Portland General Electric
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December 30, 2024

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

Attn: Filing Center

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

Enclosed is Guidehouse's final evaluation of Portland General Electric Company's (PGE's) Multifamily Water Heater (MFWH) Pilot for the Summer 2022 and Winter 2022-23 demand response (DR) seasons. This evaluation includes impact estimates and recommendations for process improvement.

The following is a summary of Guidehouse's key process and impact findings:

- **The MFWH DR program is at an inflection point where PGE needs to determine what shape it will take in the future.** Key considerations include technology and communication strategies, device installation methods, and fleet management, requiring collaboration with various stakeholders on determining next steps.
- **The pilot's core processes are providing predictable results, though market changes and shifts in pilot focus have added new challenges.** The pilot maintains strong relationships with property managers, continues to refine processes, addresses connectivity challenges, and explores various technologies and strategies. Efforts to focus on recruiting for new construction have been paused pending the availability of CTA-2045 modules.
- **Recruitment of new construction and full fleet replacement projects has been difficult.** Pilot staff have faced challenges in engaging decision-makers for new construction projects, while various logistical and financial hurdles persist, causing delays in participation under the current Pilot design.
- **Pilot staff are testing a new approach to improve connectivity of Wi-Fi switches, which require regular in-person maintenance.** To sustain consistent connectivity for over 6-7 months, Wi-Fi switches necessitate routine in-person maintenance by managers of properties rather than relying on Pilot Staff.
- **Demand reductions from events in Summer 2022 and Winter 2022-23 have stabilized on a per controlled device basis (0.20 kW) as the program has matured.** In December 2022, the Pilot removed 11 properties with low connectivity Wi-Fi devices, resulting in a peak device activation rate of 77% during events. Connectivity rates during Summer 2022 averaged 70%, slightly lower than the previous winter, and remained consistent between Winter 2021-22 and Winter 2022-23 (71% to 69%). Controllability decreased from 74% to 69%

compared to the prior summer season but increased in Winter due to fewer low connectivity properties (from 71% to 79%).

- **All but the first event in the Winter 2022-2023 MFWH DR season were all-call events.** During the Winter 2022-2023 MFWH DR season, the average event load shifted was 50% higher compared to previous evaluations, while precision and per-controlled-device impacts remained similar.

PGE continues to make changes related to the key finds and recommendations identified in this evaluation. Recognizing the program's current stage and important considerations, the Pilot shifted to maintenance mode in 2023, focusing on managing the existing fleet of both Wi-Fi and cellular signal-connected switches while preparing for a program redesign.

Looking ahead, PGE intends to evaluate the Pilot alongside a program redesign. PGE aims to maintain the existing fleet while evaluating implementation service configurations and resource allocation. Collaboration with stakeholders, including PUC Staff and NEEA, will be prioritized to thoroughly assess the feasibility, informing the program redesign based on technical insights and market channel learnings.

The following are Guidehouse's key recommendations and the Pilot team's updates:

- (1) Utilize the impact value of approximately 0.20 kW per controlled device to conduct a cost-benefit analysis. **Update:** The Pilot assessed the recommendation and will address the findings in the updating of the pilot's planning values.
- (2A): Consider addressing Wi-Fi connectivity issues; assess cost-effective approaches for installation and maintenance. **Update:** The Pilot will complete a full review of this recommendation in the redesign process.
- (2B): Contact Implementor and DRMS provider to resolve connectivity issues. **Update:** The Pilot discussed with Implementor and provider.
- (3): Consider alternative delivery methods, including midstream incentives, to promote CTA-2045 water heaters. **Update:** The Pilot will complete a full review of this recommendation in the redesign process.
- (4): Consider interviewing program managers, DERMS providers, property managers, and surveying tenants for expansion insights. **Update:** The Pilot will complete a full review of this recommendation in the redesign process.

The Pilot's evaluation results have played a pivotal role in identifying both program design and operational challenges, as well as uncovering opportunities for improvement. PGE is committed to maintaining the existing fleet, ensuring that seasonal dispatch remains efficient and effective. This resource holds significant importance within PGE's overarching decarbonization strategy, serving as an important link in our efforts to reduce carbon emissions. Finally, PGE’s Multifamily Water Heater Pilot underscores our dedication to enhancing services and providing multifamily customers with valuable opportunities for engagement and participation.

Please direct all formal correspondence and requests to the following e-mail address pge.opuc.filings@pgn.com.

Sincerely,

\s\ Robert Macfarlane

Robert Macfarlane
Manager, Pricing & Tariffs

Enclosures

cc: UM 1827 and UE 435 Service Lists and Peter Kernan, OPUC

Om:a

Multifamily Residential Demand Response Water Heater Pilot Evaluation

Summary 2022 - Winter 2023 Report to the Oregon Public Utilities Commission

FINAL

Prepared for:

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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

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

Executive Summary

Portland General Electric Company's (PGE's) Multifamily Residential Demand Response Water Heater Pilot 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 18,000 customers or up to 9 MW of Demand Response (DR) capacity by July 2023 as part of PGE's 77-MW-by-2021 DR commitment to the Public Utility Commission of Oregon (OPUC). Specific pilot objectives include:

1. Quantifying the energy consumption that can be shifted to different times from:
2. Water heaters equipped with a:
    a. communication interface that supports Direct Load Control Events, or
    b. retrofitted device with a control switch in the power supply to the tank
3. Further informing the program design for a water heater demand response program
4. Determining the appropriate incentives for property managers and tenants who participate in a demand response program for water heaters
5. Integrating and testing resource communication and control technologies
6. Implementing different demand response dispatch strategies

In summer 2022, the program had 11,939 devices installed in multi-family unit dwellings. Since the program's inception, PGE, Guidehouse (third party evaluation firm), the implementer, and device manufacturer/DRMS have sought to improve device connectivity. Following additional attempts to reset Wi-Fi routers at 13 properties with ongoing poor connectivity[1], 11 properties were unenrolled in November 2022. These 500 unenrolled devices comprised 4.5% of the total fleet. Additionally, connectivity issues were identified in the supply of CTA-2045 retrofit communications modules which were brought into the pilot in November 2021 and installed in 39 units. All 39 modules were uninstalled and the entire supply of CTA-2045 retrofit modules was returned to the manufacturer due to an identified manufacturing error. As of January 2023, the Multifamily Residential Demand Response Water Heater Pilot has been in *maintenance mode*[2], with no new installations of retrofit control switches or new construction water heater equipment with CTA-2045 communications modules.

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[1] These connectivity issues were due to the Wi-Fi router and not the device.

[2] Maintenance mode includes, but is not limited to the following services: continuing to maintain flow with active enrollees, maintenance of the fleet, including connectivity, and incentive processing and delivery to participants, technical and administrative support of PMC properties; event season strategy coordination and input; evaluation support; partnering with PGE, vendors, and the DRMS partner to foster enhanced performance of the program; inventory management; strategy, tracking, reporting, oversight, invoicing, billing and other program management functions.

This report describes the impact evaluation findings for PGE's Multifamily Residential Demand Response Water Heater Pilot for the Summer 2022 and Winter 2022-23 DR seasons. Guidehouse serves as the independent evaluator for both the process and impact evaluations.

Methodology

The process evaluation included interviews with key implementation staff at CLEAResult.

The impact evaluation used AMI data to estimate the average DR impacts for each event in the Summer 2022 and Winter 2022-23 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 or lagged dependent variable regression analysis with a comparison group. Section 2.2.2 provides more details about the modelign and comparison group.

Findings

Process Evaluation Findings

The MFWH DR program is at an inflection point where PGE needs to determine what shape it will take in the future. Outstanding questions include:

- What type of device and device communication strategies will the program use going forward (e.g., CTA-2045 or cellular)?
- Will these devices be part of new smart water heaters or need to be installed by electricians?
- How will PGE, the implementer, and the DERMS provider manage an aging fleet of switches and future devices?
- Will property managers be responsible for any maintenance (e.g., resetting routers)?

As PGE determines device type and installations, it will need to coordinate with stakeholders (program managers, implementers, DERMS, property managers, and tenants) to make the program a success.

The pilot's core processes are providing predictable results, though market changes and shifts in pilot focus have added new challenges. The pilot has developed strong relationships with key property managers in the region, refined its recruitment and installation processes, and tested different technologies and event strategies, all while working through challenges related to recruitment and supply chains during the COVID-19 pandemic. However, new challenges have emerged: PGE has decided to stop recruiting for retrofit projects (i.e., cellular switches), and there are currently no functional CTA-2045 modules (used for new construction projects) available in the market. The pilot is shifting its focus to new construction recruitment and addressing connectivity challenges at already-participating properties while waiting for a new CTA-2045 module to become available. Some of the property managers were disappointed at being unenrolled and at the decision. The communication with properties was strained at that time given the recent departure of the implementer’s outreach manager prior to the unenrollments.

Recruitment of new construction and full fleet replacement projects has been difficult. Pilot staff report challenges regarding reaching decision-makers at the right point in new construction project development. There are also some logistical and financial challenges discouraging contractors and subcontractors from participating in the pilot, including the highly variable pricing of CTA-enabled water heaters across contractors and a long delay in subcontractors receiving reimbursement for the incremental cost of the water heaters, which is a financial burden on these new construction projects with long lead times. These challenges may be mitigated by a shift to an upfront midstream incentive paid to distributors, who could aid in the recruitment of new construction projects and perhaps in installing the CTA-2045 modules themselves.

Pilot staff are testing a new approach to improve connectivity of Wi-Fi switches, which require regular in-person maintenance. To maintain a relatively high level of connectivity for more than 6-7 months, the Wi-Fi switches require regular maintenance that must be conducted in person. The pilot has recently started encouraging property managers of the properties with the lowest connectivity to send their maintenance staff into units to reset the Wi-Fi routers, rather than sending pilot staff to conduct this basic Wi-Fi network maintenance. Pilot staff will be monitoring connectivity rates to see the extent to which these efforts improve connectivity for the Wi-Fi switches.

Impact Evaluation Findings

Table 1 summarizes the pilot’s average performance for each of the evaluated DR seasons. Due to changes in event type, data structure, and event hours, readers should use caution when comparing results across seasons. For additional caveats regarding interpreting results in this table and the following plots, please review Appendix D. **Since 2021, impacts have stabalized at 0.17 to 0.20 kW per controlled device as the program has matured**.

Connectivity has been on ongoing challenge for the program, specifically among Wi-Fi devices. Unenrollment of the 11 properties with connection issues in November 2022 resulted in the highest percent of controlled devices in the program's history (77%). For context, the Winter 2021-2022 evaluation estimated a 71% controlled devices rate. As this rate increases, total event impacts will correspondingly go up. In addition, new cell device installs were an additional driver of improved device communications/controllability.

All but the first event in the Winter 2022-2023 MFWH DR season were all-call events. This resulted in more devices being deployed during events and subsequently higher kW impacts. **The average event load shifted during the Winter 2022-2023 MFWH DR season was 50% higher, while precision and per-controlled-device impacts were similar, relative to previous evaluations.**

Table 1. Impact Results by Season

	Season Average Per Event								
	Summer				Winter				
Metric	**2019**	**2020**	**2021**	**2022**	**2018-19**[3]	**2019-20**	**2020-21**	**2021-22**	**2022-23**
Avg. Event Load Shifted (kW)	107	648	827	923	0	621	1,038	811	1,581
Total Enrolled Devices	3,284	7,354	10,416	11,939	1,396	6,536	9,705	11,258	10,749†
Percent of Devices Connected	75%	88%	75%	70%	64%	91%	68%[4]	71%	80%
Percent of Devices Controlled	46%	69%	74%	69%	36%	62%	60%	71%	77%
Impact per Enrolled Device (kW)	0.07	0.13	0.13	0.12		0.22	0.17	0.14	0.15
Impact per Controlled Device (kW)	0.15	0.22	0.17	0.18	0.14[5]	0.30	0.29	0.20	0.19

Source: Guidehouse analysis

† This figure excludes devices from the 11 dropped properties.

Figure 1 shows a comparison of the average impact per controlled device across the Summer 2020 to Winter 2022-23 seasons. The black lines on each bar in the graph represent the 90% margin of error of the estimate.

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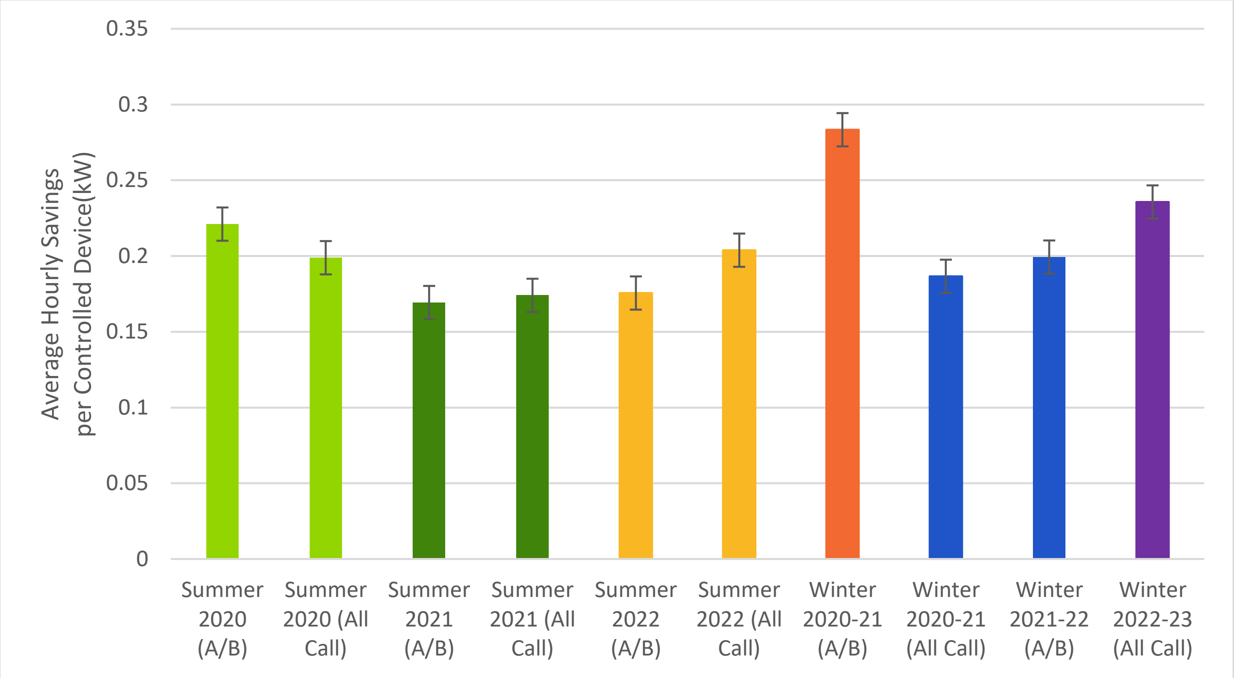
[3] The Winter 2018-19 impact analysis had noisy data due to a variety of factors, including the difficulty of calculating impacts using hourly interval data when the events had staggered start and end times. See Guidehouse's prior evaluation reports for more details.

[4] The data structure changed for the Winter 2020-2021 evaluation, which resulted in an updated method for determining device connectivity. This drop is due to the way that data was analyzed, not a meaningful change in device connectivity.

[5] This is the" full hour" impact from the Winter 2018-19 analysis.

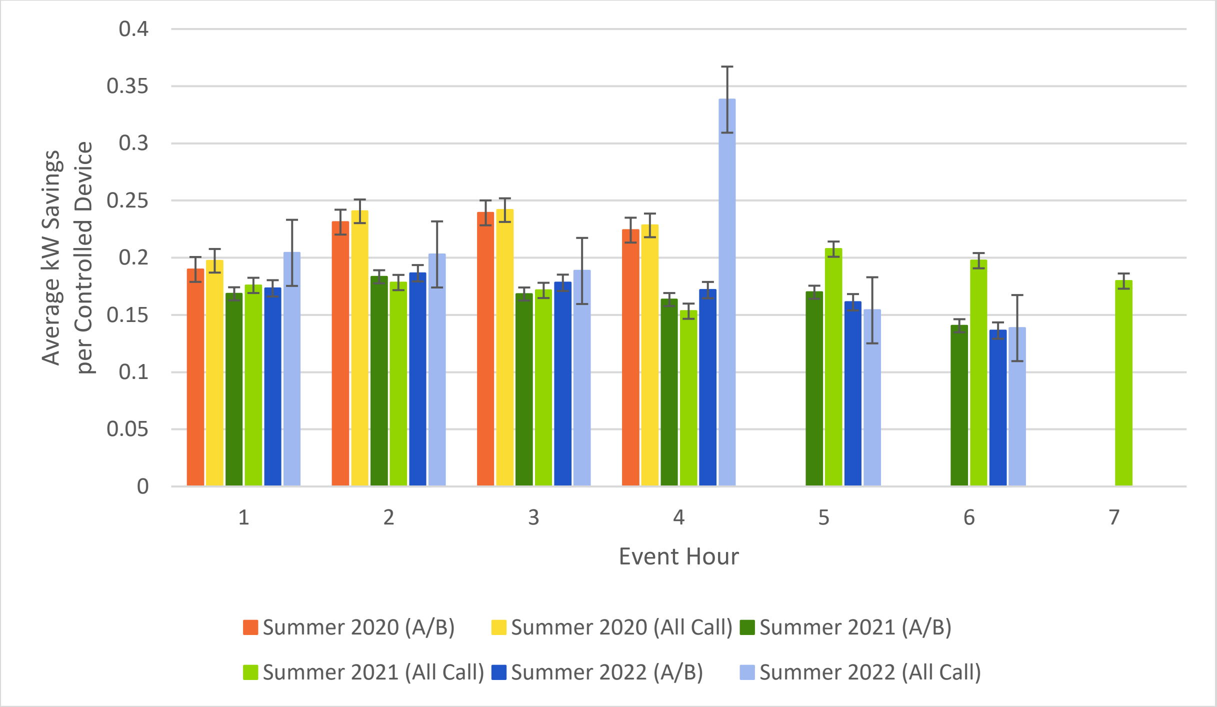
Figure 1 Average Hourly Event Impact per Controlled Device (Season Comparison)



Source: Guidehouse analysis

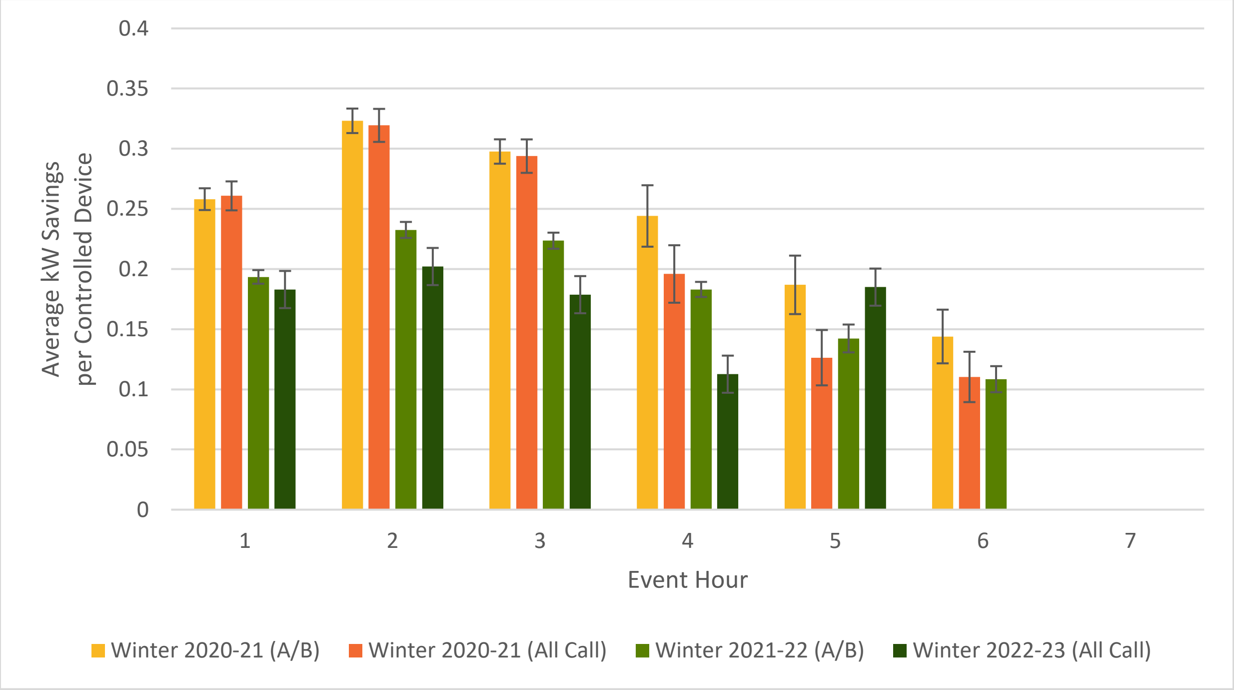
Figure 2 and Figure 3 show the comparison of average impact by hour of event per controlled device across the Summer and Winter seasons respectively. The black lines on each bar in the graph represent the 90% margin of error of the estimate. Winter events show a bigger decline in hourly impacts after the first three hours relative to summer events.

