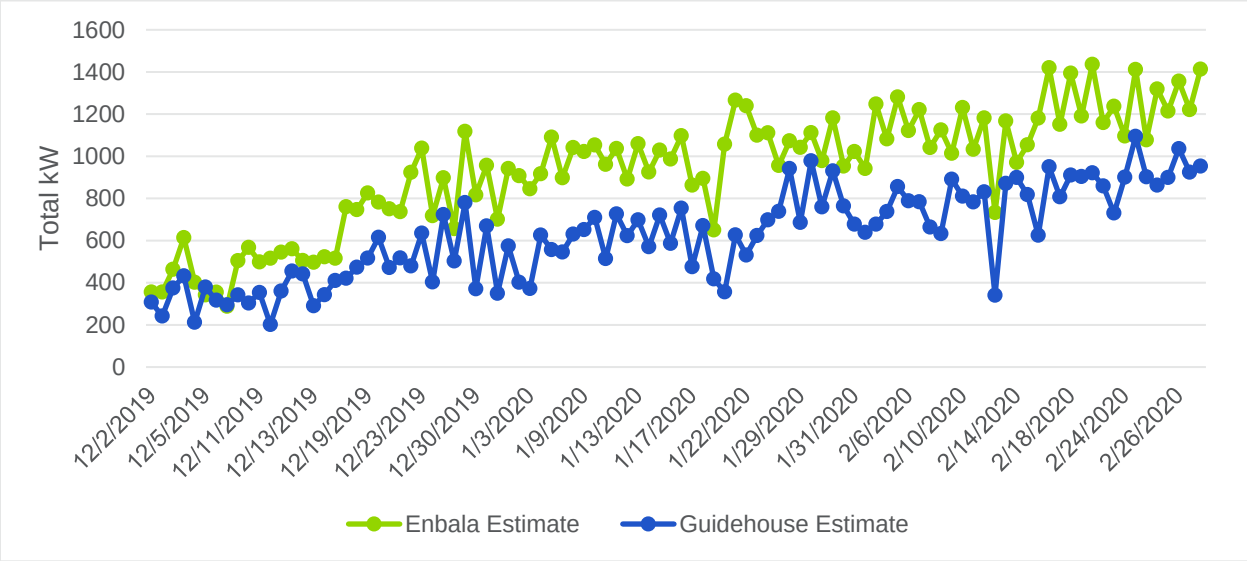
Table 8. Winter 2019-20 Effects of Midseason Changes on Impact Results

Metric	Season Average (per Event)	First Half* Season Average	Second Half* Season Average
Total Demand Reduction (kW)	627	477	771
Percent of Devices Controlled	62%	61%	64%
Impact per Controlled Device (kW)	0.30	0.25	0.35
Snapback per Controlled Device (kW)	-0.73	-0.62	-0.84

*Mid-season cutoff of January 15th.
Source: Guidehouse analysis

To support the program's interest in real-time reporting tools, Figure 18 presents a **comparison of evaluated impacts to impact estimates from Enbala**, the demand response management system vendor. On average, the Enbala estimated impacts were 54% higher than the evaluated impacts. Note that Guidehouse and Enbala use different methodologies: Guidehouse's analysis is conducted using regression analysis on hourly household electricity consumption and uses a control group for the baseline (i.e., the amount of energy that controlled devices would have been using if not controlled). Enbala's analysis uses 15-minute water heater telemetry data to estimate a customer-specific baseline from each household's past water heater usage. For all but one event, Guidehouse's estimates were lower than Enbala's estimates. Guidehouse recommends a dedicated effort to understand the similarities and differences between Enbala's baseline and the evaluation's and to potentially develop a method for scaling telemetry-based results in real-time event reporting (a task not currently within the evaluation scope).

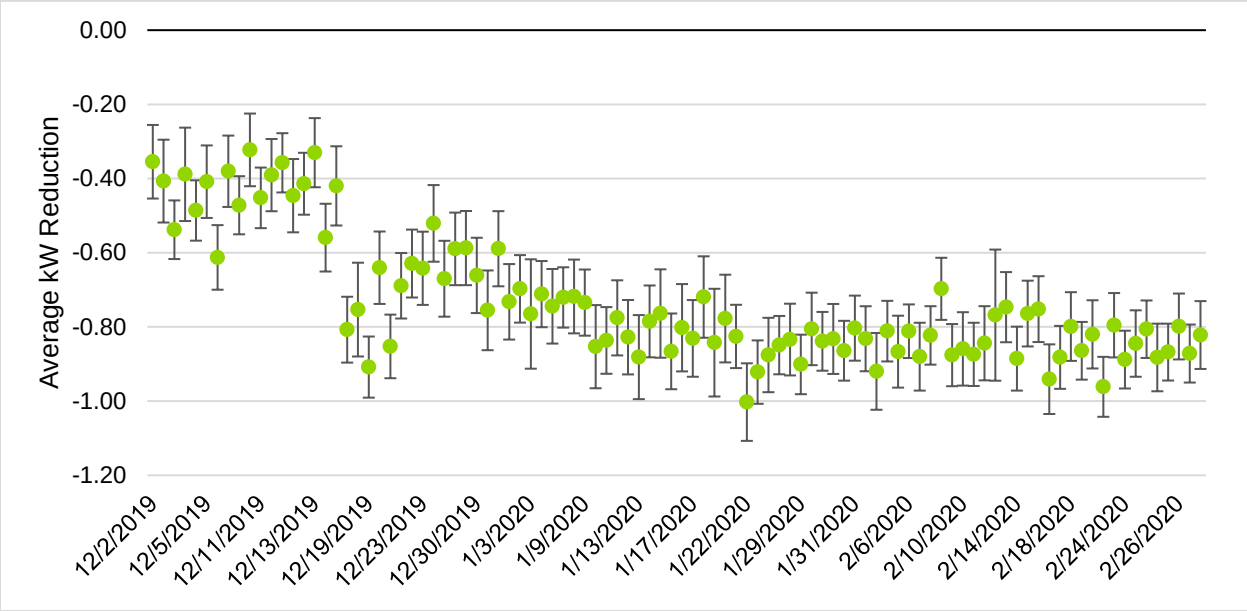
Figure 18. Total kW Impact: Guidehouse and Enbala Comparison (Winter 2019-20)



Source: Guidehouse analysis

Figure 19 presents the average **snapback per controlled device**. Snapback is the increase in overall electricity demand that occurs in the one hour after a device has been controlled for a DR event; for this program, snapback occurs when the water heaters start heating again after the event. The average snapback per controlled device was -0.73 kW, meaning that on average the participating households were using 0.73 kW *more* than the control group households during the period after the events. Per-device snapback ranged from -0.32 kW to -1.00 kW.

Figure 19. Average Snapback per Controlled Device by Event (Winter 2019-20)

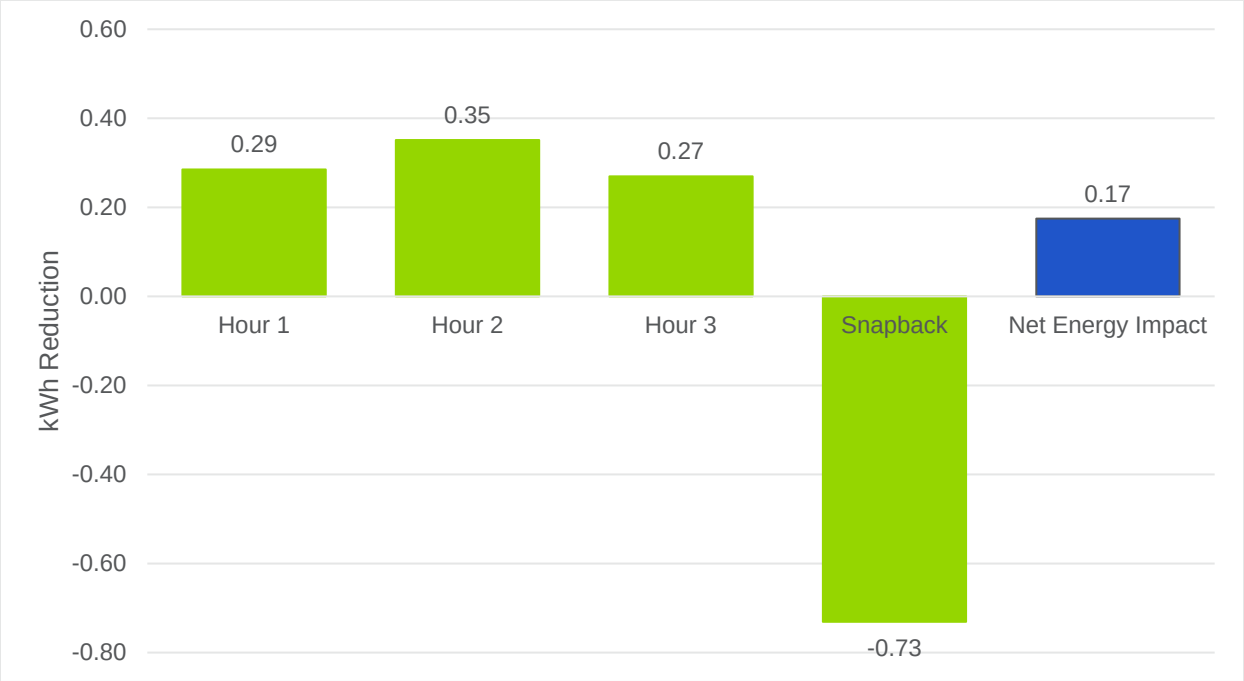


Source: Guidehouse analysis

During Winter 2019-20, events resulted in a net energy impact, as illustrated in Figure 20. The total energy reduction across each 3-hour event averaged 0.91 kWh, while the average energy increase during the snapback window, when water heaters are re-heating after curtailment has

ended, was 0.73 kWh. The net energy impact is the sum of each hour of the event plus the snapback period. Across the entire 4-hour period, the net energy impact averaged 0.17 kWh.