Figure 2 Average Impact by Event Hour per Controlled Device (Summer Seasons)



Source: Guidehouse analysis

Figure 3 Average Impact by Event Hour per Controlled Device (Winter Seasons)



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 Generac[6] (formerly 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 Generac. Prior to January 2023, the pilot recruited property owners and managers of multifamily buildings to enroll their apartment units' water heaters in the pilot. Once a property was enrolled, the pilot installed switches on all eligible, accessible water heaters as well as Wi-Fi equipment, if necessary,[7] to enable the switches to receive signals to disrupt power to the water heater during events. The pilot used water heater switches manufactured by Aquanta and Apricity (now Generac). From November 2021 on the pilot also offered incentives to property owners installing water heaters in new construction projects or conducting a full fleet replacement of water heaters; these water heaters are enabled with a communications protocol called CTA-2045 and the pilot installed CTA-2045 communications modules to control the water heaters.

Following additional attempts to reset Wi-Fi devices at 13 properties with ongoing poor connectivity, 11 properties were unenrolled due to ongoing connectivity issues in November 2022. Additionally, connectivity issues were identified in the supply of CTA-2045 retrofit communications modules which were brought into the pilot in November 2021 and installed in 39 units. All 39 modules were uninstalled and the entire supply of CTA-2045 retrofit modules was returned to the manufacturer due to an identified manufacturing error. As of January 2023, the pilot has been in maintenance mode[8] with no new installations of retrofit switches or new construction water heating equipment.

When events are called, any water heater that is actively heating and visible to the DRMS 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 either of these conditions are met, the switch releases the tank 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

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[6] Generac Holdings Inc. acquired Enbala Power Networks Inc. in October 2020: https://www.enbala.com/press_release/generac-accelerates-its-energy-technology-capabilities-with-acquisition-of-enbala-power-networks/

[7] Some devices use cellular technology or the CTA-2045 communications protocol rather than Wi-Fi.

[8] Maintenance mode includes, but is not limited to the following services: continuing to maintain flow with active enrollees, maintenance of the fleet, including connectivity, and incentive processing and delivery to participants, technical and administrative support of PMC properties; event season strategy coordination and input; evaluation support; partnering with PGE, vendors, and the DRMS partner to foster enhanced performance of the program; inventory management; strategy, tracking, reporting, oversight, invoicing, billing and other program management functions.

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 received Chinook Book coupons in prior seasons, but they have ceased operations. The pilot is searching for a replacement offer. 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 seven 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, 2020
- Summer 2020: June 1st, 2020 through September 30th, 2020
- Winter 2020-21: December 2nd, 2020 through February 28th, 2021[9]
- Summer 2021: June 1st, 2021 through September 30th, 2021
- Winter 2021-22: December 1st, 2021 through February 28th, 2022
- Summer 2022: June 1st, 2022 through September 30th, 2022
- Winter 2022-23: December 1st, 2022 through February 28th, 2023

In addition to the events reviewed in this report, the pilot has continued to schedule events through Summer 2023 and Winter 2023-24 as part of the ongoing maintenance mode.

1.2 Market Barriers

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

- Water heating is a major contributor to residential energy consumption, yet a low innovation product category.[10]
- 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, thus,minimally tested.

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[9] All events after the AM event on Feb 15th were cancelled due to the ice storm in Portland.

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

- 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 water heater unit may be located in a basement or vault, which can limit prolonged Wi-Fi connectivity and require manual router resets.

1.3 Pilot Objectives

Specific pilot objectives include:

1. Optimizing delivery and performance of the resource and program to meet cost effective goals and customer satisfaction

2. Quantifying the energy consumption that can be shifted to different times from:

    a. Water heaters equipped with a communication interface that supports Direct Load Control Events or

    b. Water heaters retrofitted with a control switch in the power supply to the tank

3. Further informing the program design for a water heater demand response program

4. Determining the appropriate incentives for property managers and tenants who participate in a demand response program for water heaters

5. Integrating and testing different technologies

6. Implementing different demand response dispatch strategies

7. Identifying strategies for maximizing the connectivity and controllability of participating water heaters

1.4 Pilot Target Market

1.4.1 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 50+ unit multifamily buildings. As of mid-2022, the pilot has shifted away from recruiting existing properties and is focused on the owners and builders of new construction multifamily properties. Pilot staff continue to work closely with the property managers and maintenance managers of existing participating properties to enable device maintenance, deliver incentives, and extend participation contracts.

1.4.2 Equipment Manufacturers

Secondary target audiences include distributors and 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. When the pilot initiated, only high cost “smart” water heaters included communications capabilities, and multifamily properties typically install low cost, basic water heaters in their tenants’ units. Improvements in technology have led to additional options for connecting to water heaters through a DR program.

2. Evaluation Methodology

2.1 Process Analysis

2.1.1 Program Manager and Implementer Interviews

Guidehouse interviewed the PGE staff or PGE Customer Programs Implementation Manager, and a program manager at CLEAResult. The staff and implementer interviews helped define program mechanisms and assess the role and performance of key programs actors, third-party implementers. The interviews also provided perspectives on the progress of the pilot into maintenance mode and challenges for a future multifamily water heater program or follow-on pilot.

The interviews also reviewed a number of staffing changes which have significantly impacted both PGE and CLEAResult since November 2022. Beginning in February 2023, the PGE Customer Programs Implementation Manager took on direct support of the pilot during program manager assignment transition. The CLEAResult program manager has supported the MFWH pilot directly for two years, but some key staff such as the participant outreach manager are no longer supporting the pilot.

2.2 Impact Analysis

2.2.1 Data Sources and Cleaning

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

- Hourly AMI data for all enabled units through February 28, 2023 (from PGE)
- Event log containing event start and end times for each test group[11] as well as program-calculated impacts (from Generac)
- Program tracking and opt-out data (from CLEAResult)
- Water heater switch connectivity and power data (from CLEAResult)

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”

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[11] The program uses an A/B design for most events 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. When both groups are called, a non-participant matched control group is used.

- Assets without an installation date (when an asset was installed at the premise[12]), 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 Generac's system and available for dispatch)
- AMI data on or before the asset's activation or enablement date
- AMI readings that were not hourly or for 15-minute intervals

2.2.2 Regression Modeling

For the impact analysis, Guidehouse used two different approaches depending on the event design. All units were randomly assigned to either the A or B group upon enrollment. For the first event design, A/B design, only one of the two groups (either A or B) is called, and the group not called (the control group) is used to estimate the counterfactual. In the second event design, both A and B groups are called. Therefore we use a quasi-experimental approach to estimate the counterfactual. The specifics of each approach are discussed below.

2.2.2.1 A/B Design Approach

To estimate A/B design event impacts, Guidehouse employed a fixed effects regression analysis using panel AMI data. A "fixed effect" controls for unit-level differences in demand driven by factors that do not change over time (e.g., apartment square footage), and panel data refers to the fact that the analysis was run across all units over the study period to estimate average hourly curtailment for each pilot event.

The random assignment of the two groups to ensure important characteristics (such as those that drive impacts) are distributed similarly across the two groups. RCT design is the preferred approach for program evaluation, as the randomization allows for stronger inference that differences in usage between the two groups during event periods are wholly attributable to the program. For example, as the pilot is designed for multifamily buildings, tenant turnover is an expected attribute in the data and 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 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

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[12] 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.

significance (and resulting confidence interval) of an impact estimate is derived from the standard error. Formally, the model specification is as follows:

Equation 1. A/B Design Model Specification

$$\boldsymbol{kW_{it} = \alpha_i + \lambda_t + \sum\nolimits_d \sum\nolimits_h \beta_{1dh} * (T_{it} * EventHour_{idht}) + \sum\nolimits_d \beta_{2d}(T_{it} * Snapback_{idt}) + \varepsilon_{it}}$$

Where:

kW_{it} = The average kW for premise *i* in time period *t*.

α_i = Premise-specific fixed effect.

λ_t = Hour-day fixed effects (e.g., hour-day)

T_{it} = A dummy variable equal to 1 if premise *i* is in the treatment group (the curtailed group) during period *t,* and 0 otherwise.

$EventHour_{it}$ = A set of dummy variables equal to 1 if time period *t* for premise *i* falls in the event hour *h* of event day *d*, and 0 otherwise.

$Snapback_{it}$ = A set of dummy variables equal to 1 if time period *t* for premise *i* falls in the snapback period (the first hour following an event) of event day *d*, and 0 otherwise.

β_{1dh} = The coefficient to be estimated measuring the impact of the event during period *t* for event hour *h* on event day *d.*

β_{2d} = The coefficient to be estimated measuring the post-event snapback impact during period *t* on event day *d.*

ε_{it} = cluster-robust model error term.

2.2.2.2 All Call Design Approach

To estimate “All Call” event impacts, Guidehouse employed the Regression with Pre-Period Matching (RPPM) approach, which is a recommended approach in Chapter 21 of the Uniform Methods Project[13] for estimating net savings from energy efficiency programs. RPPM follows Ho et al. (2007)[14] who argue that matching a comparison group to the participant group is a useful “pre-processing” step in regression analysis to ensure the distribution of the covariates (i.e., the explanatory variables on which the output variable depends) for the treatment group are the same as those for the comparison group that provides the baseline measure of the output variable. This minimizes the possibility of model specification bias. The regression model is applied only to the treatment periods, and the matching focuses on those variables expected to have the greatest impact on the output variable. The econometric approach Guidehouse used to estimate savings was an LDV regression model in which customers’ usage in the non-event period is an explanatory variable for usage in the event period. This approach controls for remaining differences in non-event period usage between the participant group and comparison group; when preceded by matching, it offers a double robustness for estimating an accurate counterfactual.

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[13] *Violette, Daniel M.; Rathbun, Pamela. (2017). Chapter 21: Estimating Net Savings – Common Practices: Methods for Determining Energy-Efficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-68578*

[14] *Ho, Daniel E., Kosuke Imai, Gary King, and Elizabeth Stuart. 2007. “Matching as Nonparametric Preprocessing for Reducing Model Dependence in Parametric Causal Inference.” Political Analysis 15(3): 199-236*

The “All Call” model predicts total building 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 participant and matched control groups as separate dummy variables and includes time variables to help control for load variation across event days. The event baseline is primarily informed by the selected matched control group not subject to a DR event and the LDV. However, if differences exist between the two groups during non-event hours on the event day, the model can correct for this.

Formally, the model specification is as follows:

Equation 2. All Call Design Model Specification

$$\boldsymbol{kW_{it}} = \boldsymbol{\lambda_t} + \boldsymbol{\beta_{1t}}(\boldsymbol{LDV_{it}}) + \sum\nolimits_{d}\sum\nolimits_{h} \boldsymbol{\beta_{2dh}} * (\boldsymbol{T_{it}} * \boldsymbol{EventHour_{idht}}) + \sum\nolimits_{d} \boldsymbol{\beta_{3d}}(\boldsymbol{T_{it}} * \boldsymbol{Snapback_{idt}}) + \boldsymbol{\varepsilon_{it}}$$

Where:

kW_{it} = The average kW for premise *i* in time period *t*.
λ_t = Event day-hour fixed effects.
T_{it} = A dummy variable equal to 1 if premise *i* is in the treatment group (the curtailed group) during period *t,* and 0 otherwise.
LDV_{it} = Average kW usage for premise *i* during the lagged the time period in the same hour of day as time period as *t*.
$EventHour_{it}$ = A set of dummy variables equal to 1 if time period *t* for premise *i* falls in the event hour *h* of event day *d*, and 0 otherwise.
$Snapback_{it}$ = A set of dummy variables equal to 1 if time period *t* for premise *i* falls in the snapback period (the first hour following an event) of event day *d*, and 0 otherwise.
β_{2dh} = The coefficient to be estimated measuring the impact of the event during period *t* for event hour *h* on event day *d.*
β_{3d} = The coefficient to be estimated measuring the post-event snapback impact during period *t* on event day *d.*
ε_{it} = cluster-robust model error term for premise i at time t; cluster-robust standard errors account for heteroskedasticity and autocorrelation at the premise level[15].

For the 2022-23 DR seasons, Guidehouse estimated the ATE for each hour of the event. This is the average DR impact across all assets targeted for dispatch for a given event (group A or group B or both), regardless of whether the asset was online or fully controlled for an event. Assets must be enabled in Generac’s system to be targeted for dispatch.

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[15] Ordinary Least Squares (OLS) regression models assume that the data are homoskedastic and not autocorrelated. If either of these assumptions is violated, the resulting standard errors of the parameter estimates are incorrect (usually underestimated). A random variable is heteroskedastic when the variance is not constant. A random variable is autocorrelated when the error term in one period is correlated with the error terms in at least some of the previous periods.

3. Process Evaluation Findings

This section summarizes the findings of Guidehouse's interviews with CLEAResult staff.

3.1 Technology Selection and Fleet Maintenance

The pilot is currently using two types of communications protocols to control water heaters: Wi-Fi (manufactured by Aquanta) and cellular (manufactured by Aquanta and Generac, formerly known as Apricity). A small trial of CTA-2045 (manufactured by Generac) modules were also installed and then removed due to manufacturing errors. This section discusses the pilot's use of these three technologies.

As of January 2023, the pilot has switched into a maintenance mode with a priority focus on maintaining the current fleet's connectivity and documenting device longevity as the first round of devices approaches the five year mark.

3.1.1 Wi-Fi Switches

The Aquanta Wi-Fi switches comprise approximately 22% of the fleet. The pilot is no longer installing these switches at new participating properties. The connectivity of the Wi-Fi switches continue to degrade over time due to the need for regular maintenance of the Wi-Fi networks. The pilot executed a plan to encourage property maintenance staff to periodically unplug and reset the Wi-Fi routers located in units, which started in late summer 2022. This effort temporarily improved connectivity in the 13 participating properties with the lowest connectivity. However, by November 2022 connectivity at the properties had degraded to the same poor levels as before (~20%).

In response to ongoing connectivity issues, 11 of these properties were formally removed from the program in December 2022. In response to ongoing wifi connectivity issues, the 11 properties with wifi switches were formally removed from the program in December 2022. CLEAResult noted that some of the property managers were disappointed at the decision by the program to unenroll their units. There is no formal process to communicate the responsibility for maintenance or removal of devices post-pilot. A recommendation for the process includes Property manager interviews (during and post-enrollment) which would provide a fuller view of the experience and was not included in the scope of this evaluation.

3.1.2 Cellular Switches

Currently the pilot uses both Generac and Aquanta cellular switches. The cellular switches comprise approximately 78% of the fleet and have the highest connectivity of any of the technologies currently in use by the pilot. The pilot has stopped installing cellular switches as of December 2022.

The previous evaluation report mentioned a group of approximately 500 Generac cellular switches that had been persistently offline for some time due to a firmware bug which required on-site maintenance to address. Generac staff conducted the maintenance in August 2022 and the issue is now resolved at the two properties with the largest number of affected switches.

3.1.3 CTA-2045

From November 2021 to October 2022, PGE offered an incentive to owners of new construction multifamily properties to install CTA-2045-enabled water heaters and to participate in the pilot. The incentives covered the incremental cost of a CTA-2045-enabled water heater above a standard electric resistance tank water heater. Pilot staff reported that the incremental cost was higher than initially estimated and that pricing is complex in the new construction market, with distributors offering different prices for the same equipment depending on project size and their relationships with the contractors. No new construction installations were completed prior to the program enering maintenance mode in January 2023. The pilot completed one installation of CTA-2045 retrofit modules manufactured by Generac in 2022, but the modules were later determined to be faulty and there are currently no functional CTA-2045 modules available in the market.

Since entering maintenance mode in January 2023, the pilot has paused monitoring of CTA-2045 module availability. Potential participants were recorded for a future program post redesign, but previous technology tracking and stakeholder engagement efforts were put on pause. As of July 2023, CTA-2045 prewired water heaters are the the new statewide standard.[16] PGE has also stopped recruitment of new construction projects for future installations. While the statewide mandate for CTA-2045 ready water heaters will eventually impact multifamily new construction, the initial delay in the planned code change has affected the market for CTA modules. Policy changes in Oregon and Washington are driving CTA-2045 technology development and delays in the code change may have impacted the pilot's ability to identify and acquire cost-effective and functional CTA-2045 retrofit devices.

3.2 Recruitment

As of January 2023, the Multifamily Residential Demand Response Water Heater Pilot has been in maintenance mode, with no new installations of retrofit control switches or new construction water heater equipment with CTA-2045 communications modules.

Prior to entering maintenance mode, the pilot has changed focus to recruiting owners of new construction multifamily properties into the pipeline for installing CTA-2045 devices when they become available. Pilot staff reported difficulties in reaching properties at the right stage of project planning, when a project is moving forward in the near future but the fleet of water heaters has not yet been purchased. New multifamily construction projects work on a significantly longer timeline than the original target audience of retrofits for this pilot. It may take several years before a property actually installs water heaters that can be dispatched for events. New construction projects also require a more complex set of stakeholders including developers, financiers, and suppliers.

3.3 Maintenance Mode

PGE staff worked with CLEAResult to move the MFWH pilot into maintenance mode in January 2023 following several months of discussion regarding current and expected water heater

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[16] ODOE Final Rules for Energy Efficiency Standard - https://www.oregon.gov/energy/Get-Involved/rulemakingdocs/2022-06-13-DOE-Tracked-Changes.pdf

communication technologies. As noted in previous sections of this report, installation of cellular communication devices was allowed to continue while supplies lasted or until December 2022.

PGE staff worked with the Oregon Public Utility Commission to close the pilot to new participants and to move the pilot into maintenance mode. Anticipating the planned code change to make CTA-2045-enabled water heater the baseline, the Pilot planned to transition away from all retrofits in 2021. However, the effective date of the CTA-2045 code continued to be delayed, and the Pilot extended cellular retrofits through 2022. With the code now anticipated to come into effect in July 2023 and due to the continual delays in transitioning to CTA-2045, the Pilot has entered maintenance mode with the existing fleet as PGE prepares for pilot redesign CTA-2045 enabled water heaters.

3.4 Future Program Design

As previously documented, pilot staff are interested in pursuing an upfront midstream incentive approach that would alleviate some of the challenges associated with working with new construction projects. Shifting to a midstream model would enable the pilot to pay distributors rather than individual property owners. This method would incent distributors to help the pilot with identifying and recruiting potential participating new construction projects, and relieve some of the financial and logistical challenges of participation faced by contractors and subcontractors. At the time of this report, PGE is still considering this approach but has not made a decision about incorporating this model into a future program redesign. Pilot staff note that the midstream incentive model would require some careful crafted agreements with distributors and property owners to ensure that the CTA-2045-enabled water heaters are actually installed at the participating properties, but believe that this is a surmountable challenge.

The evaluation was not contracted to perform tenant surveys or property manager interviews in recent evaluations. Therefore, the report cannot make assessments of satisfaction for these groups or how they could help improve program performance (e.g., impact of management entering tenant homes to reboot switches).

4. Impact Evaluation Findings

This section discusses the findings from Guidehouse's impact evaluation of the Summer 2022 and Winter 2022-23 DR seasons.

4.1 Summer 2022 Impact Results

The Summer 2022 DR season lasted from June 1st, 2022 through September 30th, 2022. 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 2 summarizes the key metrics for the Summer 2022 DR events, including the season average and the minimum and maximum values by event.

Table 2. Summer 2022 Impacts per Event

Metric	Season Average (per Event)	Minimum	Maximum
Total Demand Reduction (kW)	922.72	475.36	2,421.17
Percent of Devices Controlled	69%	62%	75%
Impact per Controlled Device (kW)	0.18	0.11	0.30
Snapback per Controlled Device (kW)	-0.49	-0.78	-0.19

Source: Guidehouse analysis

The program called a total of 80 events during the Summer 2022 season. The **total demand reduction per event** averaged 923 kW. As shown by the filled columns[17] in Figure 4, impacts varied from event to event and type of event. There were different factors that contributed to variation in impacts. First, events with more devices had higher impacts. All-call events (orange bars) had roughly twice as many devices as A/B design events (blue bars). Average load shifted per event for all-call events ranged from 866 kW to 2,421 kW whereas for A/B design events, load shifted per event was between 475 kW and 984 kW. Second, events with more controlled devices (shown as the light green line in Figure 4) had higher impacts. Specifically, the percent of Aquanta devices controlled was far less than Apricity devices for each event. The **percent of devices controlled** per event ranged from 44% to 63% for Aquanta devices and 83% to 90% for Apricity devices. Third, the groups called for each event had different proportions of controlled devices, which means the average number of devices actively contributing to demand reduction is lower. The devices controlled for A/B design events ranged from 62% to 75%, whereas the percent of devices controlled for all-call events ranged from 65% to 74%. Fourth, the total number of enrolled devices increased from the beginning to the end of the season to

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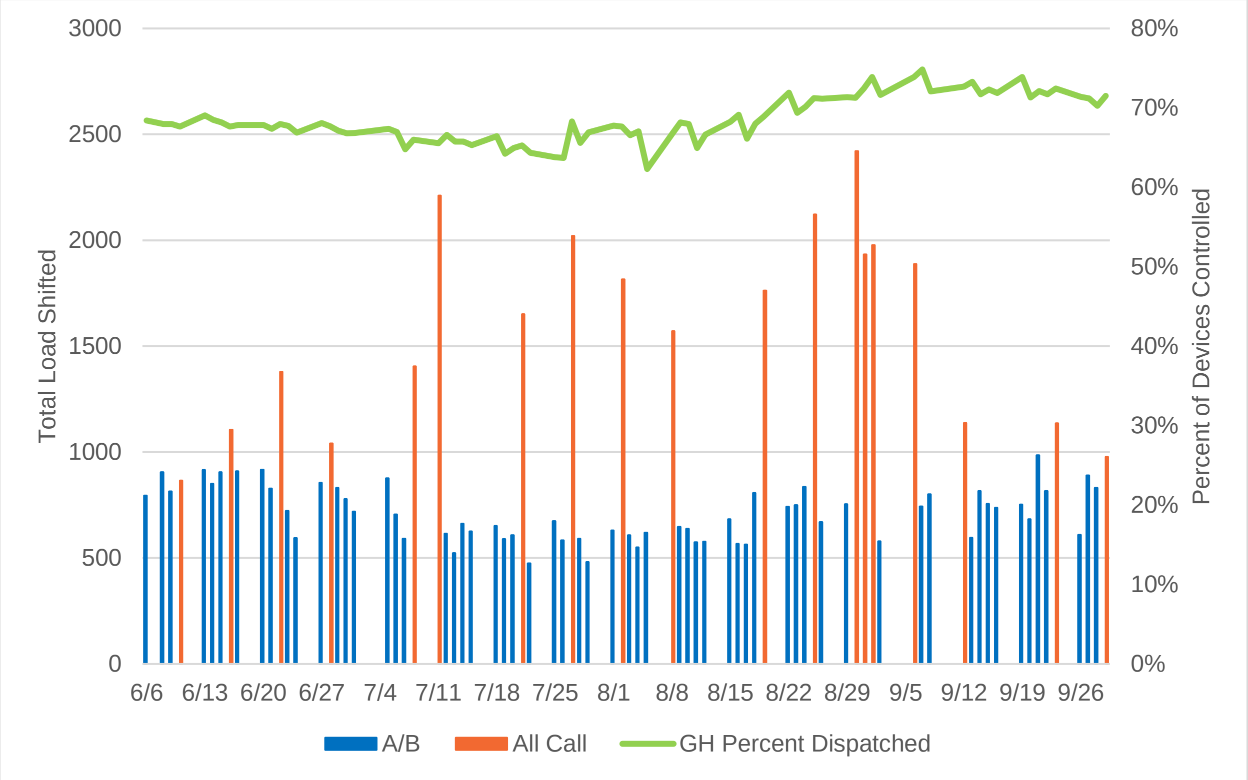
[17] The blue bars represent A/B design events while the orange bars represent all-call events.

the end.[18] For A/B design events, the number of devices enrolled increased from 5,718 to 5,979 from the beginning to the end of the season, and from 11,402 to 11,939 for all-call events.

Figure 4. Total kW Reduction and Percent Controlled per Event (Summer 2022)



Source: Guidehouse analysis

The **average load shifted per controlled device** was 0.18 kW per controlled device, with a range of 0.11 to 0.30 kW (shown in Figure 5). The impact estimates were statistically significant (i.e., statistically different from zero) for all events. These averages were calculated by dividing the total event impact (shown in the previous graphic) by the number of controlled devices[19] for that event, which is a function of water heater connectivity, heating status, and tank level.[20] The whisker bars around each dot represent the 90% margin of error in the estimate.

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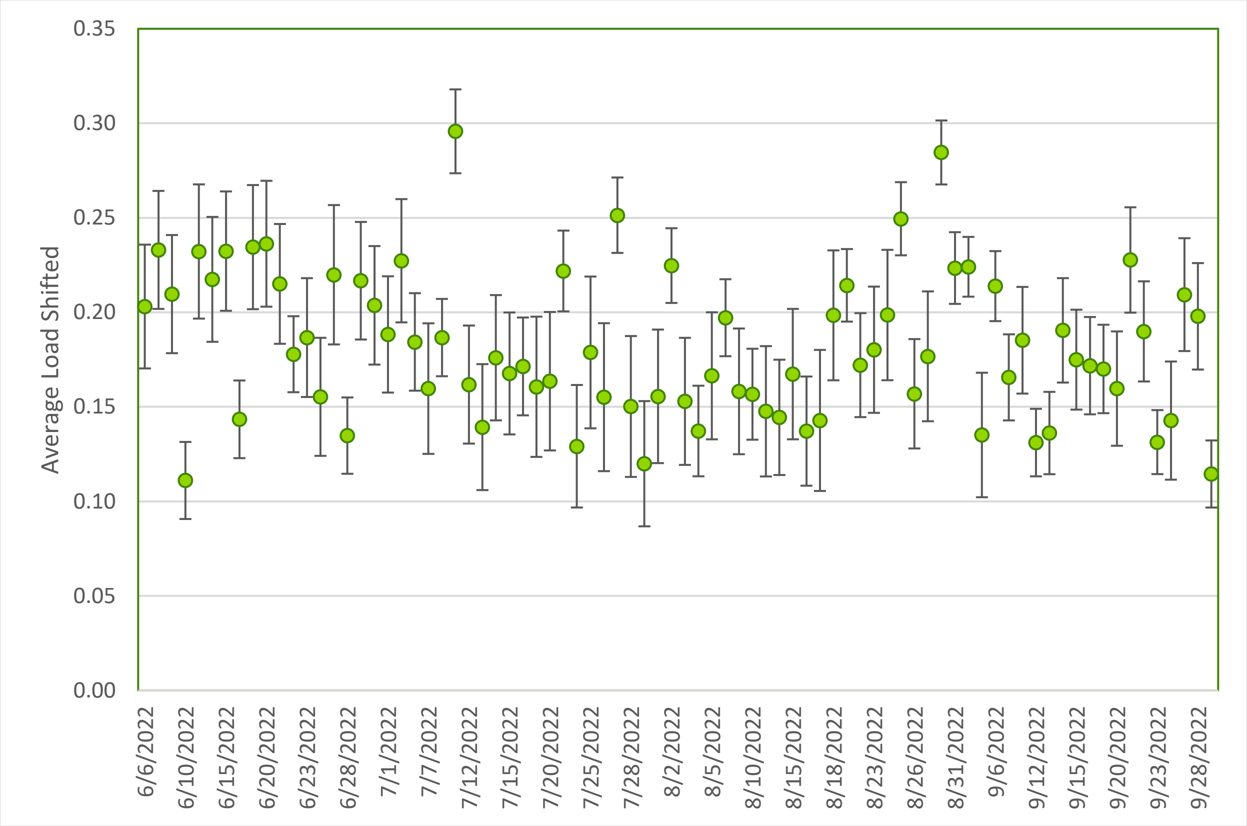
[18] Note that due to the A/B design of the program, roughly half of all participating devices were eligible for each event. On the weeks that the A group received events, the B group served as the control group, and vice versa.

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

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

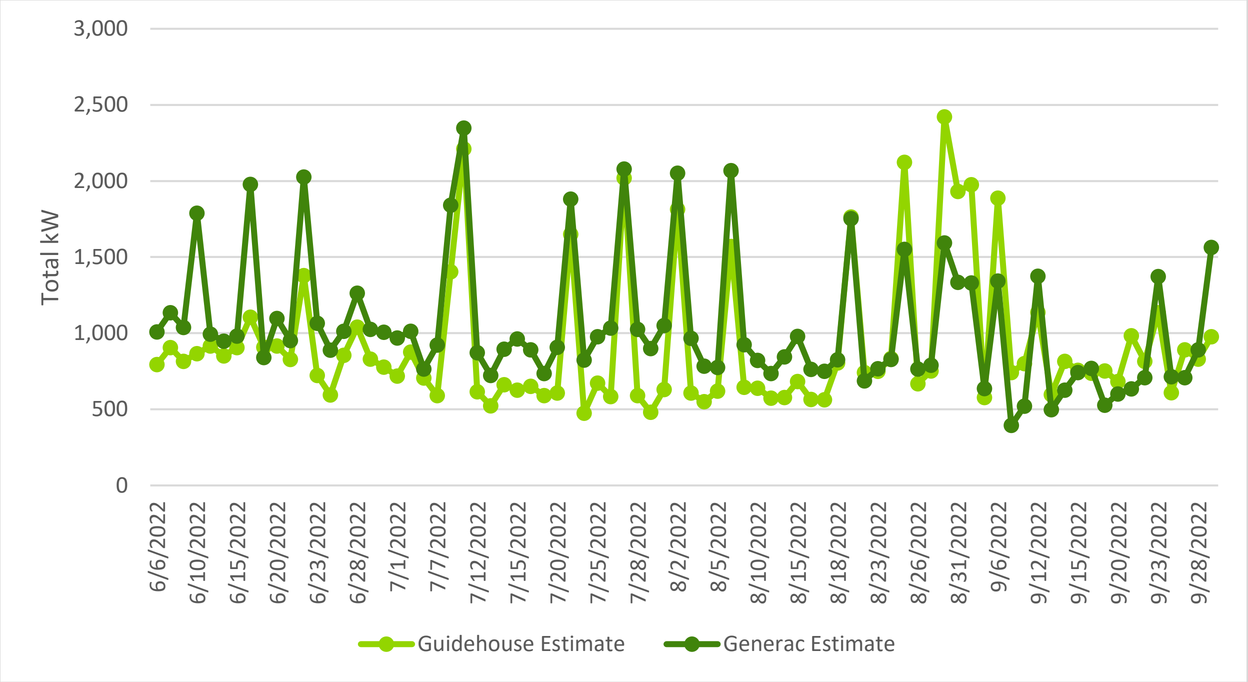
Figure 5. Average kW Reduction per Controlled Device by Event (Summer 2022)



Source: Guidehouse analysis

Figure 6 presents a **comparison of Guidehouse's evaluated impact estimates with Generac's derived from customer baseline load estimates**. Note that Guidehouse and Generac 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). Generac supplies interim real-time estimates using 15-minute water heater telemetry data to estimate a customer-specific baseline from each building's past water heater usage. The majority of Summer 2022 events had similar estimates between Guidehouse's and Generac's results.

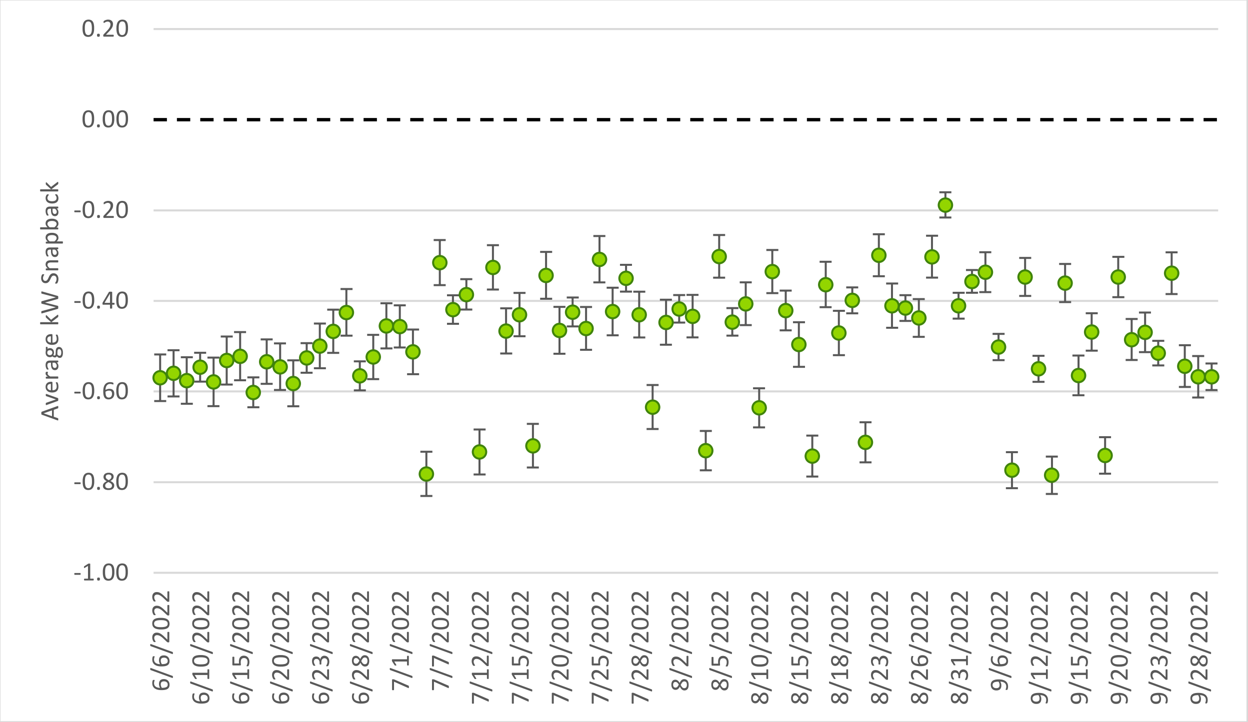
Figure 6. Total kW Impact: Guidehouse and Generac Comparison (Summer 2022)



Source: Guidehouse analysis, Generac Performance Summary from 3/15/2022

Figure 7 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 -0.49 kW, meaning that on average the participating households were using 0.49 kW *more* than the control group households during the period after the events. Average per-device snapback ranged from -0.19 kW to -0.78 kW.

Figure 7. Average Snapback per Controlled Device by Event (Summer 2022)



Source: Guidehouse analysis

During Summer 2022, events resulted in a net energy impact, as illustrated in Figure 8. The total energy reduction across events varied according to event length. After incorporating hourly curtailment and snapback, two-hour and six-hour evening events showed the lowest savings per controlled device, 0.16 kWh savings for both. Three-hour evening events showed 0.18 kWh savings per controlled device[21]. Hourly impacts per controlled device ranged from 0.11 to 0.30 kWh savings. Hourly impacts generally stayed consistent across each hour of an event, with a slight decrease in the final hour.

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[21] Hourly impact per controlled device was calculated by multiplying the hourly estimates for enrolled devices by the ratio of enrolled to controlled devices.