Figure 20. Average Hourly and Total Event Energy Impact



Source: Guidehouse analysis

4.2.2 Device Statuses: Connectivity and Overrides

Figure 21 shows the breakdown of device dispatch status by event across the summer season. Device participation is broken down into one of six categories:

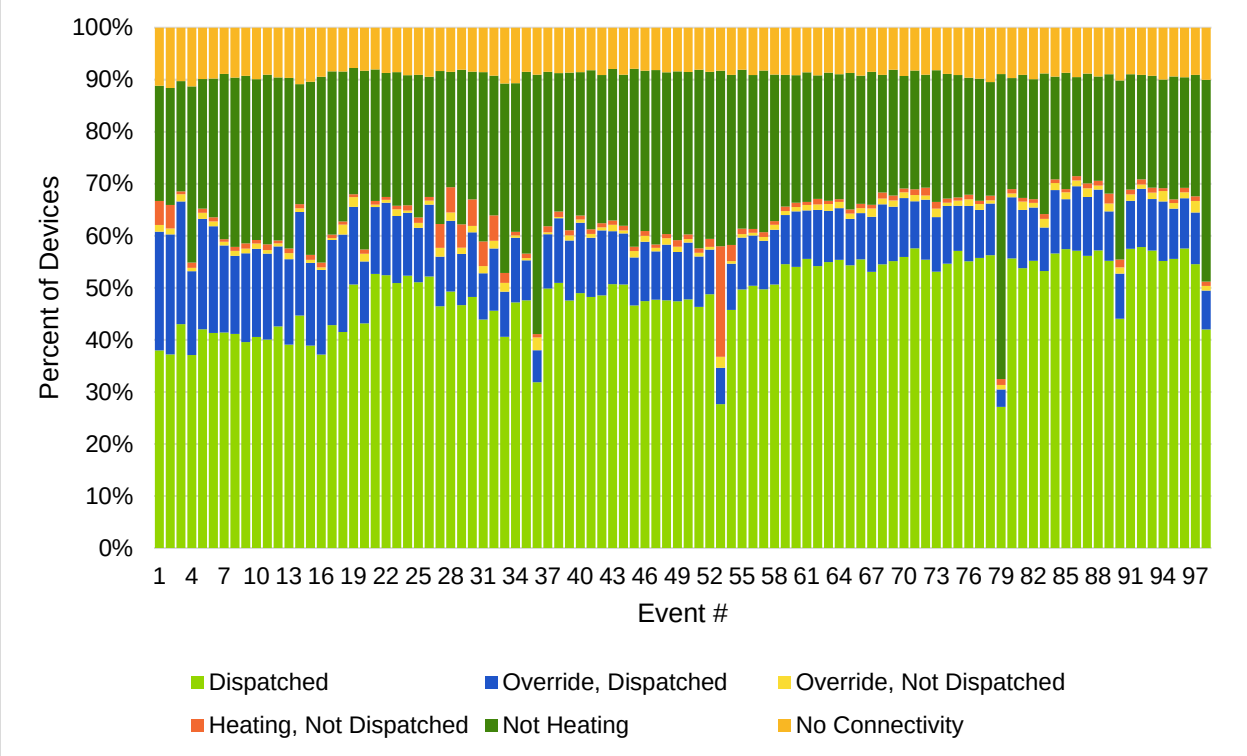
- **No Connectivity:** a device that was not actively connected to Wi-Fi and could not receive a dispatch signal
- **Not Heating:** a device that was not actively heating and thus had no load to curtail
- **Heating, Not Dispatched**[19]**:** a device that was actively heating, but was not dispatched
- **Override, Not Dispatched:** a device in override mode[20] that was not dispatched for any part of the event
- **Override, Dispatched:** 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

[19] These are a small number of cases, but this status should not occur.

[20] Aquanta devices enters override mode when its tank drains more than 30 percent and cannot be curtailed until the tank refills.

During Winter 2019-20, connectivity rates were higher than the previous winter. Winter 2019-20 connectivity rates were at 88% or higher for all events throughout the season, averaging 91%. As noted previously, the percent of devices controlled (dispatched) varied from event to event, averaging 62% (an increase over the Winter 2018-2019 season's 36%).

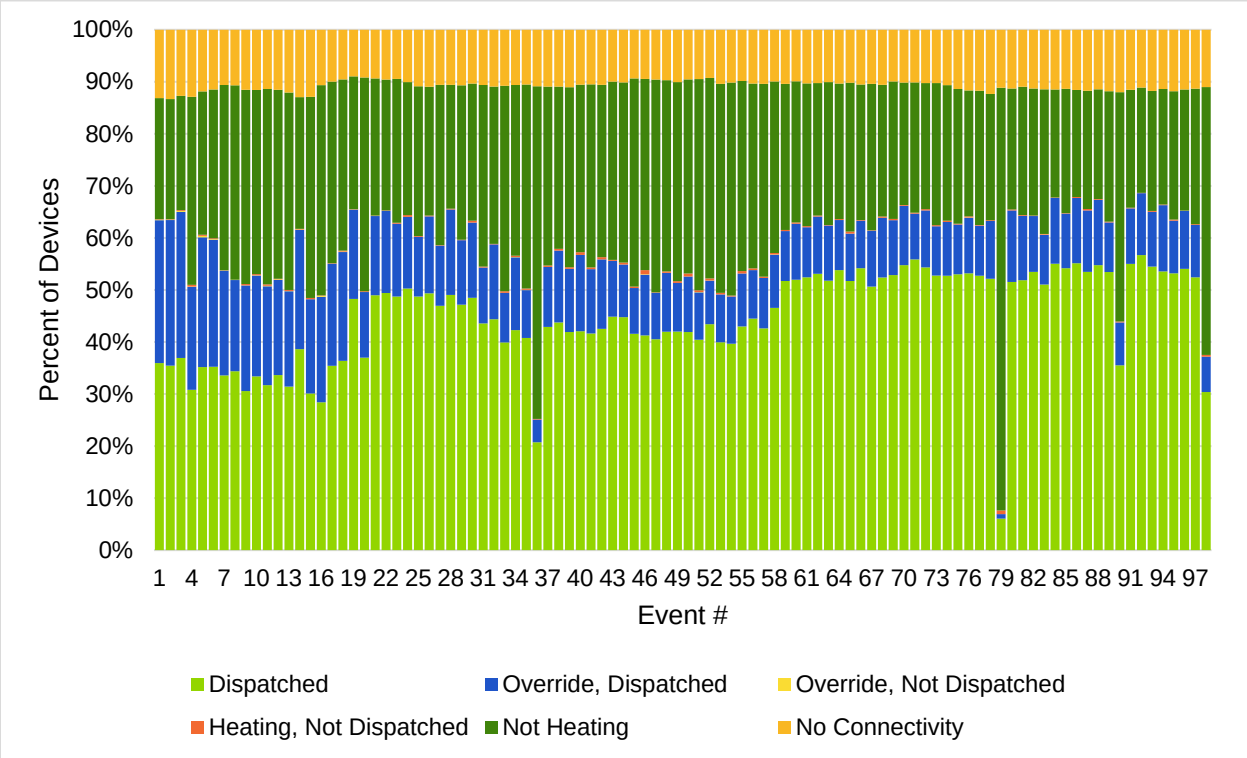
Figure 21. Device Dispatch Status by Event (Winter 2019-20)



Source: Guidehouse analysis

Figure 22 shows the device dispatch status by event for Aquanta devices. In mid-December, the pilot directed Aquanta to change the way they detected the tank water level, which had been overly conservative when putting devices into override mode. A noticeable jump in dispatched devices can be observed around event 21 (the December 18th AM event). Subsequently, the pilot reduced the threshold at which devices enter override from 50% to 30% of the tank capacity in early January. The controllability rate for Aquanta devices averaged 58%. Connectivity was vastly improved for Aquanta devices by the Winter 2019-20 season, with the percent of connected devices averaging 89%.

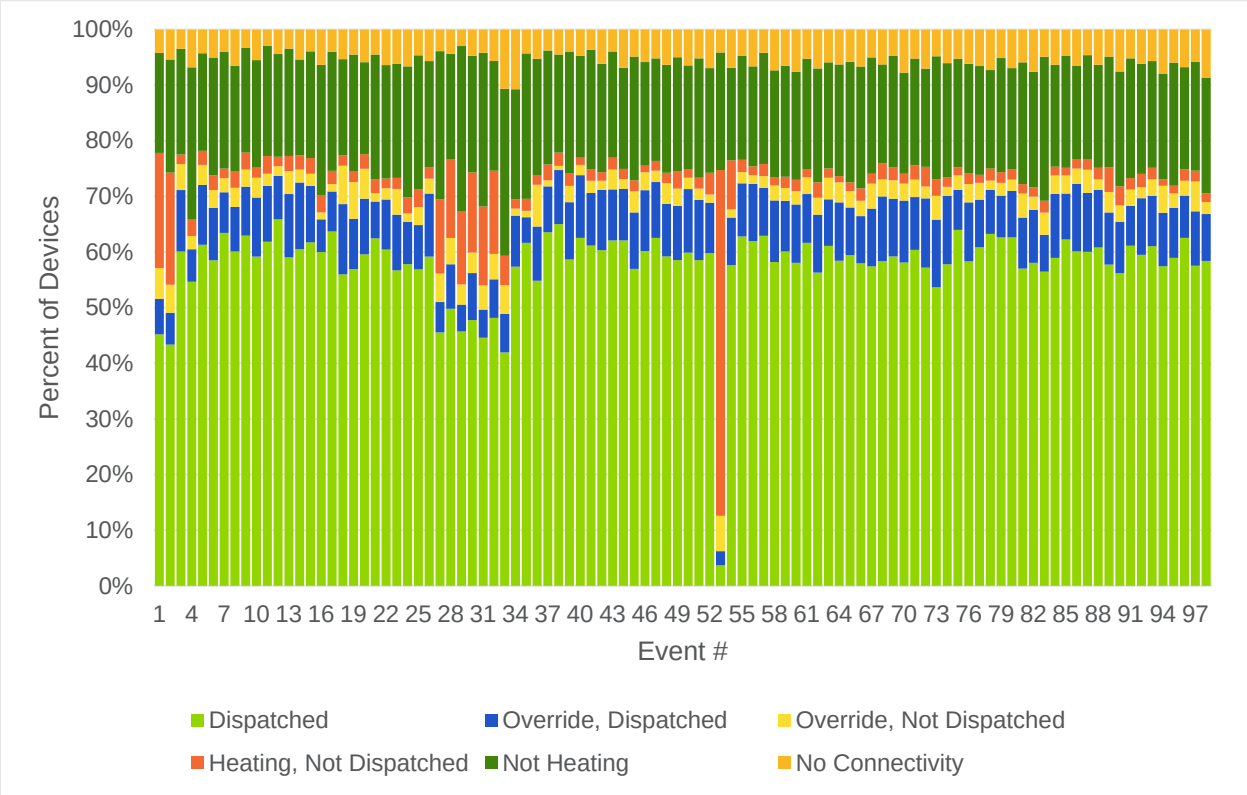
Figure 22. Aquanta Device Dispatch Status by Event (Winter 2019-20)



Source: Guidehouse analysis

Figure 23 shows the device dispatch status by event for Apricity devices. Apricity devices, being cell-enabled, had high levels of connectivity throughout the season, averaging 94%. The controllability rate for Apricity devices was higher than for Aquanta, averaging 67% throughout the season. Apricity devices had a noticeably lower rate of devices not heating during events, averaging 20% compared to Aquanta's average of 31%. This could be partially explained by connectivity but could also be due to differences in how the devices detect heating. Additionally, there could be differences in the types of multi-family buildings, occupants, or water heaters across the two device types that could result in different water heating patterns.