Figure 8. Average Hourly and Total Event kWh Impact by Event Length (Summer 2022)

Source: Guidehouse analysis

4.1.2 Device Statuses: Connectivity and Overrides

Figure 9 and Figure 10 show the breakdown of device dispatch status by event across the 2022 summer season. Device participation was 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[22]**:** a device that was actively heating, but was not dispatched

Override, Not Dispatched: a device that entered override mode[23] 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

In addition, this report uses the status ***Controlled*** to identify devices dispatched resulting in demand curtailment. The *Controlled* status encompasses both *Dispatched* and *Override, Partial Dispatched* device statuses.

During summer 2022, connectivity rates were slightly lower than the previous winter, at 70% on average for the summer 2022 season. Like the 2021 summer analysis, nearly 99% of devices across all events were either in *Dispatch*, *Override, Dispatch,* or *No Connectivity* mode, which is why average connectivity and controlled rates are so similar. This is a testament to the implementer and DERMS provider improving their device status communication relative to earlier in the Pilot.

The connectivity rates varied greatly across the two devices. Throughout the summer events, connectivity rates for Apricity devices did not fall below 83% for any event, whereas connectivity rates for Aquanta devices did not go above 63% for a single event.

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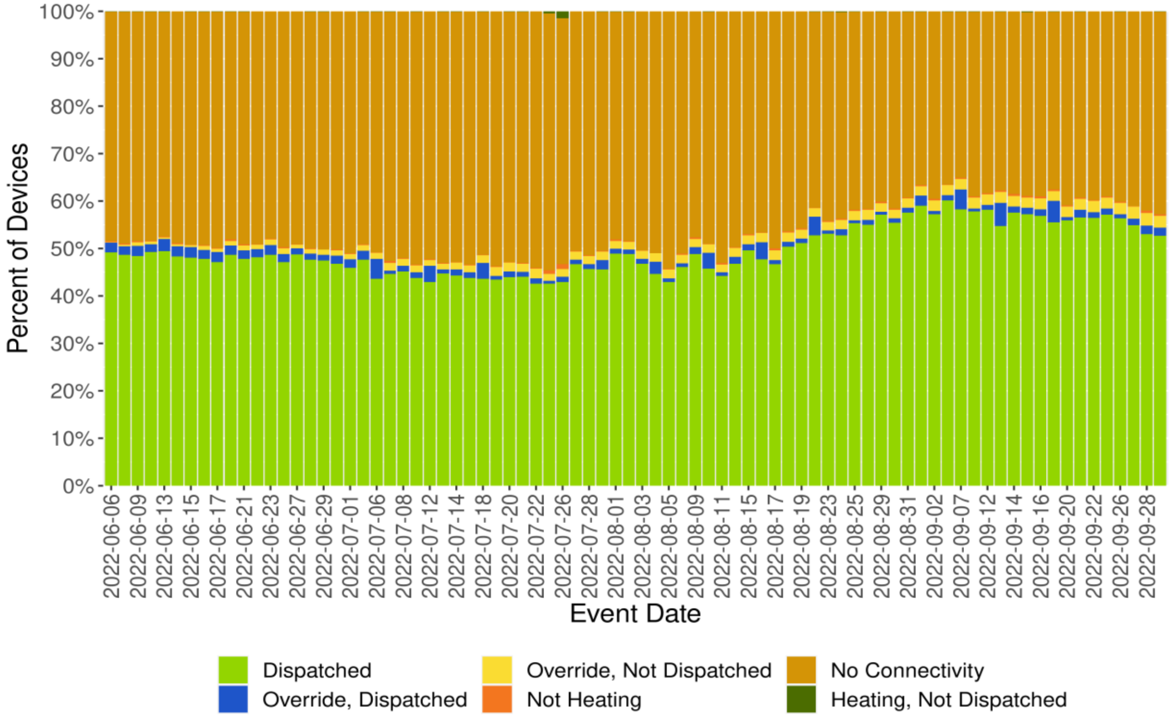
[22] These are a small number of cases, but this status should not occur.

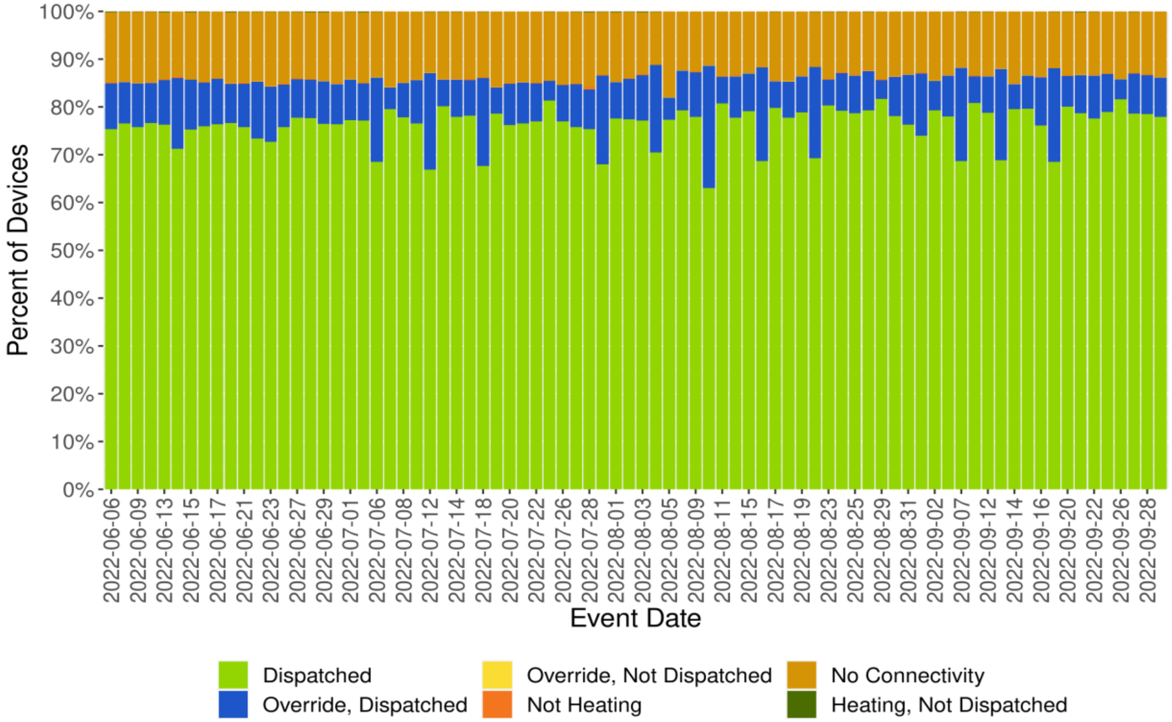
[23] Devices enter override mode when its tank drains more than 30 percent and cannot be curtailed until the tank refills.

Figure 9. Aquanta Device Dispatch Status by Event (Summer 2022)



Source: Guidehouse analysis

Figure 10. Apricity Device Dispatch Status by Event (Summer 2022)



Source: Guidehouse analysis

4.2 Winter 2022-23 Impact Results

This section discusses the findings from Guidehouse's impact evaluation of the Winter 2022-23 DR season, which lasted from December 1, 2022 through February 28, 2023. 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 3 summarizes the key metrics for the Winter 2022-23 DR events, including the season average and the minimum and maximum values by event.

Table 3. Winter 2022-23 Impacts per Event

Metric	Season Average (per Event)	Minimum	Maximum
Event Demand Reduction (kW)	1,581	101	2,777
Percent of Devices Controlled	79%	48%	84%
Impact per Controlled Device (kW)	0.19	0.01	0.32
Snapback per Controlled Device (kW)	-0.50	-0.97	-0.02

Source: Guidehouse analysis

PGE sought insight into how morning and afternoon events performed from an impact perspective. Table 4 breaks down aggregated impacts in Table 3 according to time of day. PM events showed higher values according to event impacts, impacts per controlled device, and snapback per controlled device.

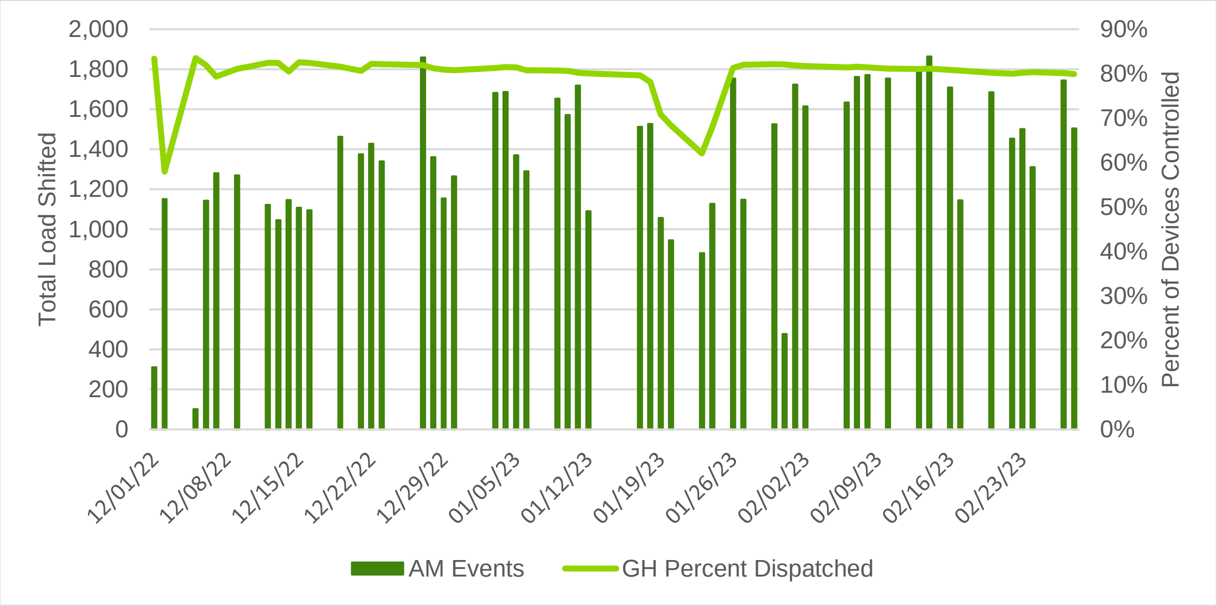
Table 4. Winter 2021-22 Impacts per Event by Time of Day

Metric	Daytime	Season Average (per Event)	Min	Max
Total Demand Reduction (kW)	AM	1,359	101	1,864
	PM	1,804	681	2,777
Percent of Devices Controlled	AM	80%	58%	84%
	PM	78%	48%	82%
Impact per Controlled Device (kW)	AM	0.16	0.01	0.21
	PM	0.21	0.08	0.32
Snapback per Controlled Device (kW)	AM	-0.43	-0.89	0.02
	PM	-0.58	-0.97	-0.31

Source: Guidehouse analysis

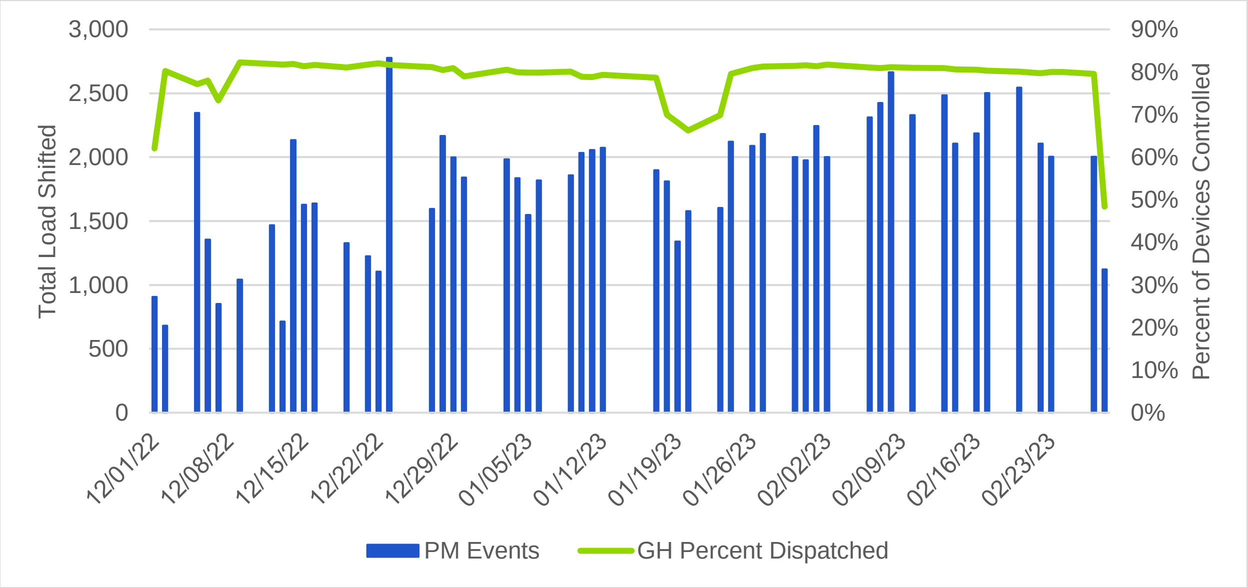
The program called a total of 106 events during the Winter 2022-23 season. The **total demand reduction per event** averaged 1,364 kW for AM events and 1,824 kW for PM events. As shown in the green bars in Figure 11 and Figure 12 impacts varied from event to event, with a range of 101 to 1,864 kW during AM events and 681 to 2,777 for PM events. The **percent of devices controlled** ranged from 58% to 84% for AM events and 48% to 82% for PM events.

Figure 11. Total AM kW Reduction and Percent Controlled per Event (Winter 2022-23)



Source: Guidehouse analysis

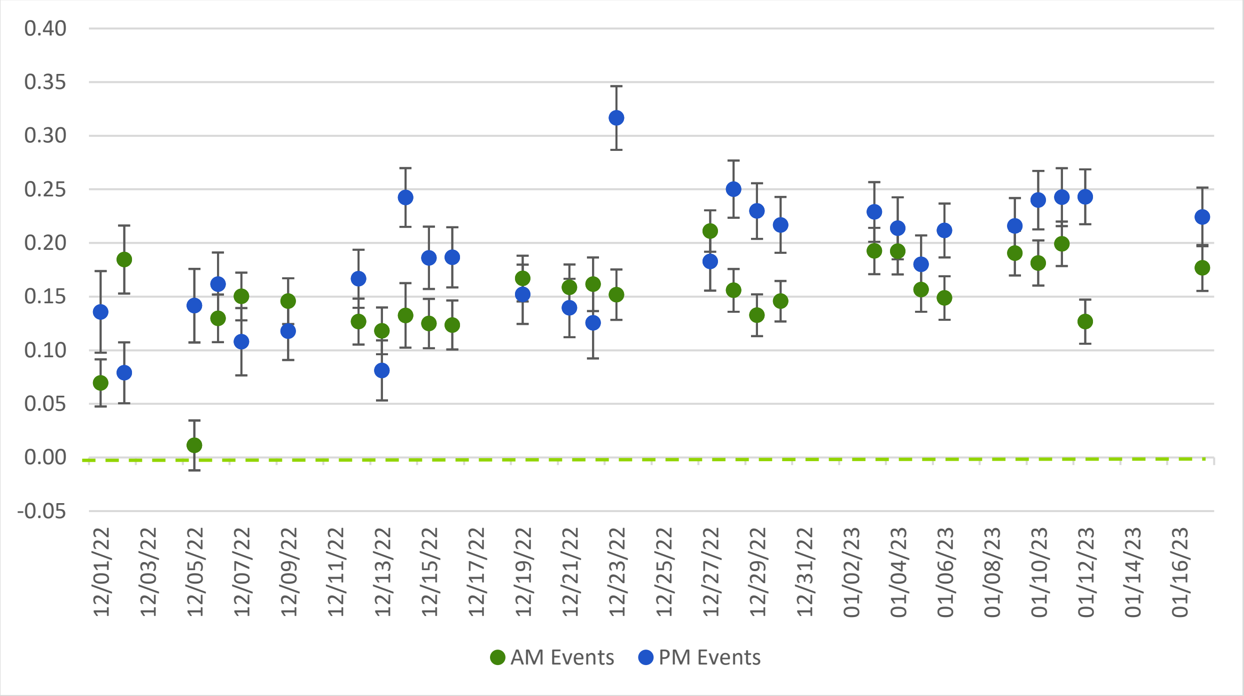
Figure 12. Total PM kW Reduction and Percent Controlled per Event (Winter 2022-23)



Source: Guidehouse analysis

The **average impact per controlled device** was 0.19 kW per controlled device (shown in Figure 13), with a range of 0.01 to 0.31 kW. The impact estimates were statistically significant (i.e., statistically different from zero) for all events except the 2022-12-05 AM event.

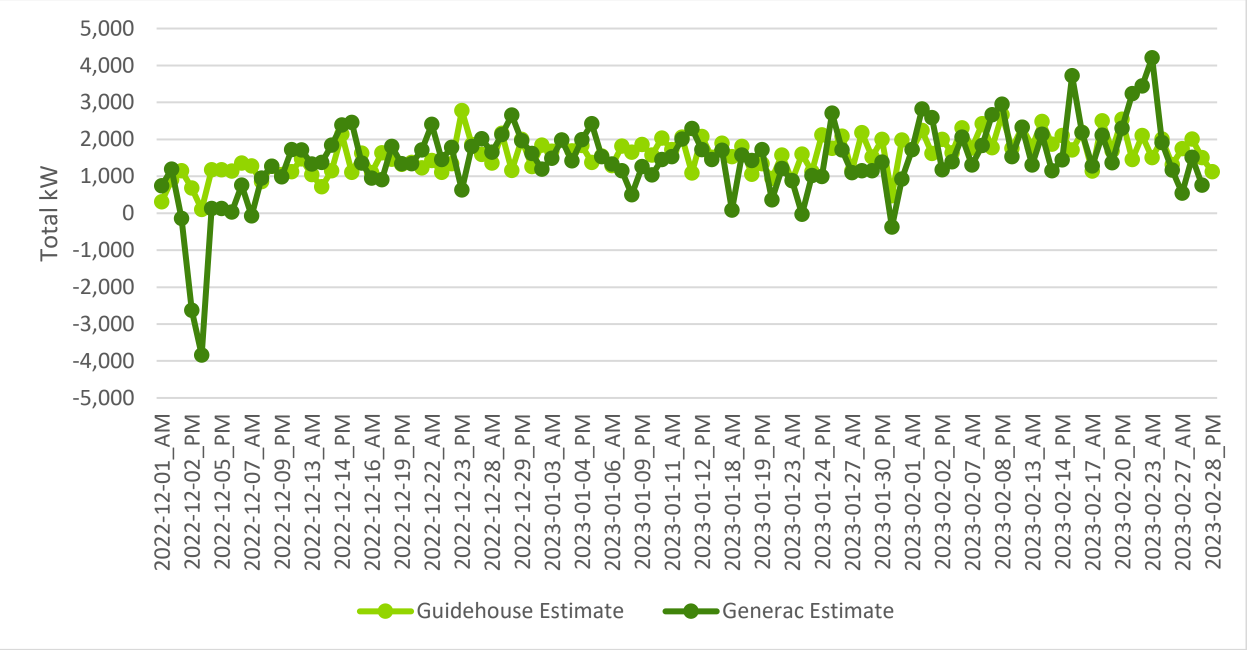
Figure 13. Average kW Reduction per Controlled Device by Event (Winter 2022-23)



Source: Guidehouse analysis

To support the program’s interest in real-time reporting tools, Figure 14 presents a **comparison of evaluated impacts to customer baseline load estimates from Generac**. Although Guidehouse and Generac calculated different impact values for most events, there wasn’t a difference between the two estimates on average. This represents a decrease from Winter 2021-2022, where the Generac estimates were 21% higher than the Guidehouse evaluated impacts.