Figure 23. Apricity Device Dispatch Status by Event (Winter 2019-20)



Source: Guidehouse analysis

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 and documented here to verify ongoing pilot evolution.

Finding #1: Many of the challenges identified in the previous evaluation have been resolved. PGE, CLEAResult, and Enbala have developed a strong working relationship and completed the integration of a second switch manufacturer's technology much more quickly than the first integration. Recruitment strategies and installation processes have been streamlined and the program is meeting its targets for the number of installed units. Responsibilities and procedures for dealing with implementation issues such as cold water calls and connectivity problems are more clearly defined. The implementation team has developed additional reporting capabilities to enable easier monitoring of event results. Connectivity rates have improved and average device curtailment savings increased as a result of deploying updated override algorithms across the installed device fleet.

> **Recommendation #1:** Maintain the collaborative and collegial approach to implementation as the pilot brings on additional properties and potentially additional vendors and technologies.

Finding #2: Pilot staff are eager to explore the pilot's potential role in PGE's future demand response strategies. After resolving many of the pilot's early technological and logistical challenges, pilot staff are starting to use the pilot to explore what this technology is capable of and how it might scale with increased enrollment. Pilot staff are aware of the potential grid operation challenges which might be posed when PGE Power Operations dispatches this resource at scale under their own dispatching strategies. However, the short remaining timeline of the pilot and lack of insight into how PGE might want to use the water heater demand response resource leave pilot staff wondering what questions they should be seeking to answer at this stage.

> **Recommendation #2a:** Consider holding a working session including PGE Power Operations, evaluation, and pilot staff to discuss the pilot-to-program transition criteria and identify research questions that pilot staff can explore during the remaining months of the pilot. Use the remaining time to produce targeted insights that can inform the design of a full-scaled program that fits into the broader PGE demand response portfolio.

> **Recommendation #2b:** Consider adding a task for the Guidehouse evaluation team to collaborate with Enbala to better understand discrepancies between the baselines used in Enbala's reporting and Guidehouse's evaluation. This task is not currently within Guidehouse's contracted scope, but will allow pilot staff to have more accurate insight into the magnitude of event impacts and snapback in real time rather than waiting until the end of the DR season for the evaluated results.

Finding #3: Property managers and tenants 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 with the pilot overall was not as high as with the installation process, and satisfaction appears strongly correlated with whether or not tenants recall any communication about how the pilot works. Pilot staff have made several concerted efforts to assist property managers' communications with tenants since the evaluation team fielded its last survey in December 2019.

> **Recommendation #3:** Continue existing efforts to maintain high satisfaction with the installation process while being sensitive to property manager and tenant concerns about in-home installations during the COVID-19 pandemic. This may be a good time to refocus recruitment efforts on new construction properties due to their unoccupied status at the time of installation. Consider adding messaging about specific health and safety protocols in use to pre-installation communications with tenants.

Finding #4: The COVID-19 pandemic impacted installations at additional properties as well as the ability to evaluate the effects of program improvements. The pilot was unable to proceed with some scheduled installations in mid-March through June 2020 as a result of the stay-at-home orders, although the winter 2019-20 installations target was met, recruitment activities continued to build a large pipeline of future installations, and events at installed properties occurred as planned. At PGE's request, Guidehouse did not conduct planned interviews with participating property managers and surveys with participating tenants, to avoid bothering customers during this challenging period. As a result, Guidehouse was unable to assess the effectiveness of efforts made to improve property manager and tenant experiences, particularly related to program communications and awareness of the Chinook Book incentives.

> **Recommendation #4:** Resume property manager interviews and tenant surveys after the summer 2020 DR season to assess the effectiveness of the new pilot communications efforts. At this point, customers are likely willing and able to complete telephone interviews and online surveys, and this research is important for assessing customer satisfaction and ensuring that customers aren't experiencing negative impacts as a result of the pilot.

Finding #5: Demand reductions from events in Summer 2019 and Winter 2019-20 increased in total and on a per device basis relative to the prior Winter 2018-19 season. The Summer 2019 and Winter 2019-20 DR season events started and ended on the hour, making event impacts easier to detect in the AMI data. The program worked with Aquanta to update their firmware's water level threshold algorithm to extend event overrides longer relative to tank water hot water reserves, resulting in greater curtailment capacity per device by mid-Winter 2019-20. A second switch type, Apricity, that uses cell communication instead of Wi-Fi was added to the program for the Winter 2019-20 season. Enrollment, connectivity, and the percent of devices controlled all increased in the Summer 2019 and Winter 2019-20 seasons. These factors all contributed to improved impacts over the first Winter season.

> **Recommendation #5a:** Continue to call events that start and end on the hour to allow for robust impact estimation.

Recommendation #5b: Consider converting AMI meters at participating premises to collect data at 15-minute intervals.[21] This will allow for granular estimates of event impacts and flexibility in event scheduling.

Finding #6: Snapback poses a potential risk to grid operations at scale as snapback demand increases following events are more than double the average hourly demand reductions during events. When events conclude, most curtailed water heaters begin reheating simultaneously, causing large demand increases relative to the baseline. As the program scales in size, this ramp-up in demand may have implications for grid operations if not managed appropriately. This highlights the need to time events carefully and to consider strategies for mitigating or flattening snapback.

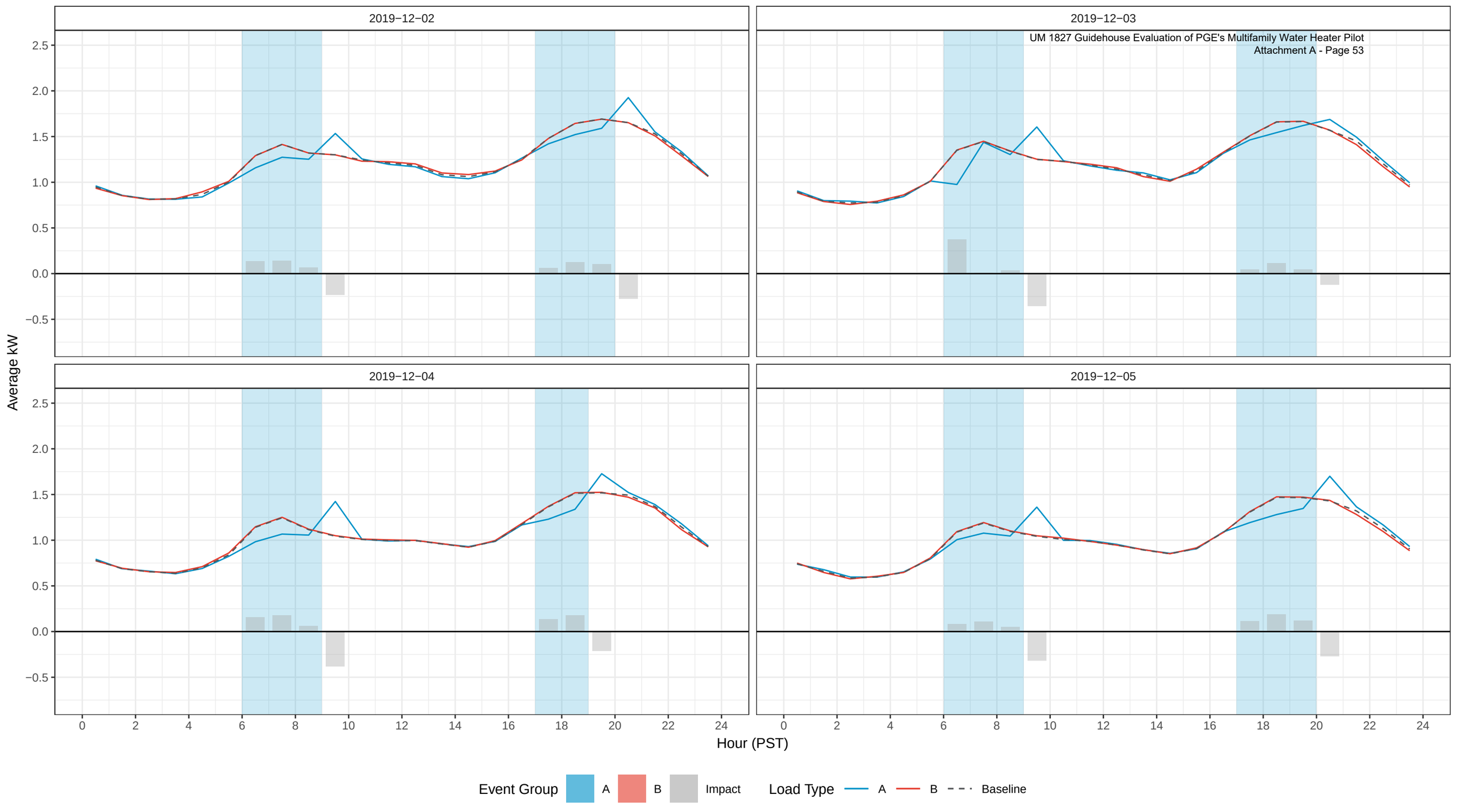
Recommendation #6: Consider different event lengths for subsets of devices such that the event end and subsequent snapback are spread across multiple hours for the program as a whole. If more meters are converted to collect 15-minute data, event ends could be staggered at the 15-minute level and allow for more granularity in event and snapback impacts. If AMI meters are not converted, event end times should be staggered by the hour, while still ending on the hour (to avoid partial event hours, which can make impacts more difficult to estimate).

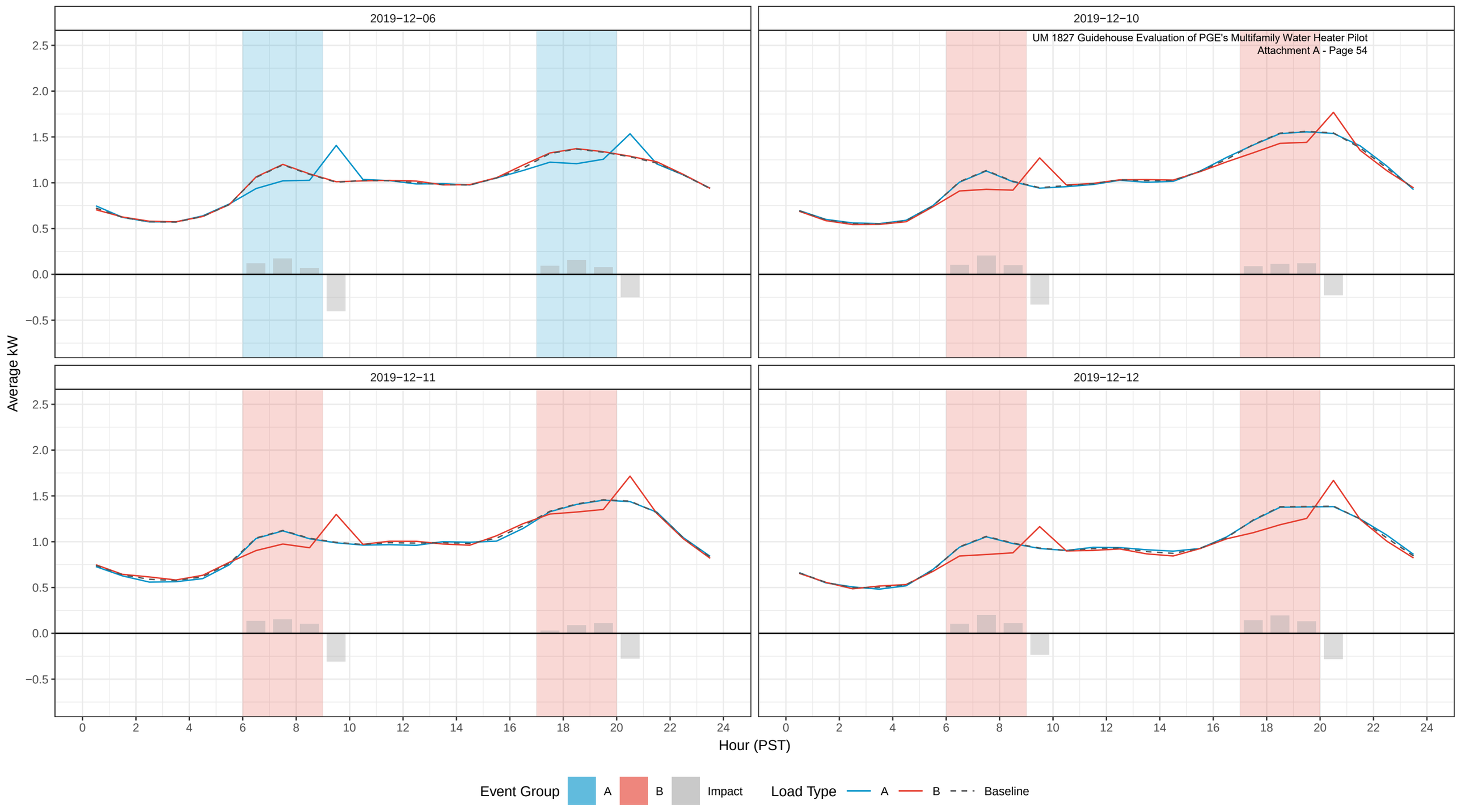
Finding #7: Connectivity and controllability rates improved significantly, with controllability rates increasing by 10 and 26 percentage points during Summer 2019 and Winter 2019-20, respectively, over the Winter 2018-19 season. By the Winter 2019-20 season, average connectivity (the percentage of devices able to receive the signal to curtail during events) reached 91%. This was a noticeable connectivity increase over the Summer 2019 season, which averaged 75%. Differences did exist between the two device types, with Aquanta averaging 89% connectivity and Apricity averaging 94% connectivity. The controllability rate (the average percentage of devices curtailed during an event) also differed between the two devices: Apricity averaged a 67% **controllability** rate and Aquanta averaged a 58% **controllability** rate. During the Summer 2019 season, Aquanta averaged a 46% **controllability** rate.

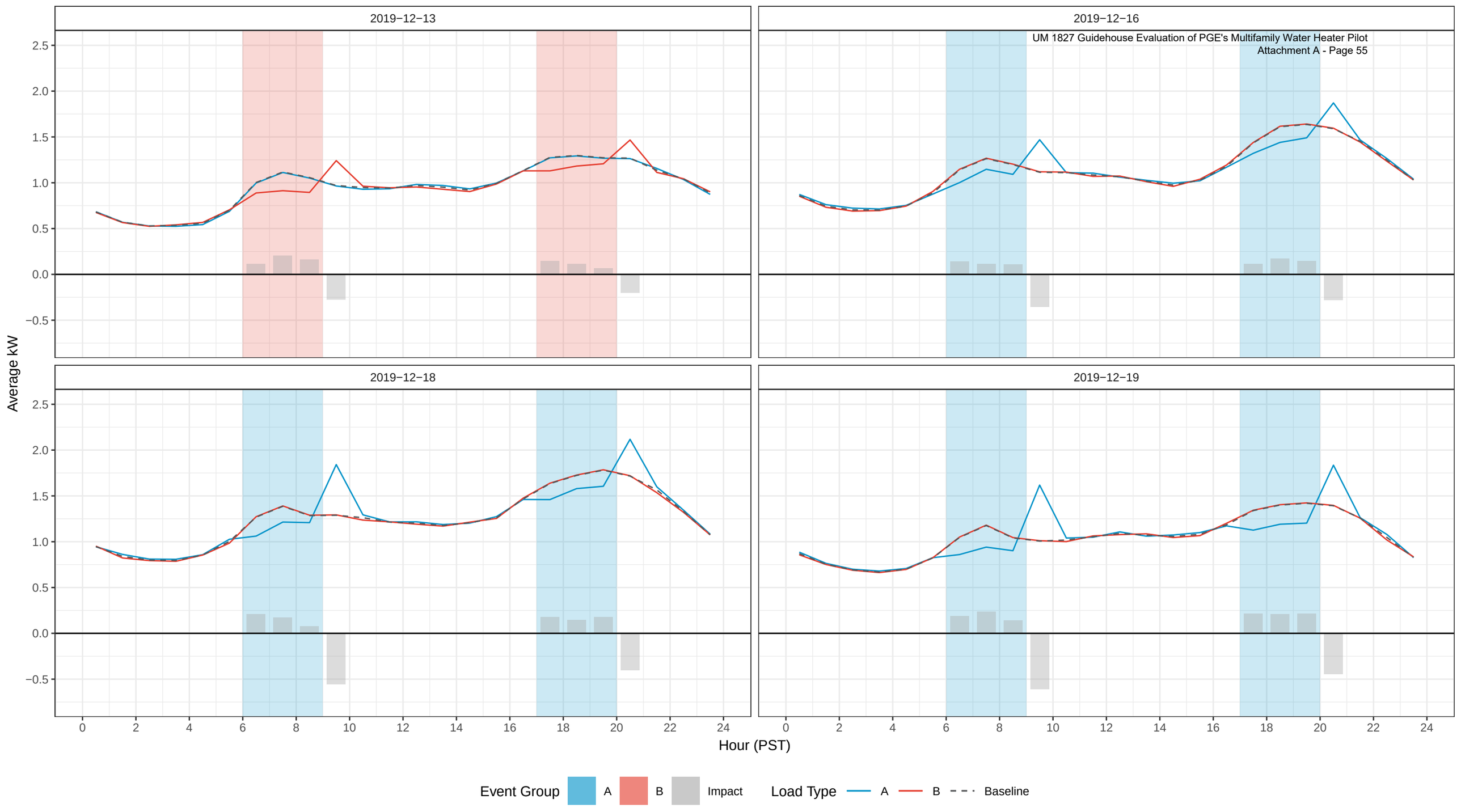
Recommendation #7: Consider further investigation into the connectivity rates by device type to identify if there are changes to the device algorithm or heating detection that could be improved, as connectivity alone does not account for the differences in connectivity dispatch rates.

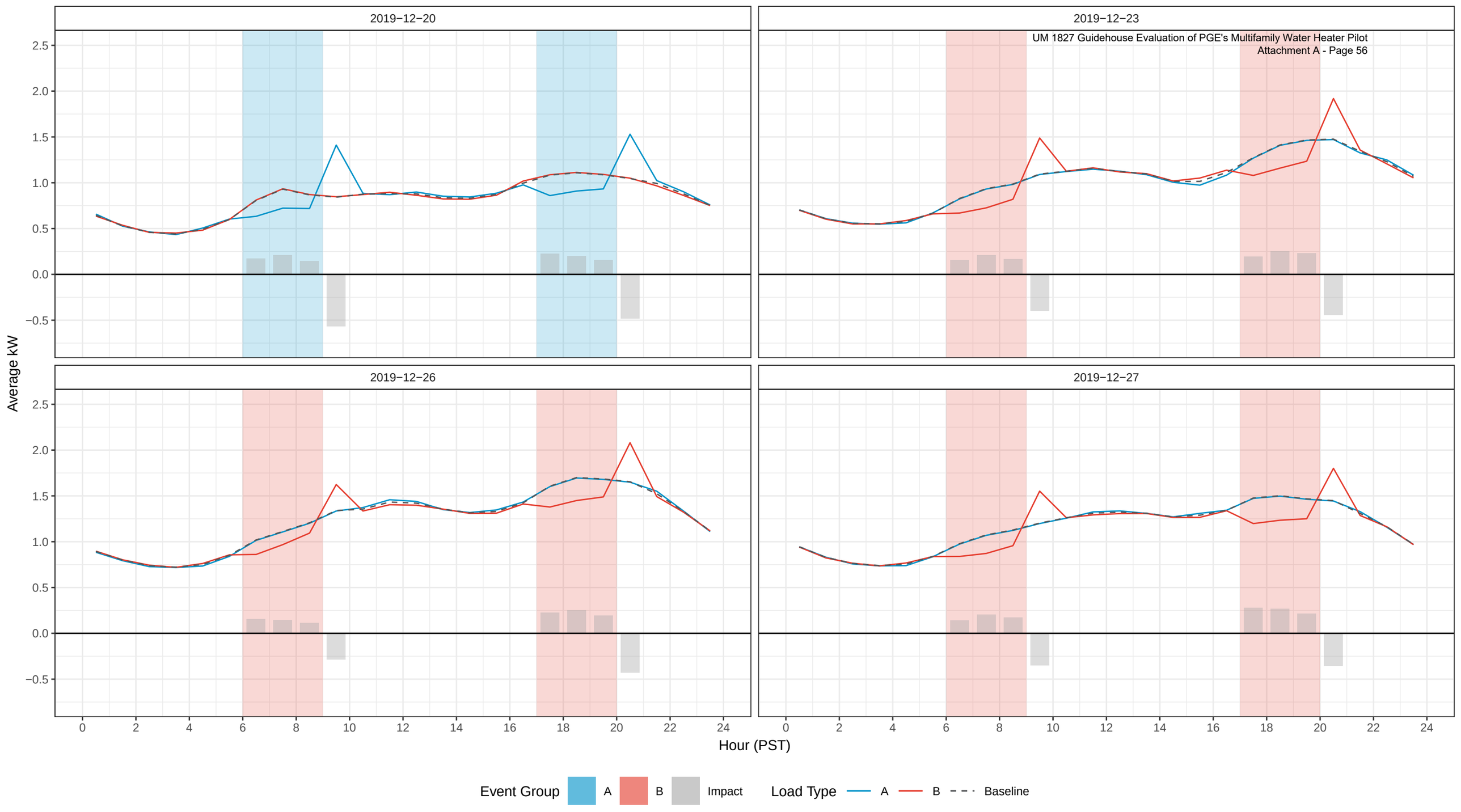
[21] The program explored moving to 15-minute interval data collection for the Winter 2018-2019 season, but PGE resource constraints made this conversion unfeasible.