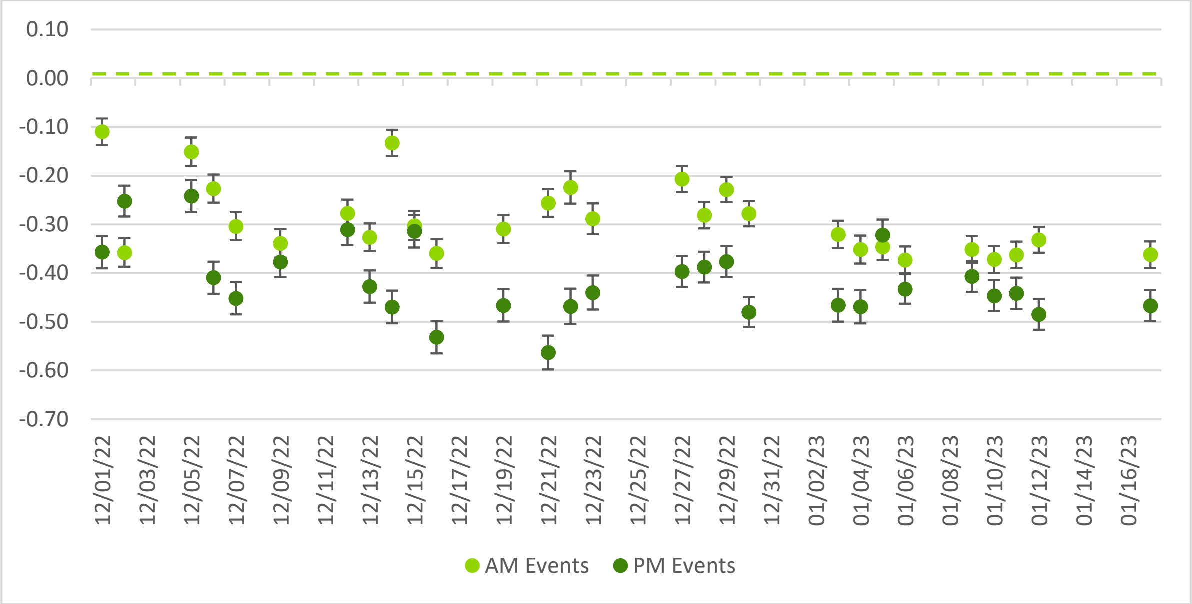
Figure 14. Total kW Impact: Guidehouse and Generac Comparison (Winter 2022-23)



Source: Guidehouse analysis

Figure 15 presents the average **snapback per controlled device** for events. The average snapback per controlled device for events was -0.50 kW, meaning that on average the participating households were using 0.50 kW *more* than the control group households during the one-hour period after the events. Snapback per controlled device ranged from 0.02 kW to -0.97 kW.

Figure 15. Average Snapback per Controlled Device by Event (Winter 2022-23)



Source: Guidehouse analysis

During Winter 2022-23, events resulted in a net energy impact, as illustrated in Figure 16. The total energy reduction across events varied according to time of day and event length. Three-hour PM events showed higher hourly impacts and snapback relative to AM events. After incorporating hourly curtailment and snapback, three-hour event events showed 0.07 kWh savings per enrolled device, while three-hour morning events showed 0.06 savings per enrolled device. Events showed an slight decrease from hour 2 to 3 of the event, likely as some devices went into override status.

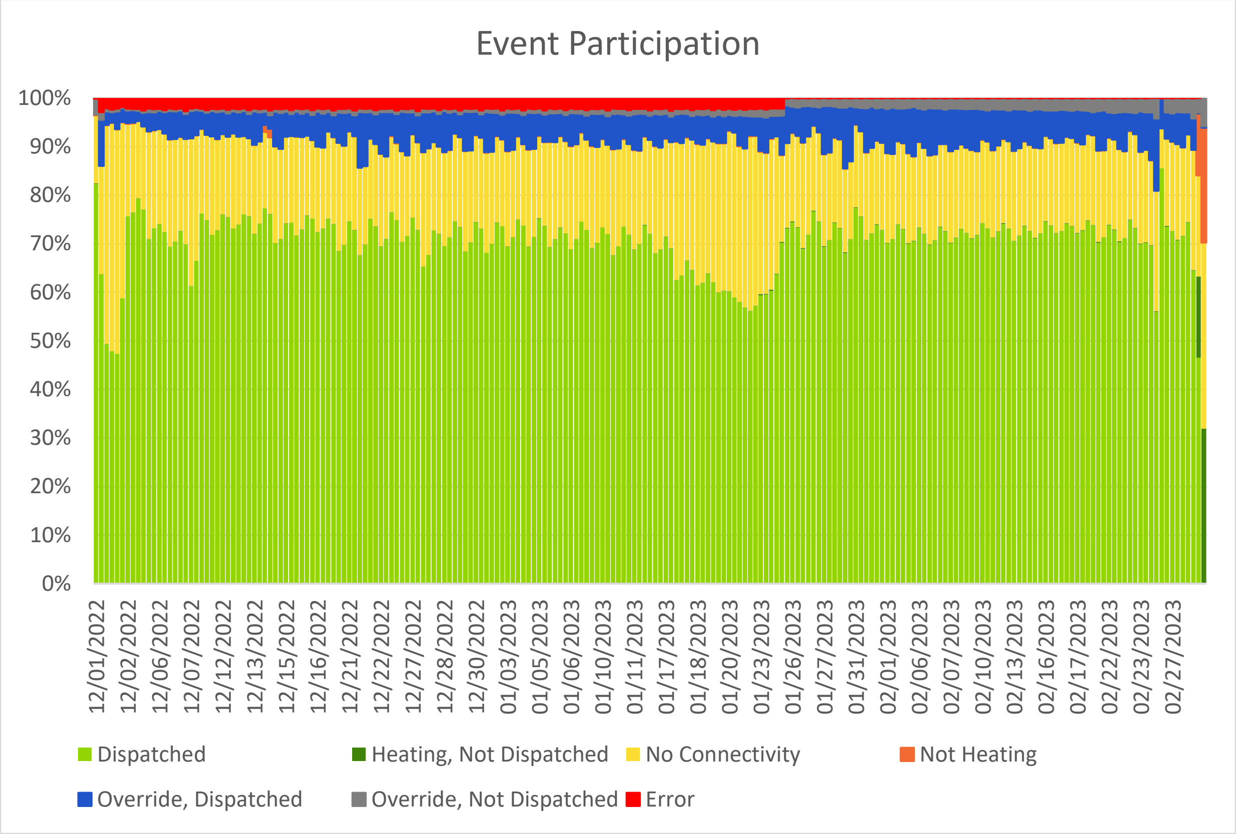
Figure 16. Hourly and Event Energy Impact by Event Length (Winter 2022-23)

Source: Guidehouse analysis

4.2.2 Device Statuses: Connectivity and Overrides

Figure 17 shows device dispatch status by event. After the *Dispatched* status, *No Connectivity* was the second most common status, followed by *Override, Dispatched*, and *Not Heating.* Event device statuses by AM/PM and device type are available in Appendix C. The additional status of *Error* indicates the switch is offline.

Figure 17. Device Dispatch Status by Event (Winter 2022-23)



Source: Guidehouse analysis

Table 5 shows device dispatch status by manufacturer for three-hour events. Similar to the previous evaluations, Apricity devices, being cell-enabled, had higher levels of connectivity relative to Aquanta devices (71% vs. 68%). However, Apricity devices showed an increased likelihood of being overridden after being dispatched (7% vs. 5%). Even though Apricity devices had a higher dispatch rate, some of this curtailment was reduced because it was overridden.

Table 5. Average Device Dispatch Status by Device Type (Winter 2022-23)

Device Status	Apricity	Aquanta
Dispatched	71%	68%
Heating, Not Dispatched	0%	0%
No Connectivity	18%	24%
Not Heating	0%	0%
Override, Dispatched	7%	5%
Override, Not Dispatched	0%	3%
Error	3%	0%

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. Since the program is in maintenance mode, these conclusions will hopefully inform decision-makers at PGE as they seek to decide the pilot's future.

Finding #1: Impacts have stabilized at roughly 0.20 kW per controlled device. Guidehouse analysis has found impacts of approximately 0.20 kW per controlled device for the first three event hours since the Winter 2021-2022 DR season.

> **Recommendation #1:** Use this value to estimate a cost benefit analysis for the PGE MFWH program. This analysis should include snapback that can be delayed up to seven hours.

Finding #2: Removing properties with low-connectivity Wi-Fi devices resulted in the highest proportion of devices being activated during DR events (77%) in the program's history. PGE removed 11 properties from the program in December 2022 due to on-going connectivity issues with Wi-Fi devices. This helped increase connectivity for Aquanta devices from 55% in Summer of 2022 to 68% in Winter 2022-2023. New cell device installs were an additional driver of improved device communications/controllability.

> **Recommendation #2a:**.Wi-Fi devices have not offered reliabile connectivity over the past several evaluation seasons. PGE should consider the most cost-effective way for the pilot to move forward given Wi-Fi device connectivity issues, installation costs, and maintenance costs.
>
> **Recommendation #2b:**.Even with the recent increase in proportion of devices dispatched during events, there are still approximately 20% of devices that are not connected. PGE should continue working with Generac and CLEAResult to address outstanding connectivity issues.

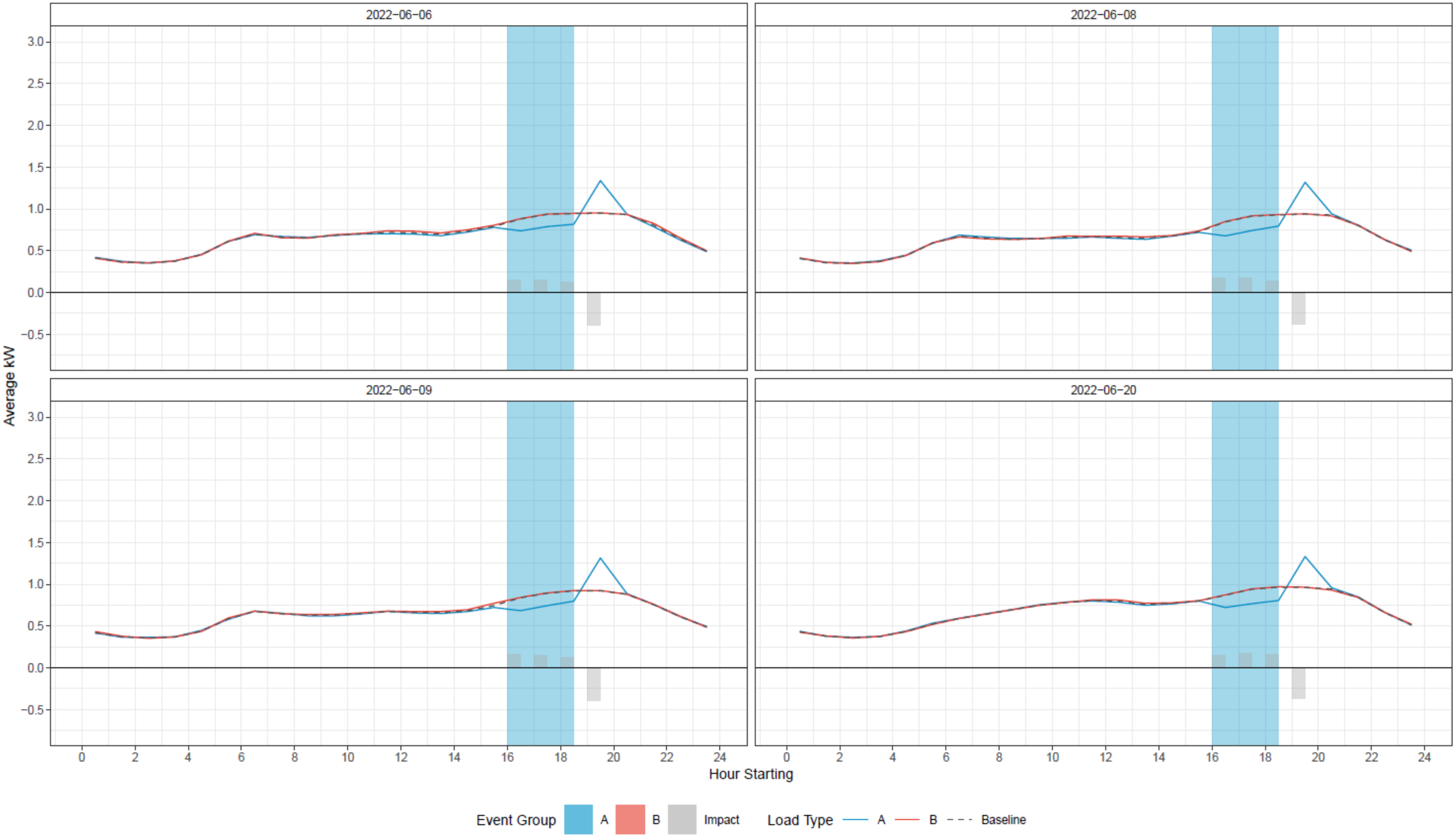
Finding #3: The pilot is in maintenance mode and will no longer install new retrofit cellular or CTA-2045 communication devices. PGE staff are looking towards a redesign of the program to better support the new CTA-2045 communication standard which was formalized in July 2023.

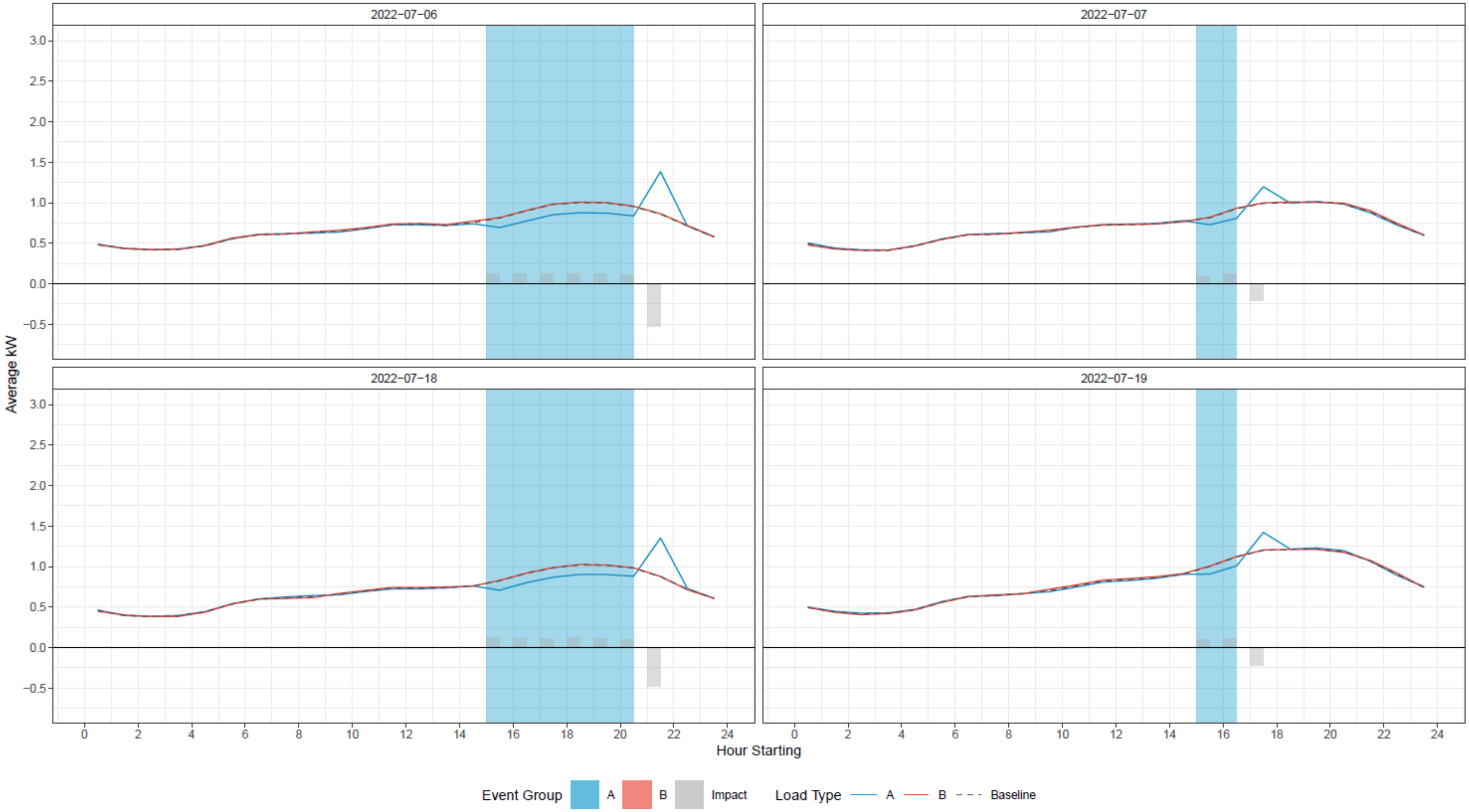
> **Recommendation #3:** PGE should consider alternative delivery models for incentivizing adoption of new CTA-2045 enabled water heaters including midstream.

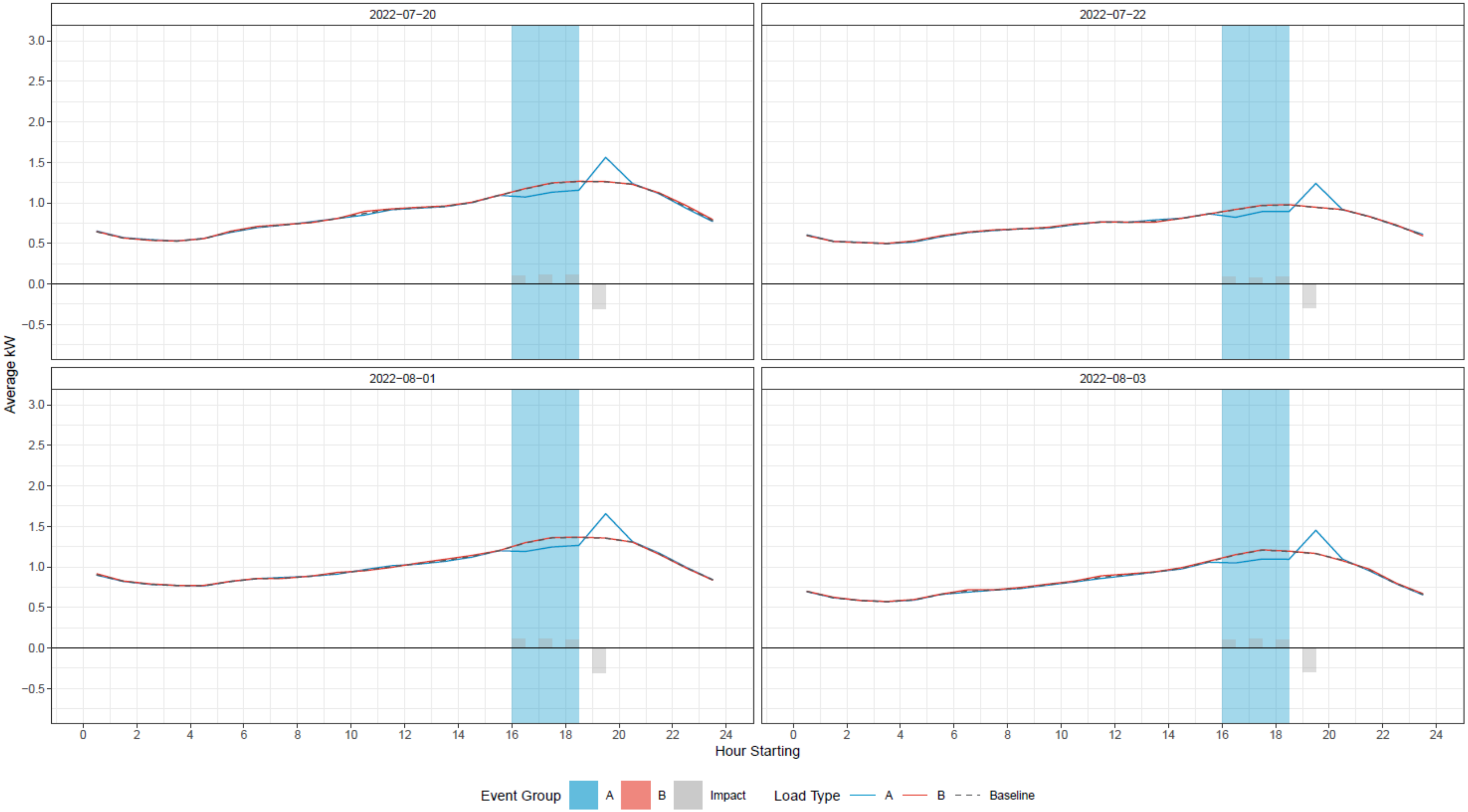
Finding #4: The program is at a decision point, and stakeholders need to align to make it a success. As this period of the pilot finishes, decision makers need to decide whether to continue it and how to address connectivity, cost, and device issues.

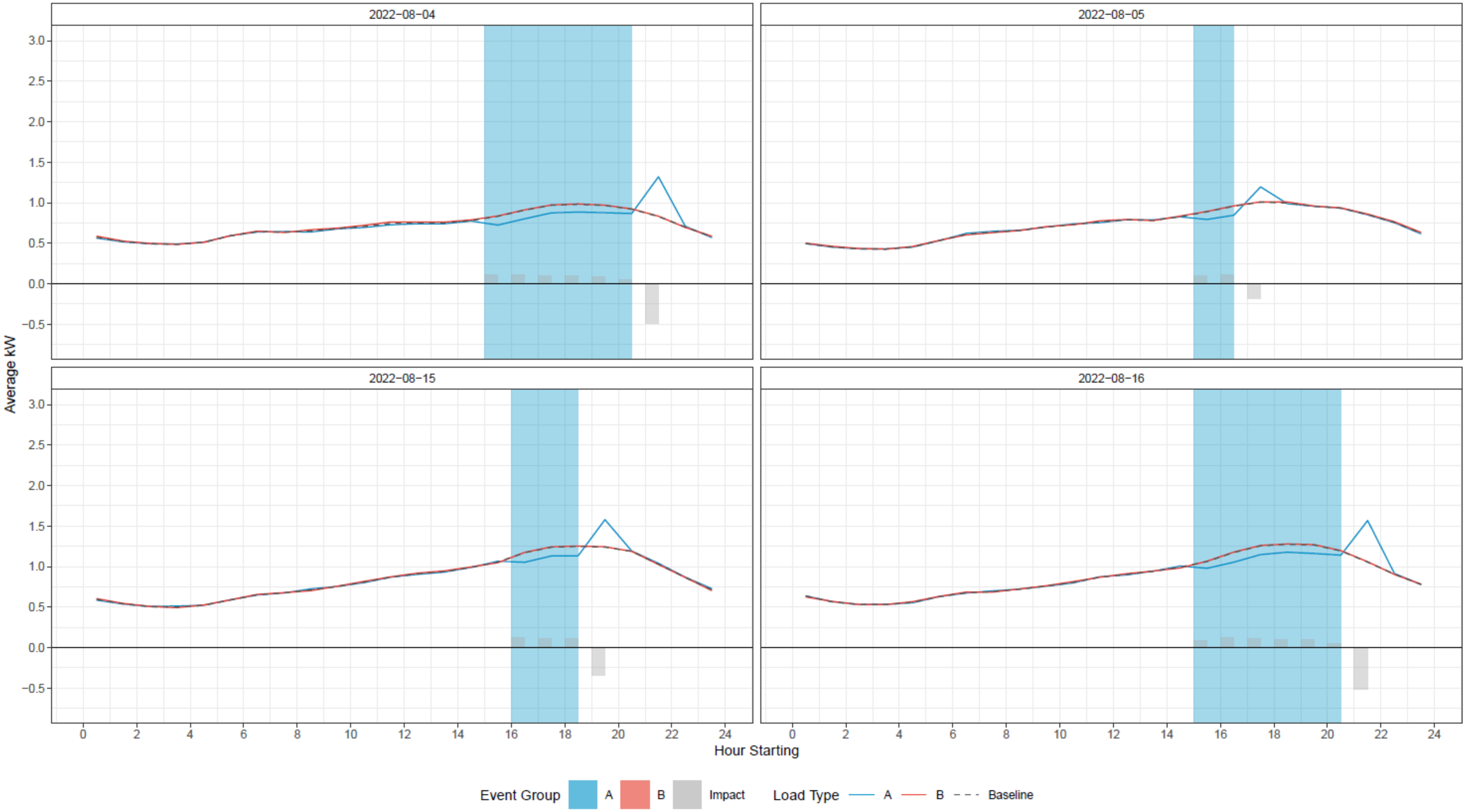
> **Recommendation #4:** PGE should interview program managers, DERMS providers, and property managers and survey tenants to ensure it understands stakeholder perspectives if it decides to expand this pilot.

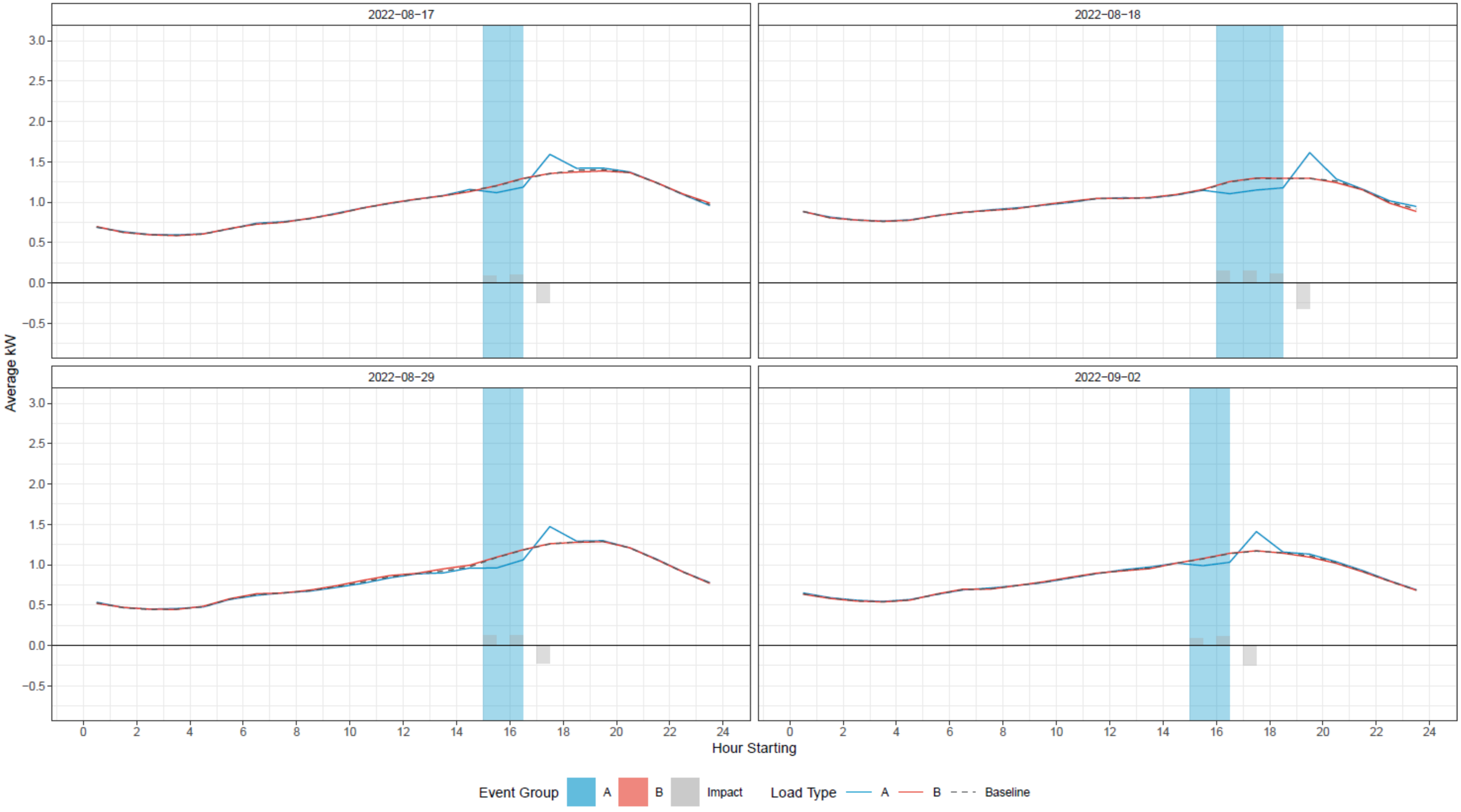
Appendix A. Summer 2022 Event Plots

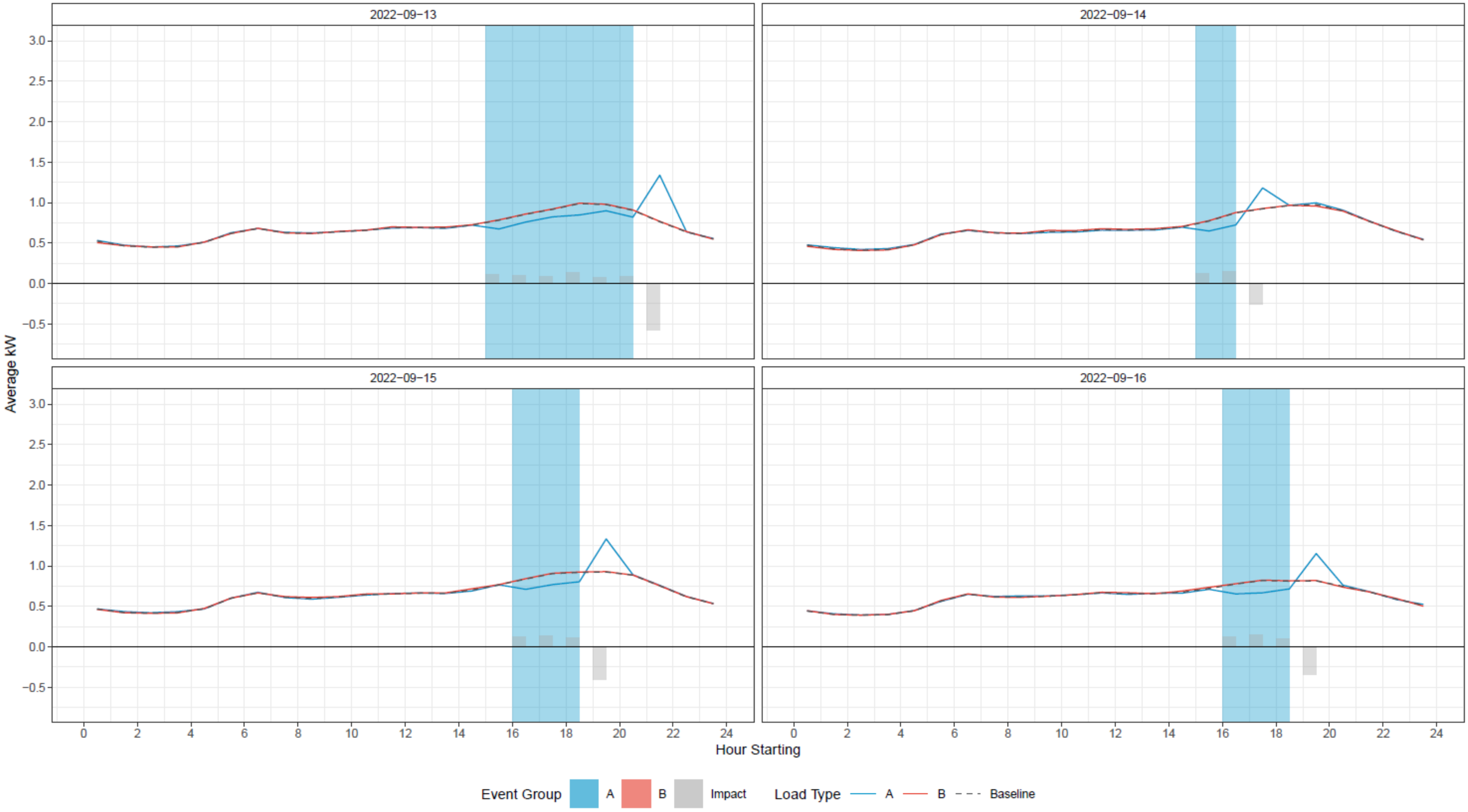

2022−06−06
2022−06−08
2022−06−09
2022−06−20
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

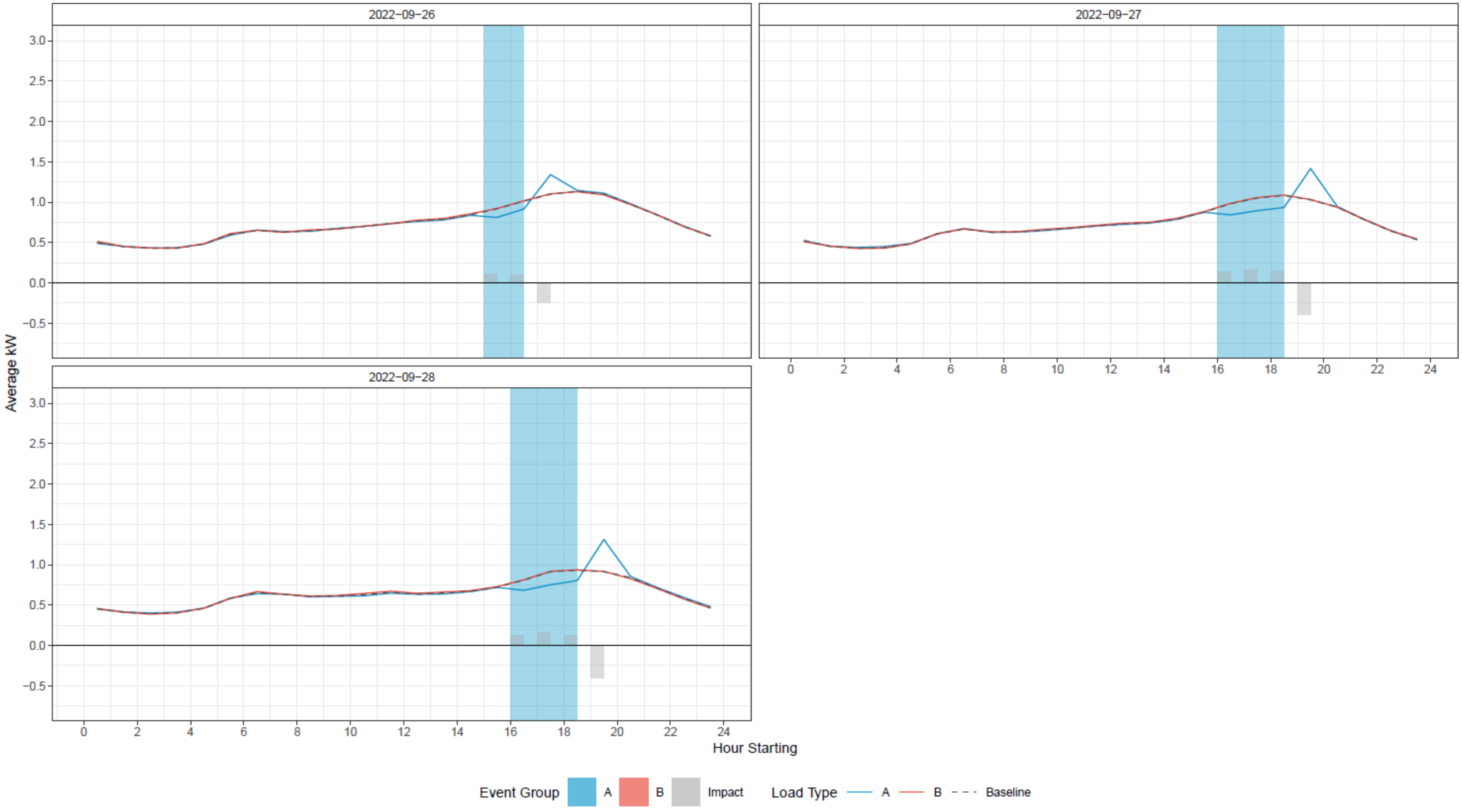

2022−07−06
2022−07−07
2022−07−18
2022−07−19
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