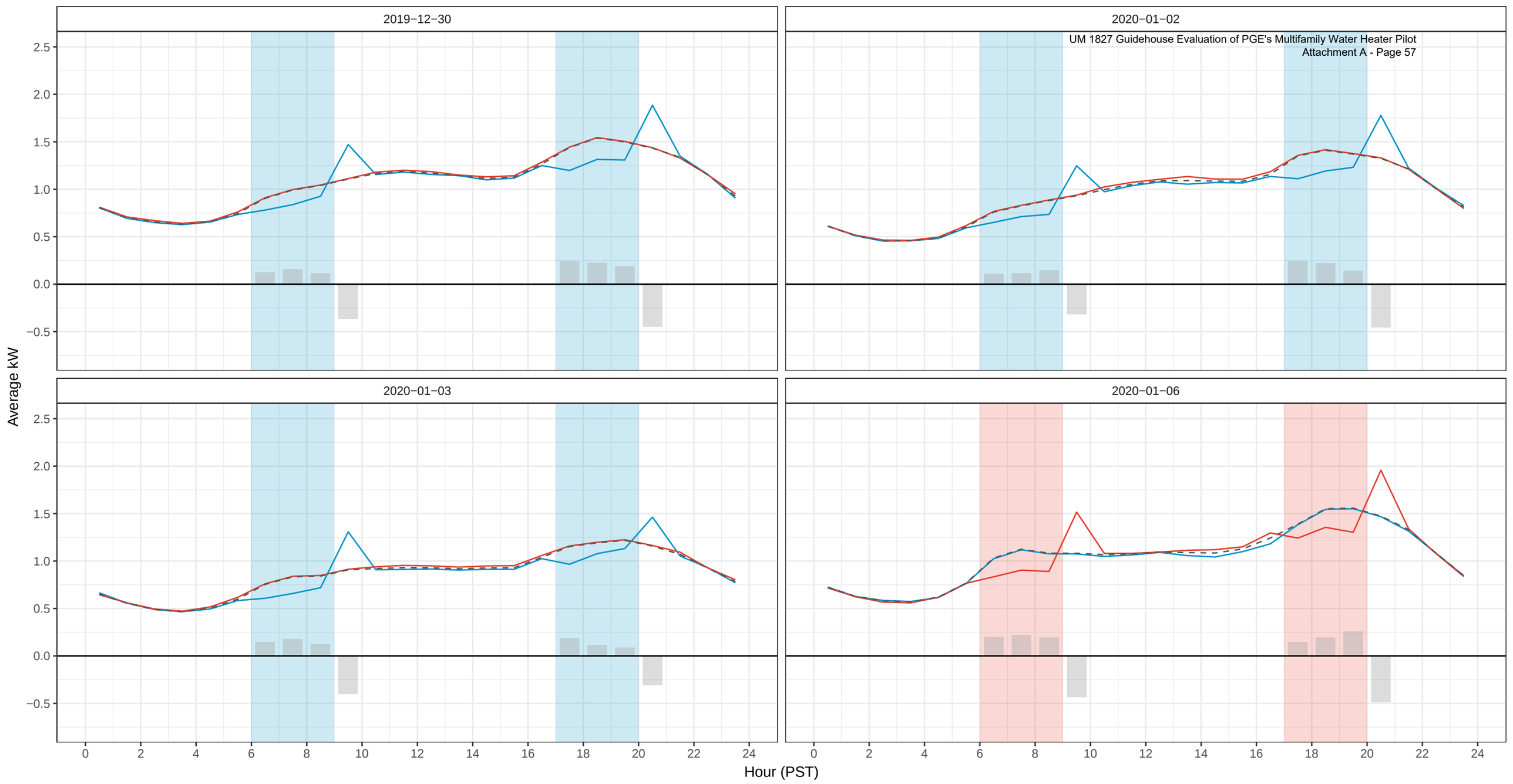
Appendix A. Winter 2019-20 Event Plots


2019−12−02
2019−12−03
2019−12−04
2019−12−05
Average kW
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2019−12−06
2019−12−10
2019−12−11
2019−12−12
Average kW
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2019−12−13
2019−12−16
2019−12−18
2019−12−19
Average kW
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2019−12−20
2019−12−23
2019−12−26
2019−12−27
Average kW
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2019−12−30
2020−01−02
2020−01−03
2020−01−06
Average kW
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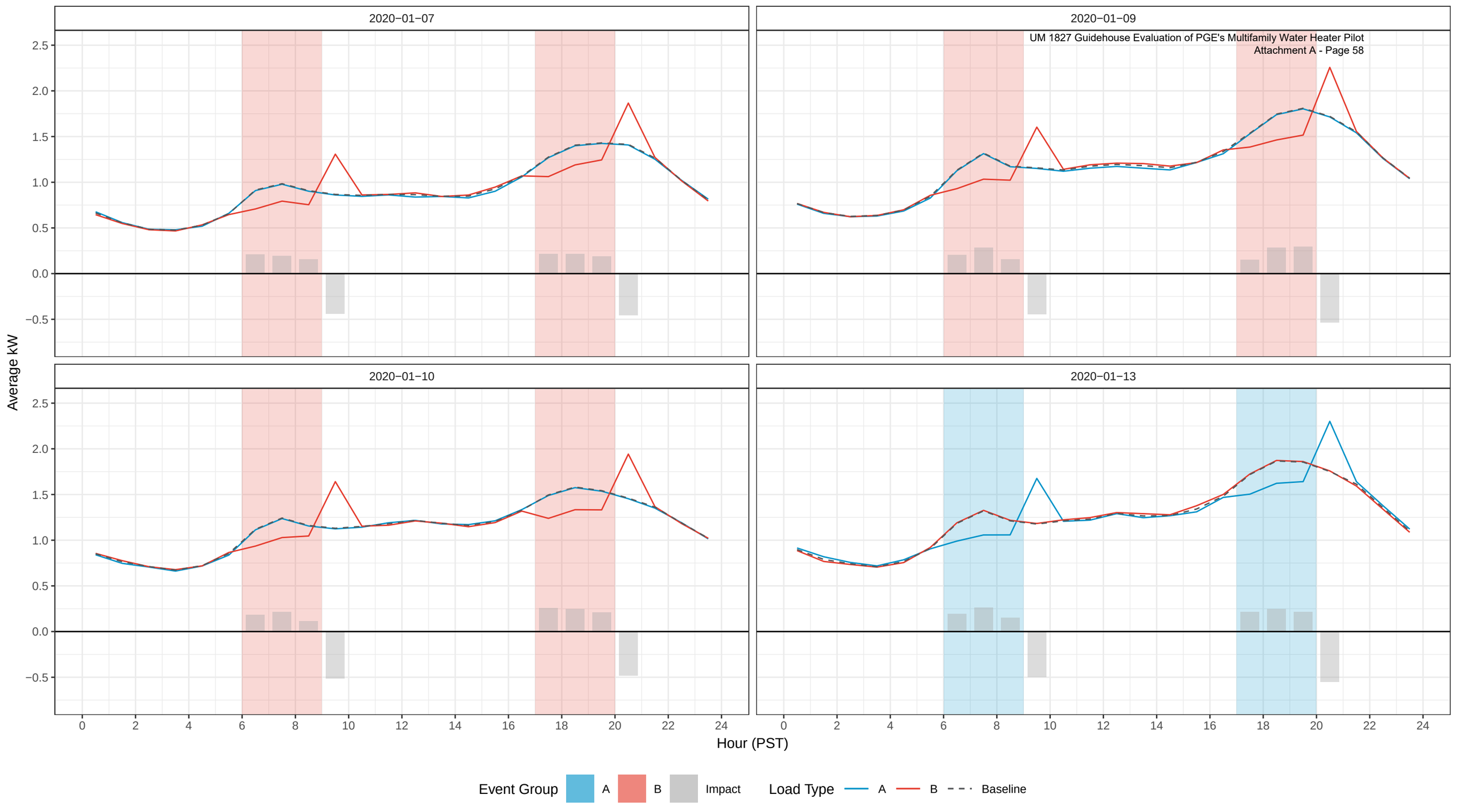
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2020−01−07
2020−01−09
2020−01−10
2020−01−13
Average kW
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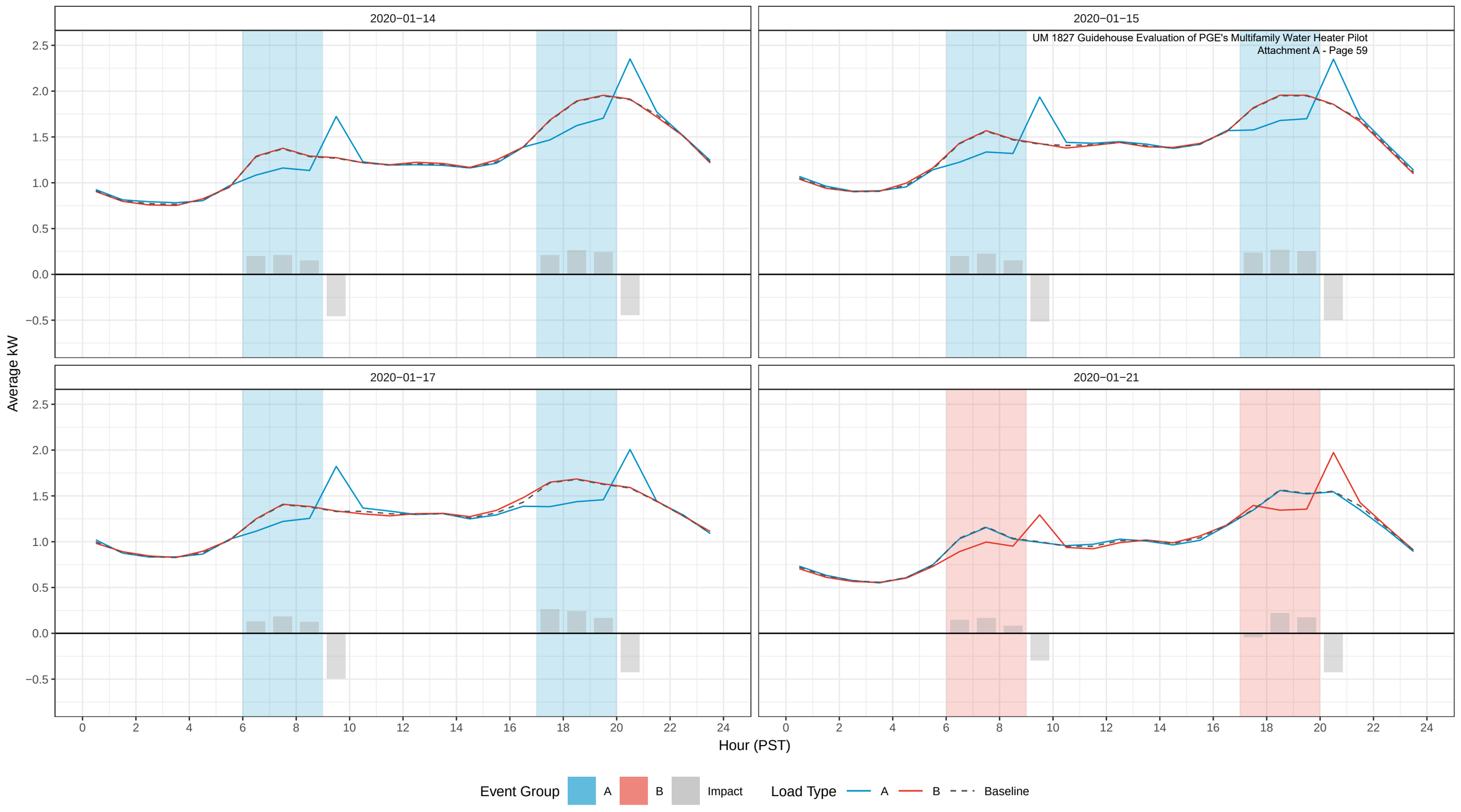
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2020−01−14
2020−01−15
2020−01−17
2020−01−21
Average kW
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2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
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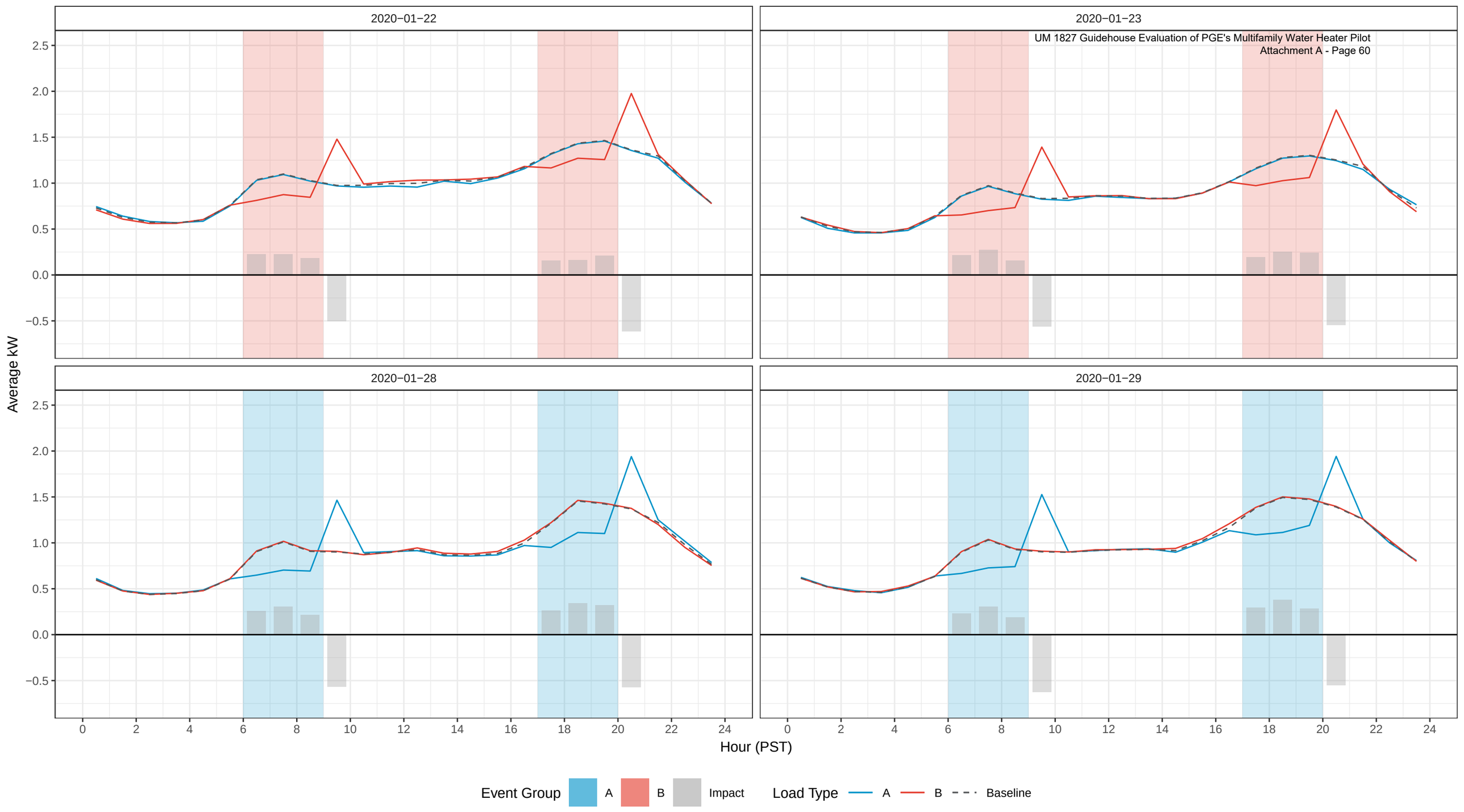
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2020−01−22
2020−01−23
2020−01−28
2020−01−29
Average kW
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2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
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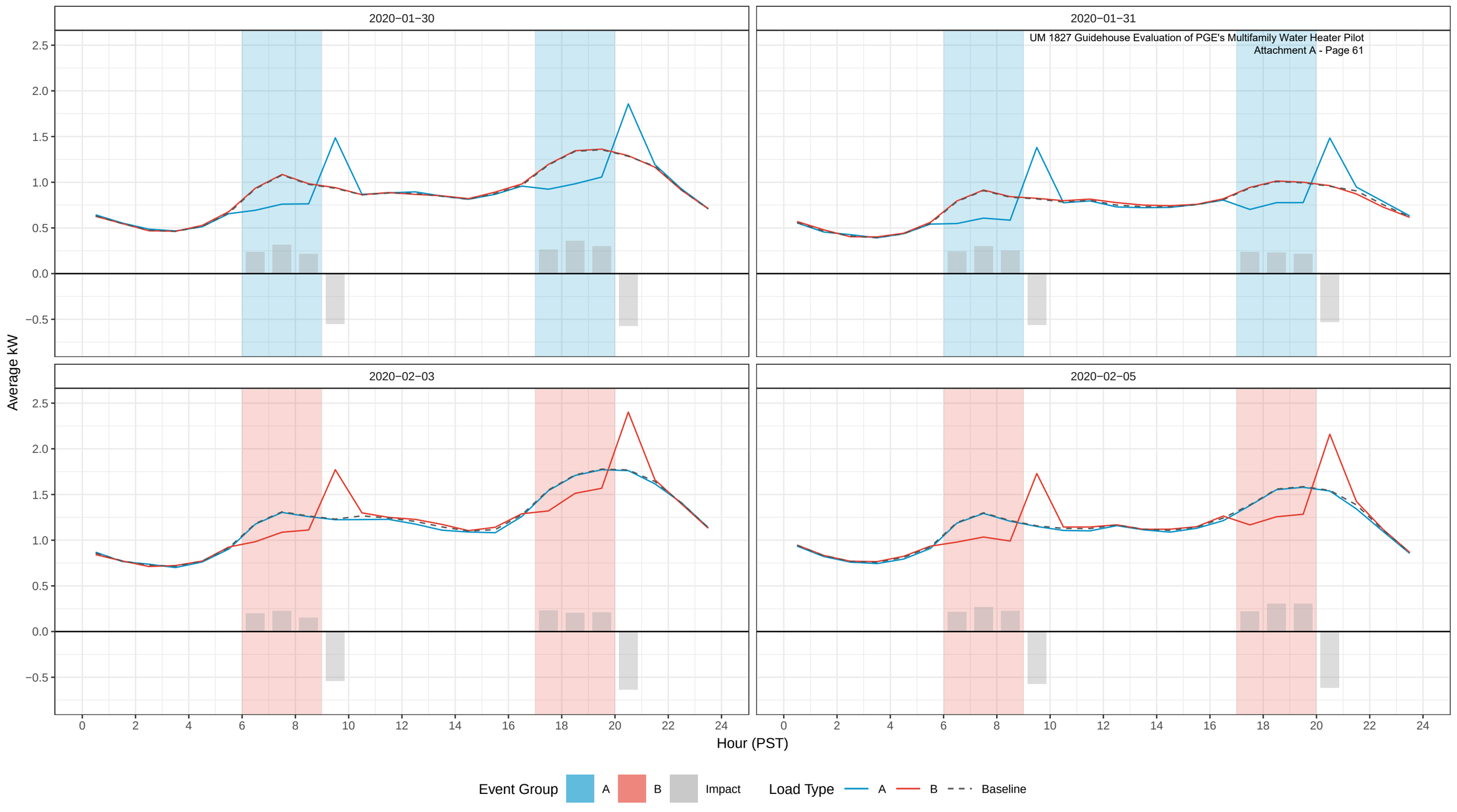
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2020−01−30
2020−01−31
2020−02−03