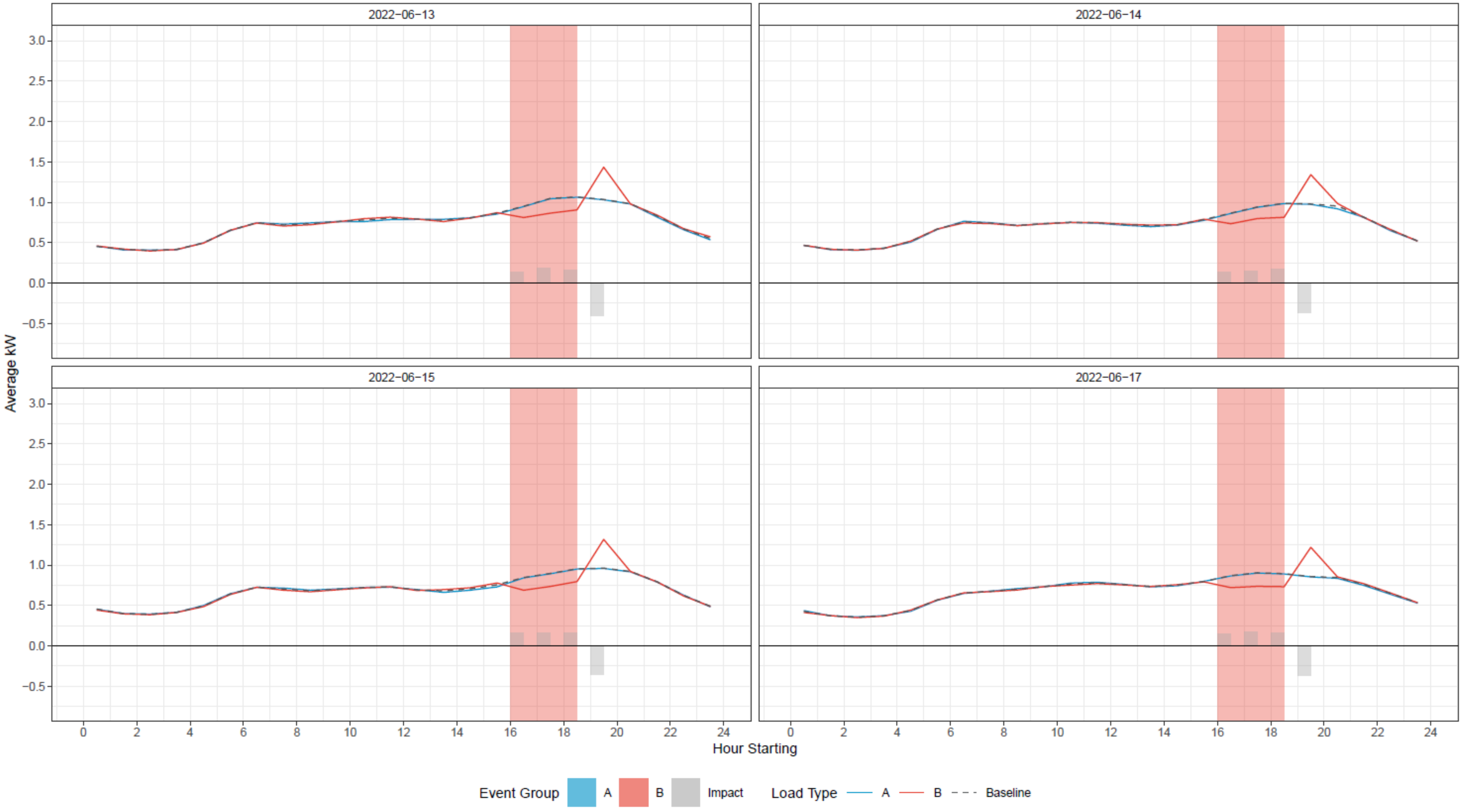

2022−07−20
2022−07−22
2022−08−01
2022−08−03
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

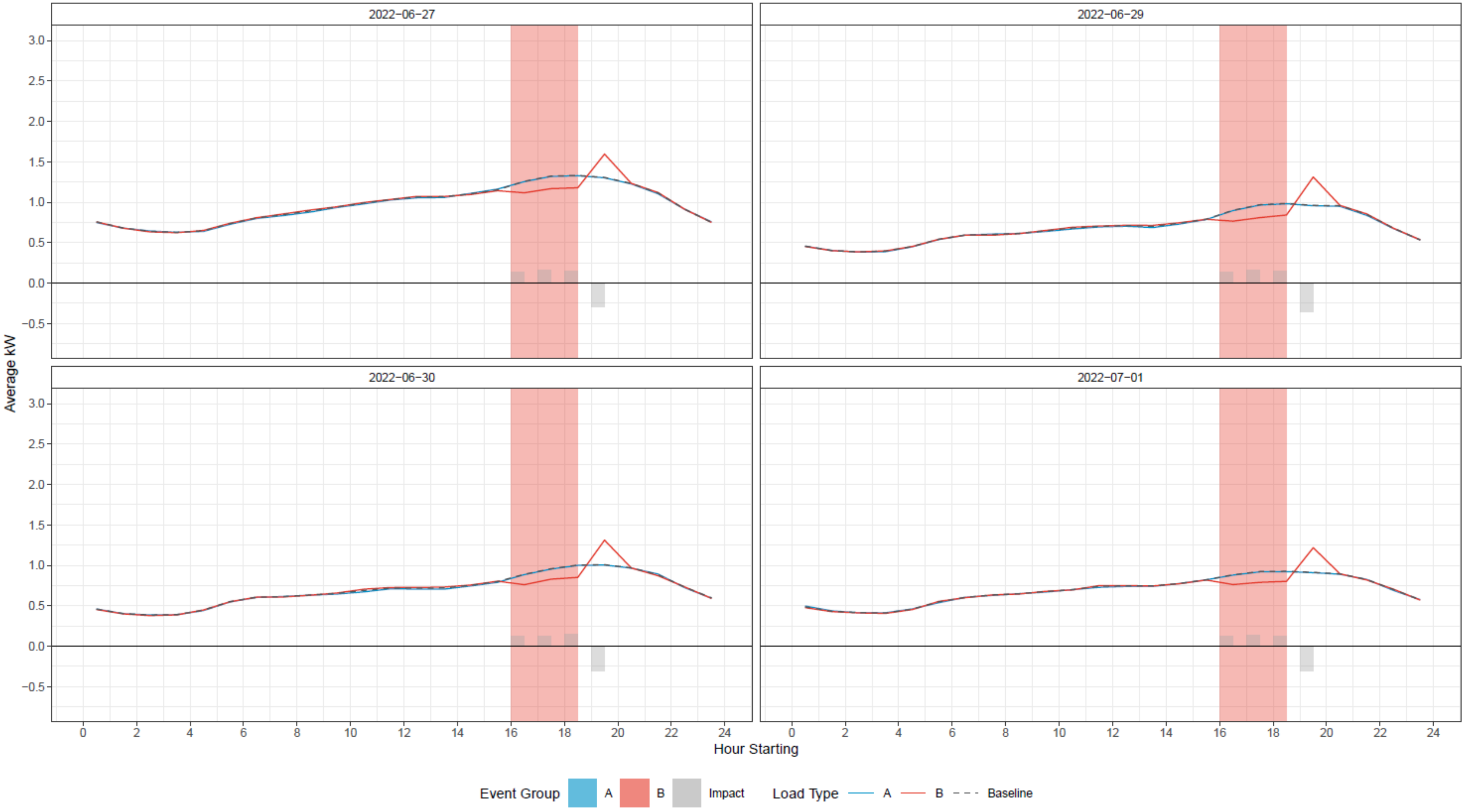

2022−08−04
2022−08−05
2022−08−15
2022−08−16
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

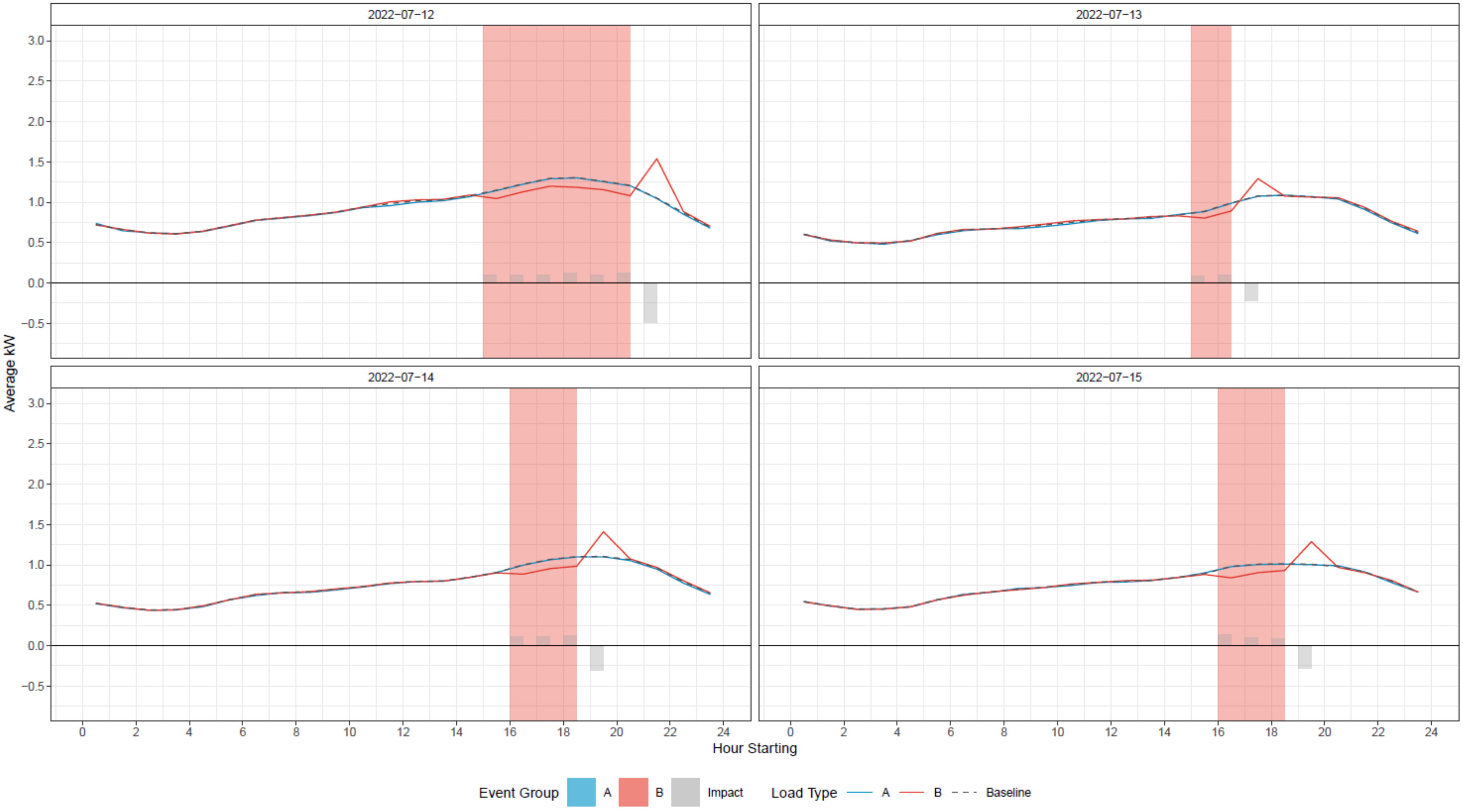

2022−08−17
2022−08−18
2022−08−29
2022−09−02
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

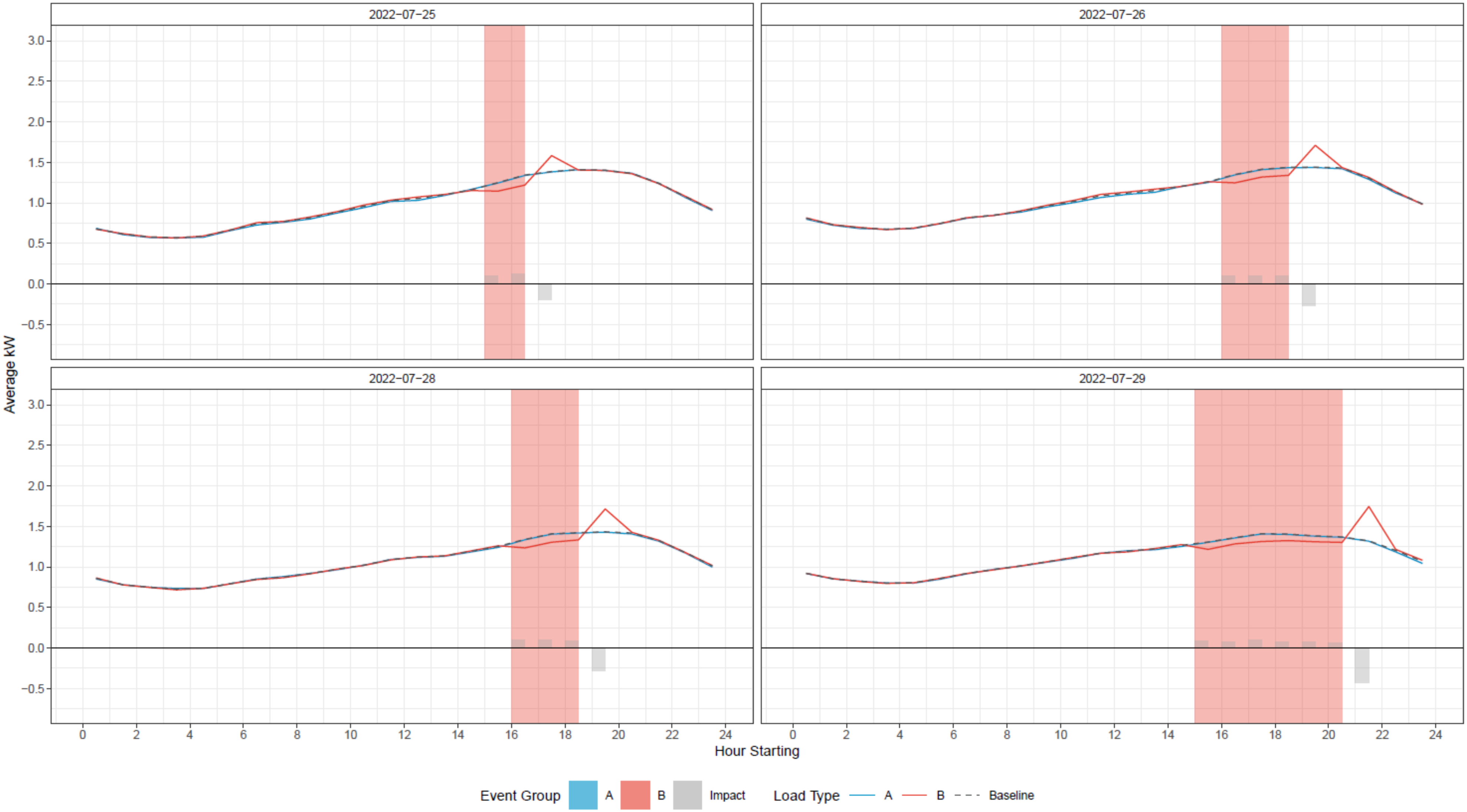

2022−09−13
2022−09−14
2022−09−15
2022−09−16
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

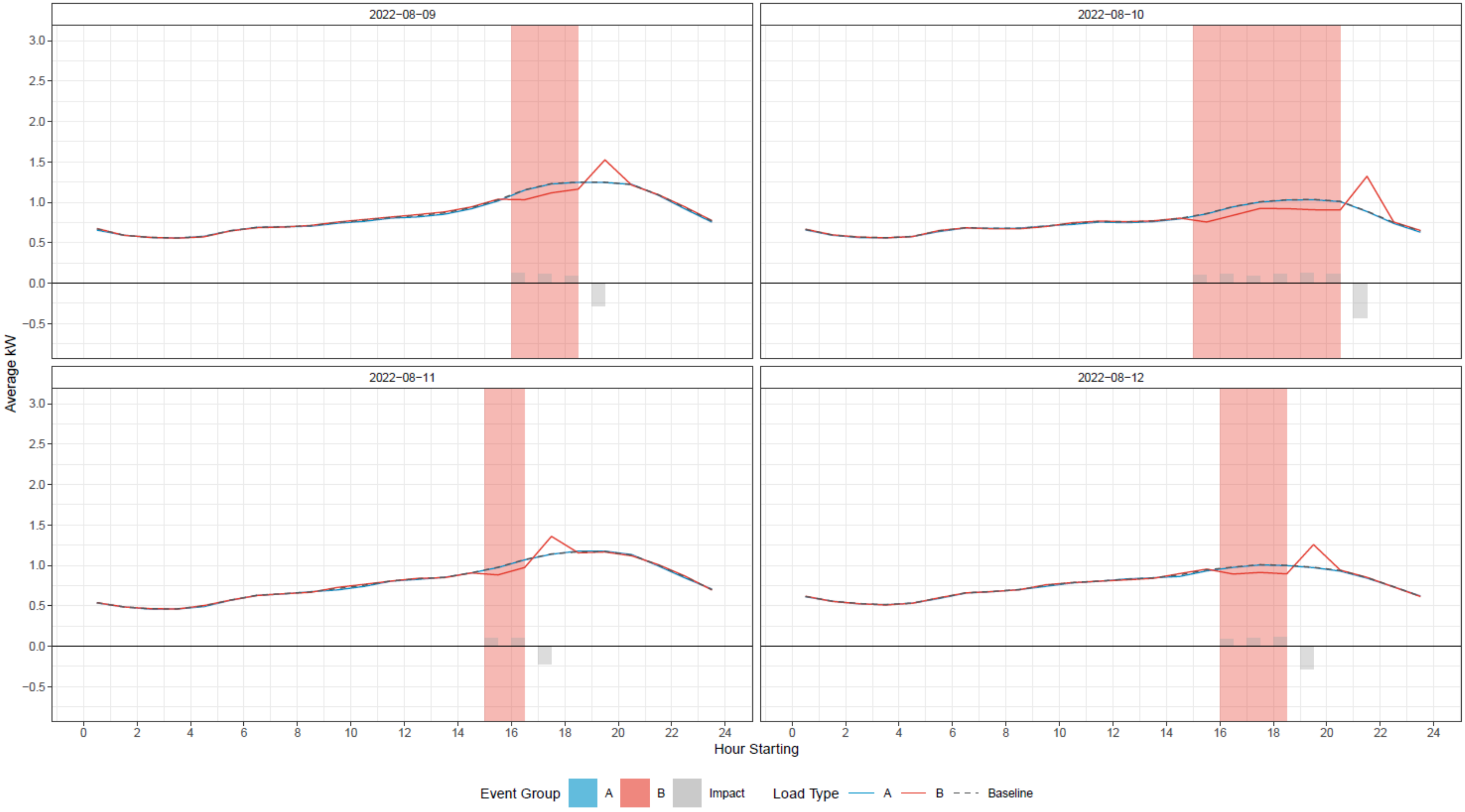

2022–09–26
2022–09–27
2022–09–28
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