2020−02−05
Average kW
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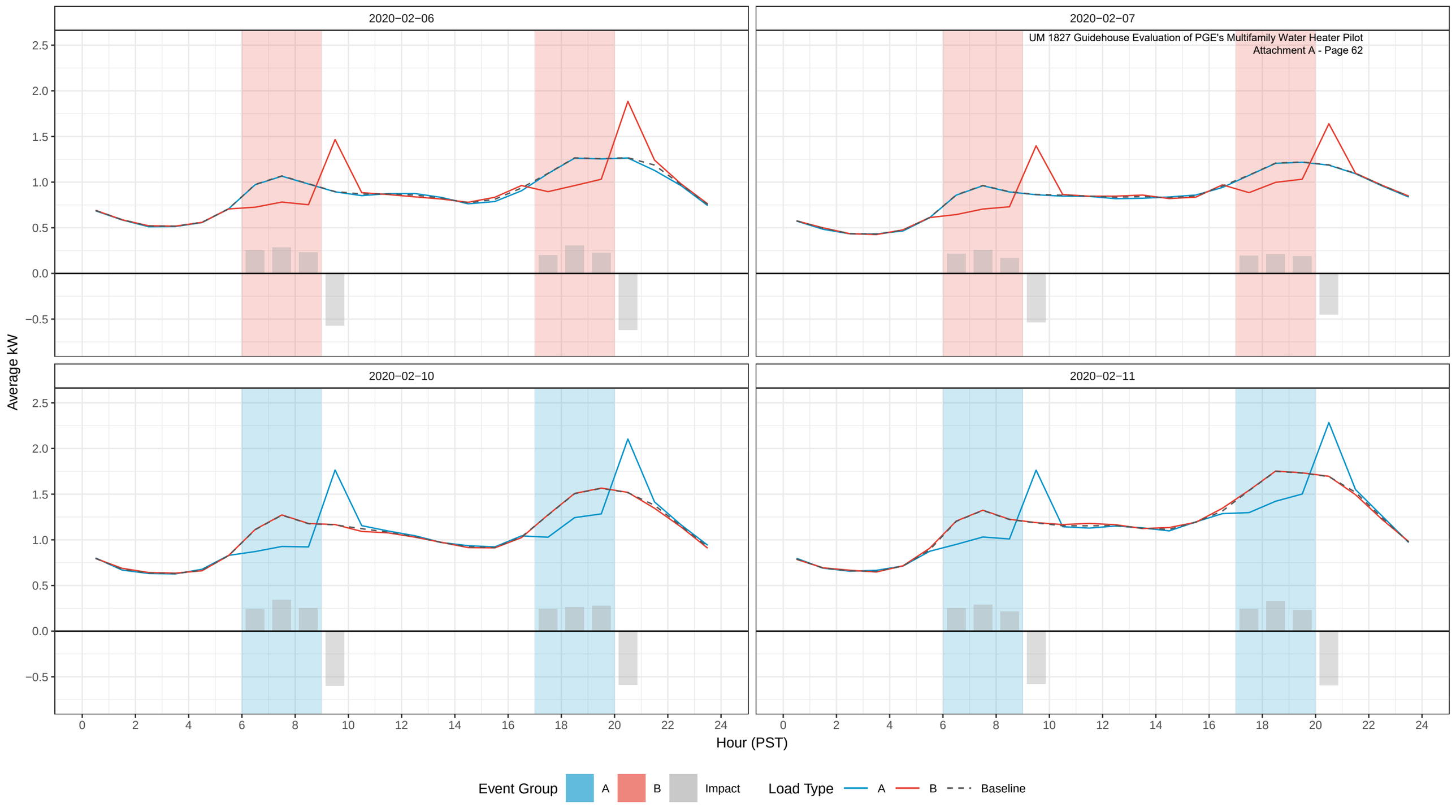
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2020−02−06
2020−02−07
2020−02−10
2020−02−11
Average kW
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2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
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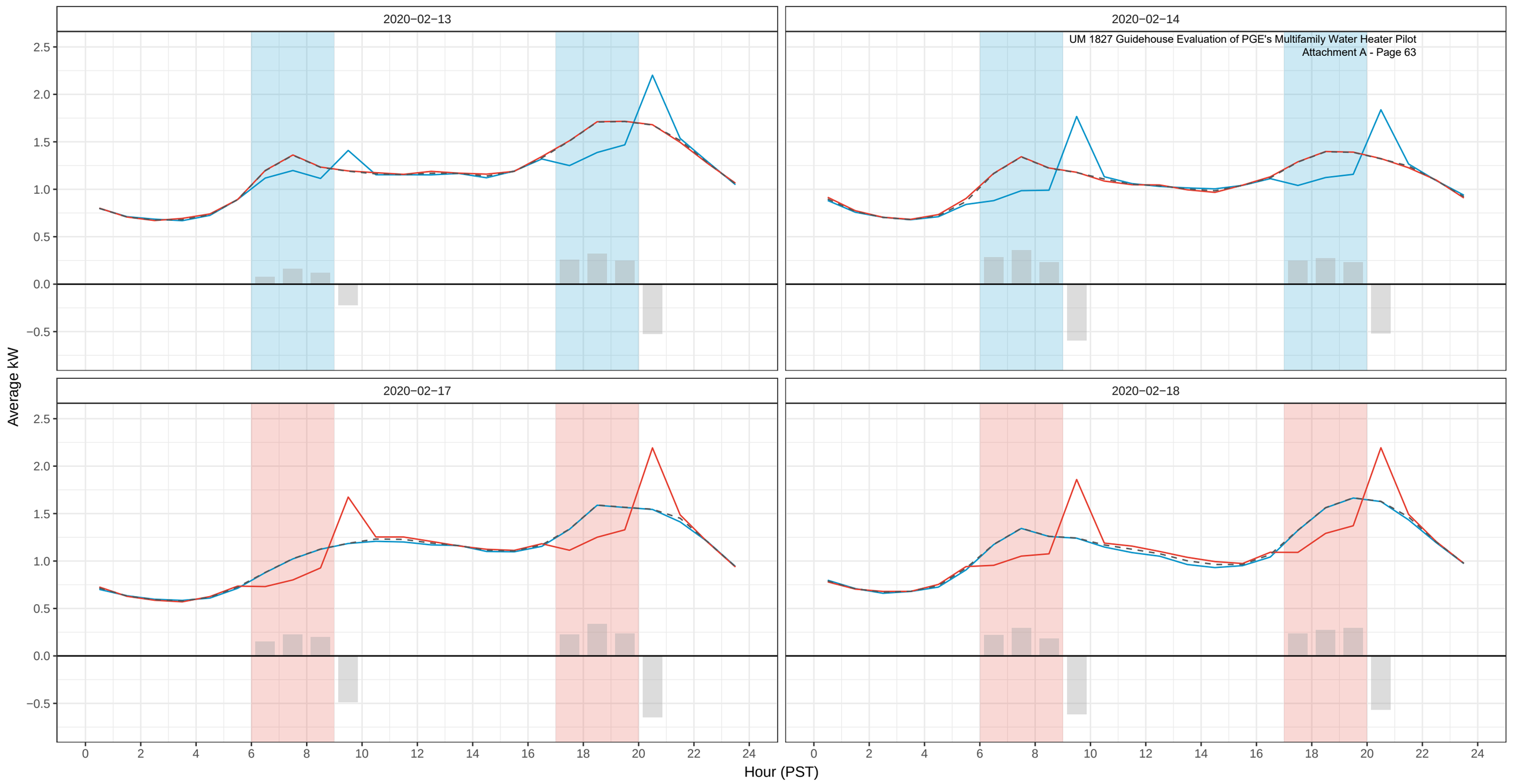
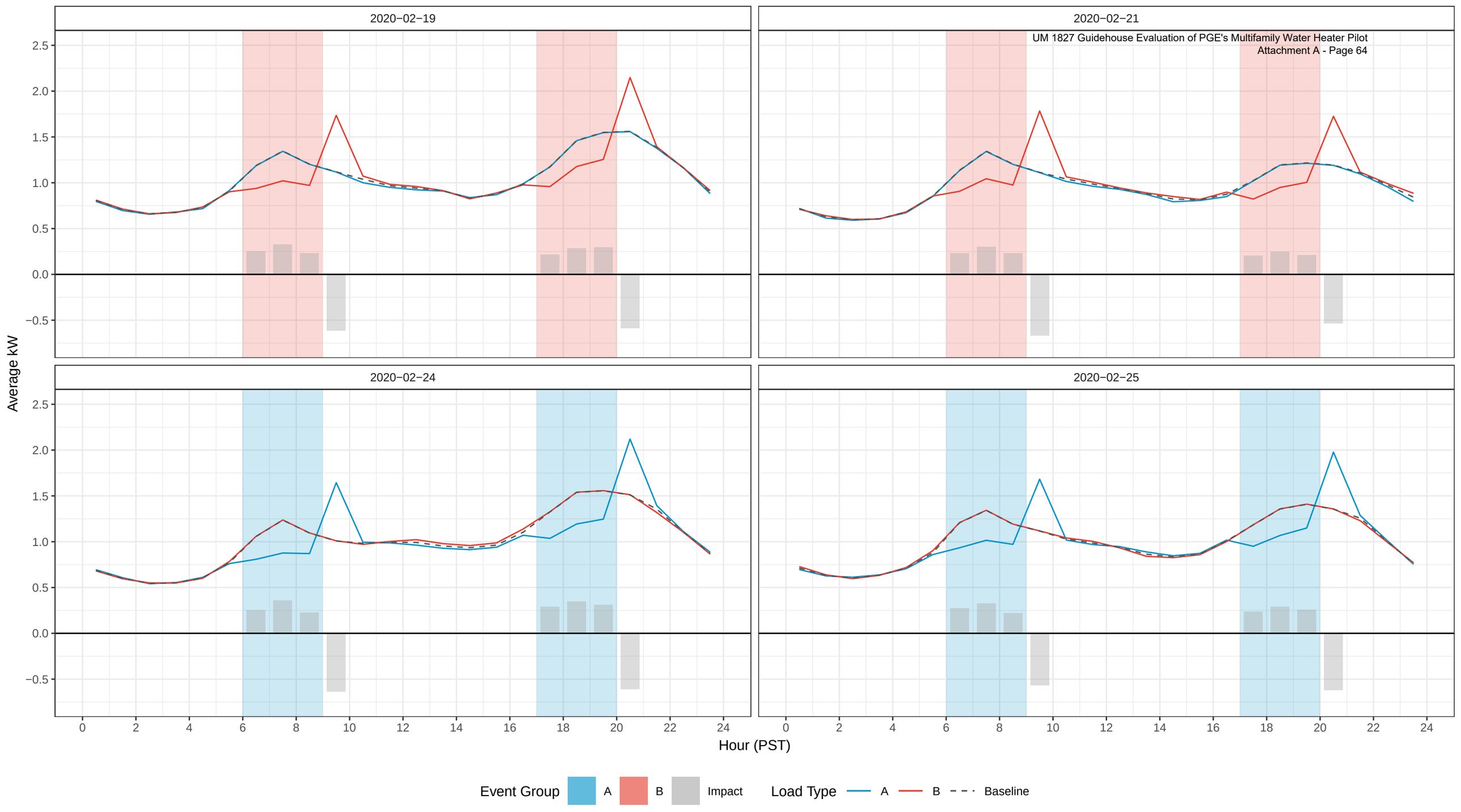
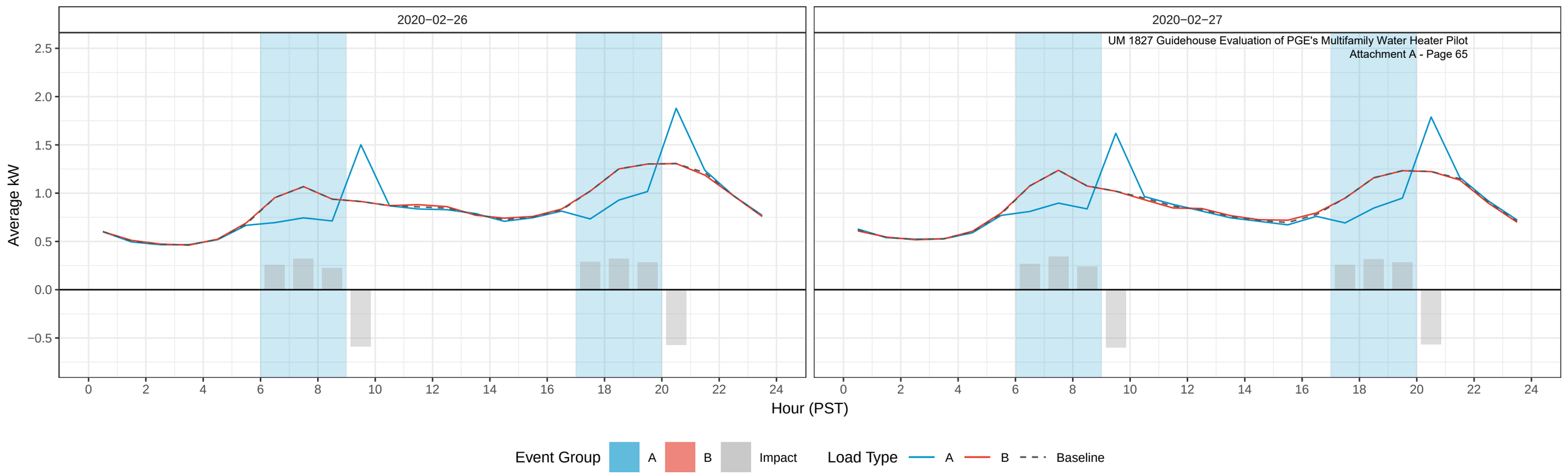
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2020−02−13
2020−02−14
2020−02−17
2020−02−18
Average kW
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2020−02−19
2020−02−21
2020−02−24
2020−02−25
Average kW
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline


2020−02−26
2020−02−27
Average kW
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
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16
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22
24
Hour (PST)
Event Group
A
B
Impact
Load Type
A
B
Baseline

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

August 14, 2020

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

RE: UM 1827 Guidehouse Evaluation of PGE's Multifamily Water Heater Pilot Winter 2019-2020

Enclosed is Guidehouse's evaluation of Portland General Electric Company's (PGE's) Multifamily Water Heater (MFWH) Pilot for the Winter 2019-2020 demand response (DR) season (Attachment A). PGE committed to providing an evaluation to the Commission in Q3 2020 in PGE Advice No. 20-05. PGE contracted with a third-party evaluation company (Guidehouse; formerly Navigant) to identify potential improvements to the pilot process for winter and summer seasons through September 2020. Guidehouse's evaluation report is enclosed.

Key findings from the Winter 2019-20 evaluation are:

- Nearly all events produced statistically significant demand reductions that are measurable in the AMI data
- Connectivity rates averaged 91% for the season which is a 16% increase from Summer 2019
- Aquanta's dispatch rate improved 12 percentage points, from 46% to 58%. Apricity averaged a 67% dispatch rate for the Winter 2019-20 season[1]
- Changes to Aquanta's technical settings (override mode) significantly improved the average kW per device by 50%

Connectivity and Callability. Pilot staff's ongoing efforts to integrate and evolve the DR technology are producing overall gains in connectivity (percent of units that are eligible for dispatch) and callable (percent of units that are heating and can be curtailed). Connectivity and callability rates are strongly correlated to each other, however, Apricity outperformed Aquanta for both connectivity and callability. The average connectivity rate for Summer 2019 was about 75% with a callability rate of 46%, while Winter 2019-20 achieved a 91% connectivity rate with 62% (Table 1. Season Average per Event). Roughly a 20% increase in connectivity contributed towards a 16% increase in callability.

1 Aquanta and Apricity are water heater switch manufacturers. Aquanta tracks water heater capacity, Apricity detects if the top heating element turns on

PGE suspects that a greater connectivity rate will be achieved through the deployment of Apricity's new switch that utilizes mesh technology. Mesh technology will enable unresponsive switches to connect with neighboring devices rather than direct to the network.

Due to installation delays as a result of COVID, Apricity's cellular-mesh switch will not have statistically significant samples in the Summer 2020 and callability results may not be known until the Winter 2020-2021 evaluation season. The ongoing COVID health crisis is limiting our ability to install for retrofits and new multifamily units.

Load Impact. Load impacts results from this evaluation will inform future load planning DR values of connected water heaters, regardless of whether the water heater is controlled by switches (standard tank retrofits) or CTA 2045 communication module (smart water heaters). Based on evaluation results, the initial planning values per controllable device used in the 2017 pilot filing may be slightly inflated due to variances between single family water heater assumptions and the real-world conditions of the multi-family water heater market. This variance may indicate additional opportunity to evolve and optimize technologies for greater load impacts. As a result, PGE has been closely monitoring and improving the kW per controllable device as well as the total kW value during an event. The initial planning value assumed that the average kW per controllable device for a standard tank (above 38 gallons) was .5 kW per water heater, representing .4 kW in Summer and .6kW in the winter. These values were determined by the best available data at the time in 2017 and leveraged 1.) PNNL's water heater pilot results and 2.) water heater emergency DR values for standard electric resistance tanks. The demand response kW value per device is important to this pilot because the DR kW value is a primary driver in determining the total kW impact during an event. The total impacted kW per event considers both the kW demand per device as well as the overall callability of the fleet.

In the Flexible Load Plan (FLP), the Multifamily Water Heater pilot's average per device kW reflect the anticipated shift to Apricity devices as well as improving AMI evaluation results. By 2023, the average per device kW impact is estimated to be 0.47 kW in winter and 0.37 kW in summer (average of 0.42 kW). These updated average per device kW assumptions result in a Total Resource Cost Test of 0.82 (TRC Test stated in 2020 FLP). AMI data shows a lower average kW impact per controllable device of 0.35 kW in the Winter (Table 8. Winter 2019-20 Impacts per Event) and 0.15 kW in the Summer (Table 6. Summer 2019 Impacts per Event).

Currently telemetry results are trending higher than the AMI data. The use of telemetry data is in consideration for future demand response planning, but values are not included in today's cost-effectiveness calculations. Winter 2019-20 Season preliminary results (PGE's Residential Demand Response Pilot Update, January 27, 2020) using telemetry data showed an average of 0.48 kW per device and preliminary results for Summer 2020 indicate 0.52 kW per device. A comparison of kW per unit by season is captured below (Figure 1.)

Figure 1. KW per Unit Comparison for Electric Resistance Water Heater

	Winter	*Summer*	*Average*	*Description*
Planning Values	*0.6*	*0.4*	*0.5*	*Initial pilot assumptions using PNNL study; 2016 IRP targets*
PGE Forecast	*0.47*	*0.37*	*0.42*	*Revised planning values for cost effectiveness; flexible load plan (April 2020)*
Proposed NWPC estimates	*0.5*	*0.75*	*0.63*	*As of July 2020; based on various utility planning values*
AMI (Guidehouse)	*0.35**	*0.15*	*0.25*	*Third-party validated; results from 2019 Summer and Winter 2019-20*
Telemetry (Enbala)	*0.48*	*0.52***	*0.5*	*Preliminary results; Summer 2020* and Winter 2019-20*

*Second Half Season Average; period after Jan 15 results yielded stabilized DR reductions and takes permanent firmware improvements into account
**represents 25 events called from June 2nd to July 15th

Guidehouse's impact evaluation leveraged AMI data to estimate the average DR impacts for each event in the Summer 2019 and Winter 2019-20 demand response seasons using a fixed effect regression analysis. While Guidehouse's analysis is rooted in AMI data, telemetry data from Enbala is used as a benchmark within the load impact evaluation. Specifically, Figure 13 presents a total kW impact by event comparison of Enbala's telemetry to Guidehouse's AMI methodology for the Summer 2019 season, whereas Figure 18 represents the total KW load impact for the Winter 2018-19 season. These graphs from the Guidehouse evaluation show that AMI data had a higher kW impact per event during the summer season and kW load impacts from telemetry data trended higher in the Winter Season. Another notable observation was that the Winter season had more consistent kW results in comparison to the summer season, as well as a stronger correlation between AMI and telemetry data. Nearly all events in the Winter showed that telemetry data reported higher curtailment, where there were only a few occurrences in Summer where telemetry-based reporting showed higher impacts than AMI based reporting.

Both AMI and telemetry data sources have merit, where each approach informs the load performance of water heaters during events. PGE recognizes that telemetry data provides a more granular view of the end-use. With funding for future evaluations and anticipated Advanced Distribution Management System (ADMS) improvements, a third-party evaluator may validate new value streams from telemetry data, such as freq. reg., distribution-based event calling, and load impact measurement—enhancements which generally cannot be produce from less granular AMI data. It is hypothesized that telemetry data will facilitate a more accurate depiction of KW demand. Since telemetry data is available in shorter intervals (5 minutes) and almost available in real-time, there are numerous benefits of telemetry date that have not been realized yet.

For example, due to the complexity of regression modeling using AMI data is only performed once the season has ended rather than monitoring results while the pilot is operating. In turn, this will allow PGE to report performance more efficiently and effectively. Guidehouse recommends a dedicated effort to understand the similarities and differences between Enbala's baseline and the evaluation's and to potentially develop a method for scaling telemetry-based results in real-time event reporting (a task not currently within the evaluation scope).

Demand response planning values (e.g., realization rates), which includes the multifamily water heater pilot, will be addressed through Distributed Resource Planning (DRP) efforts, which will be conducted in 2021/2022. The DRP will address how various data sources (AMI and telemetry) should be leveraged and how regional values compare to our findings. The DRP will create a framework on how planning values will be used to inform internal power operations, IRP targets, and cost-effectiveness. Additionally, the DRP will address how callability and connectivity rates impact the realization of the total capacity impact (kW) during an event. As a result, PGE recommends not changing its planned assumptions used to calculate progress towards goal or to determine cost effectiveness at this time.

PGE has made significant advancements to the pilot using the key findings identified in the three evaluations and currently in the Summer 2020 season. These programmatic enhancements were 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. This resource is critical to PGE's decarbonization strategy as well as its commitment to better serve, and offer opportunities to, our multifamily customers.

Please direct questions to Santiago Laborde at (503) 464-7902. Please direct all formal correspondence and requests to the following email address pge.opuc.filings@pgn.com

Sincerely,

\s\ *Robert Macfarlane*

Robert Macfarlane
Manager, Pricing & Tariffs

Enclosure
cc: UM 1827 Service List and Nick Sayen, OPUC