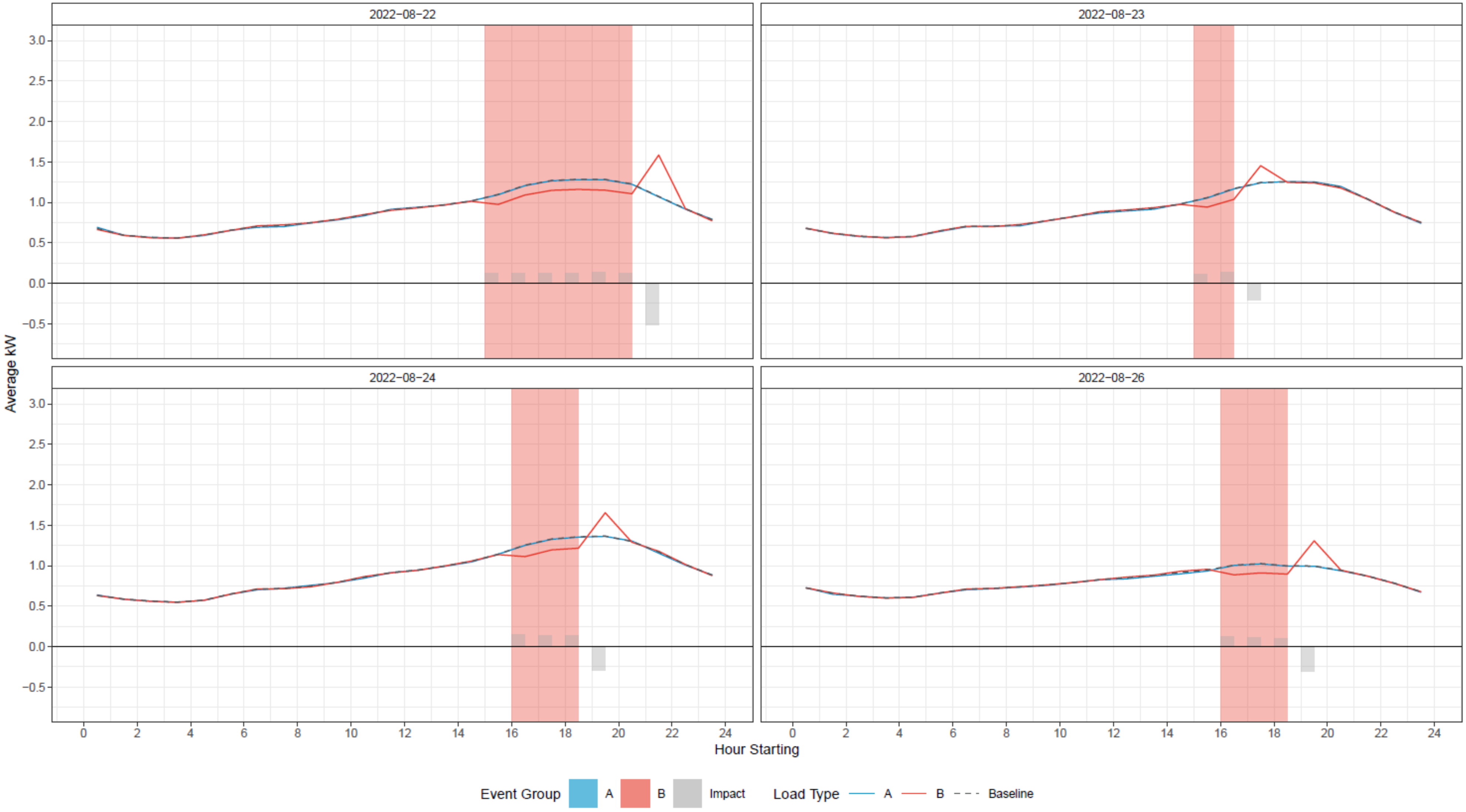

2022-06-13
2022-06-14
2022-06-15
2022-06-17
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

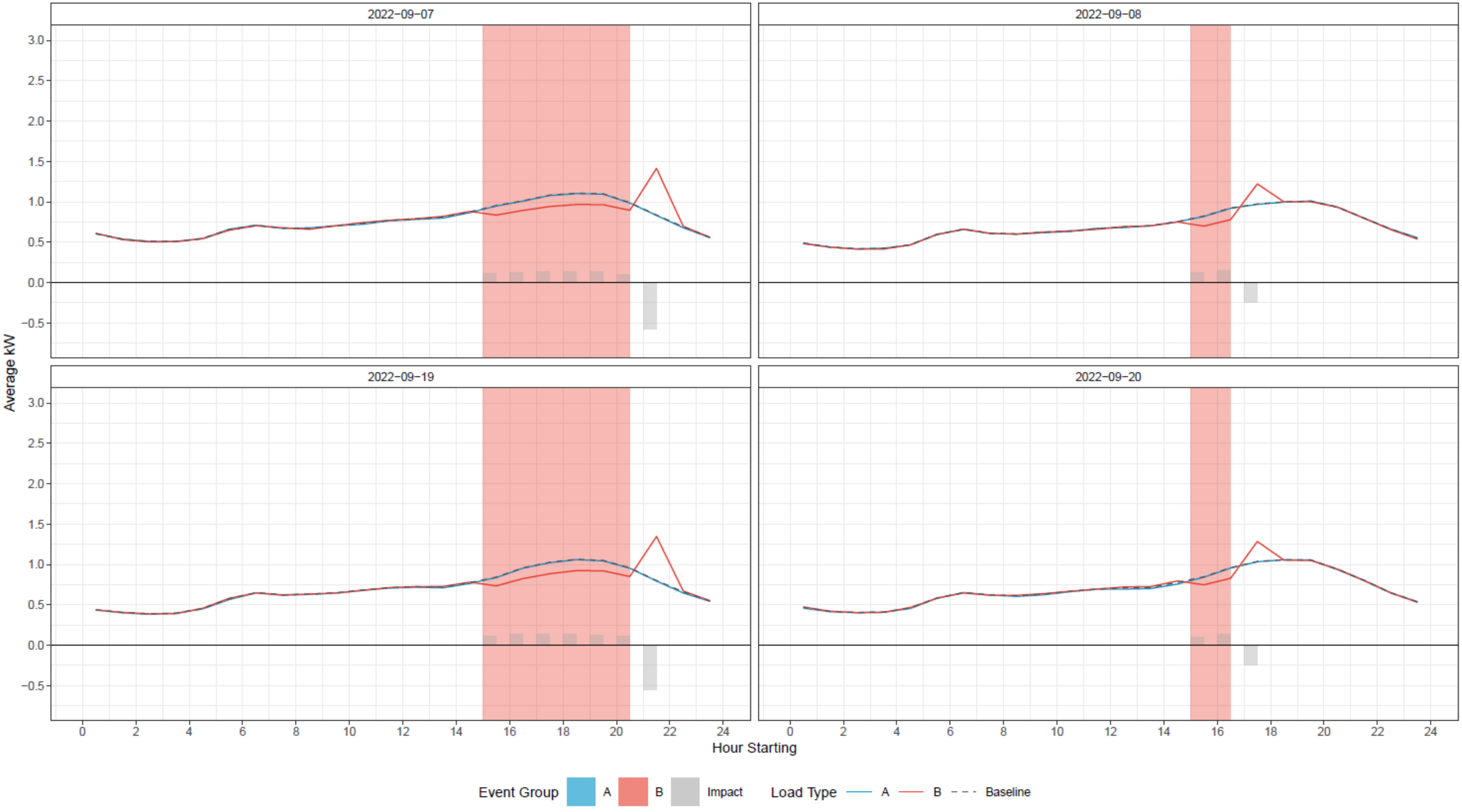

2022−06−27
2022−06−29
2022−06−30
2022−07−01
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline


2022−07−12
2022−07−13
2022−07−14
2022−07−15
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
Hour Starting
0
2
4
6
8
10
12
14
16
18
20
22
24
Event Group
A
B
Impact
Load Type
A
B
Baseline

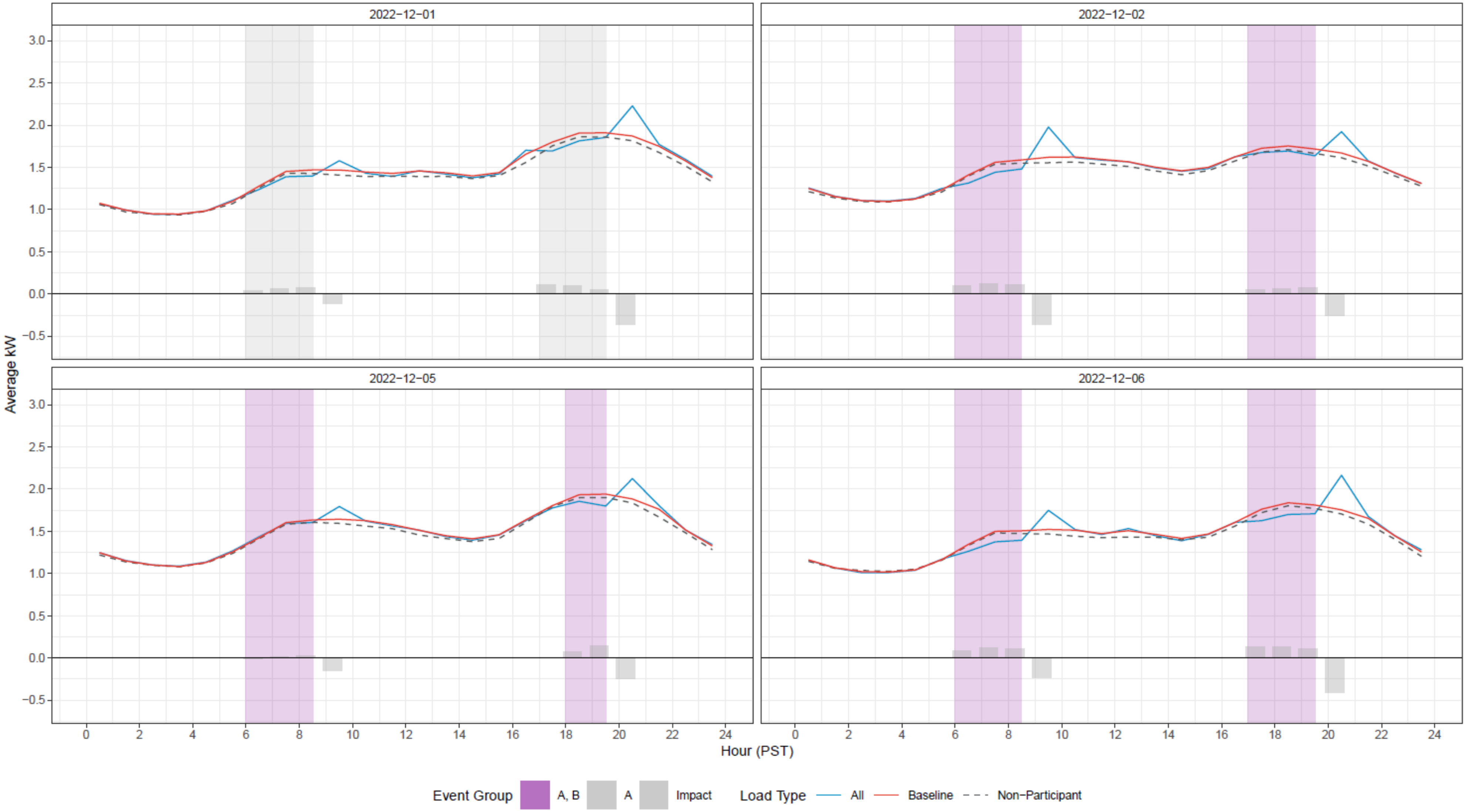

2022−07−25
2022−07−26
2022−07−28
2022−07−29
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

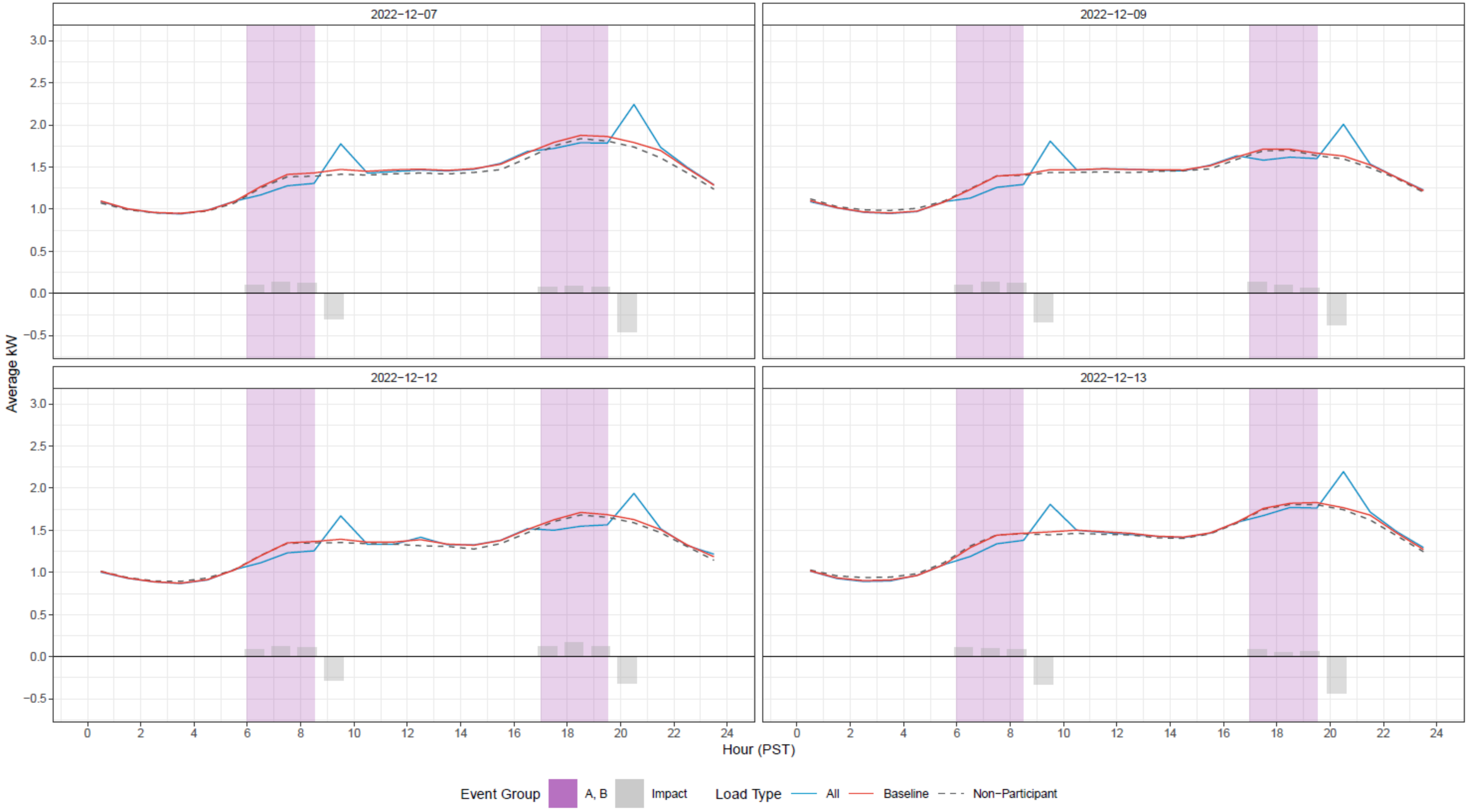

2022−08−09
2022−08−10
2022−08−11
2022−08−12
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

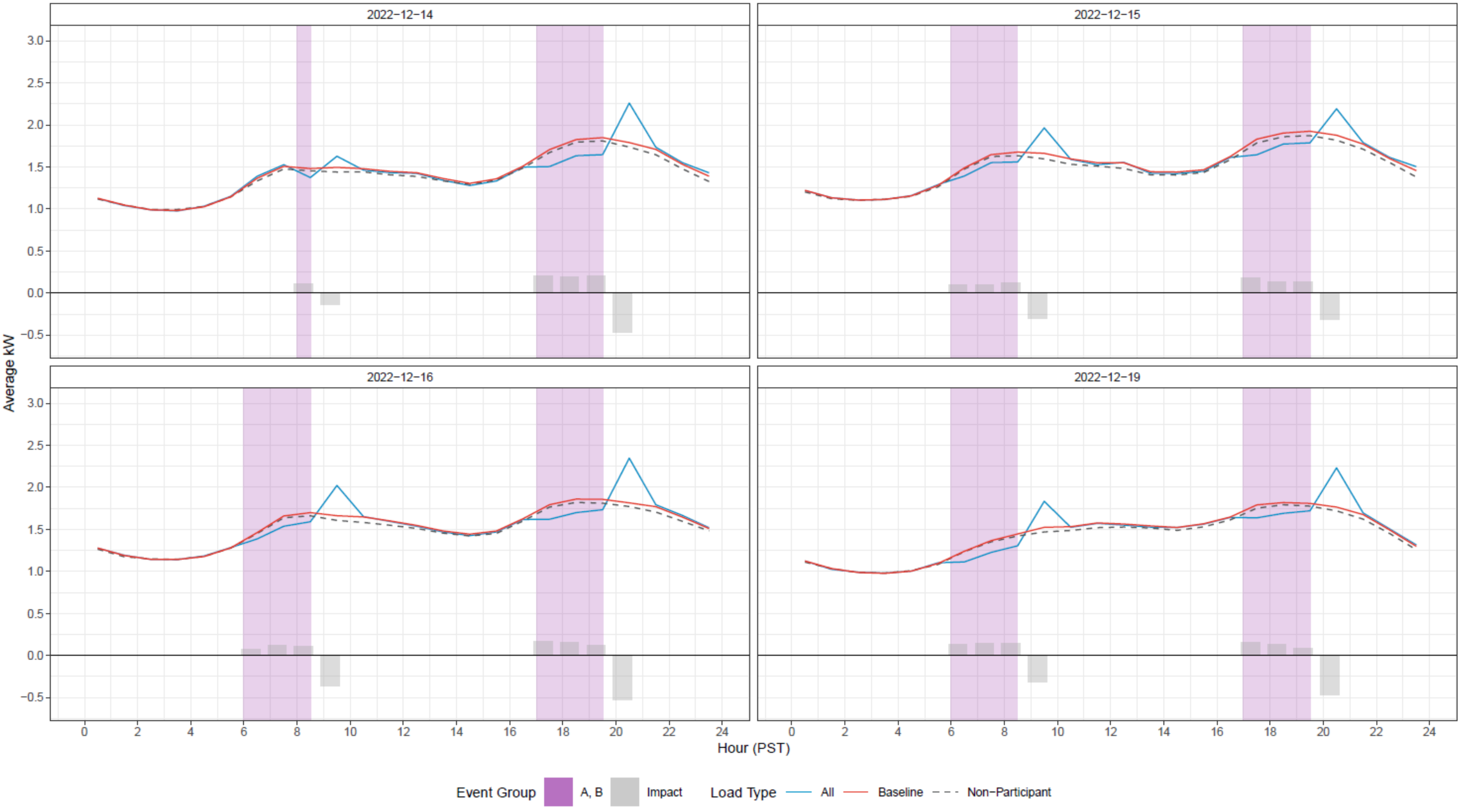

2022−08−22
2022−08−23
2022−08−24
2022−08−26
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

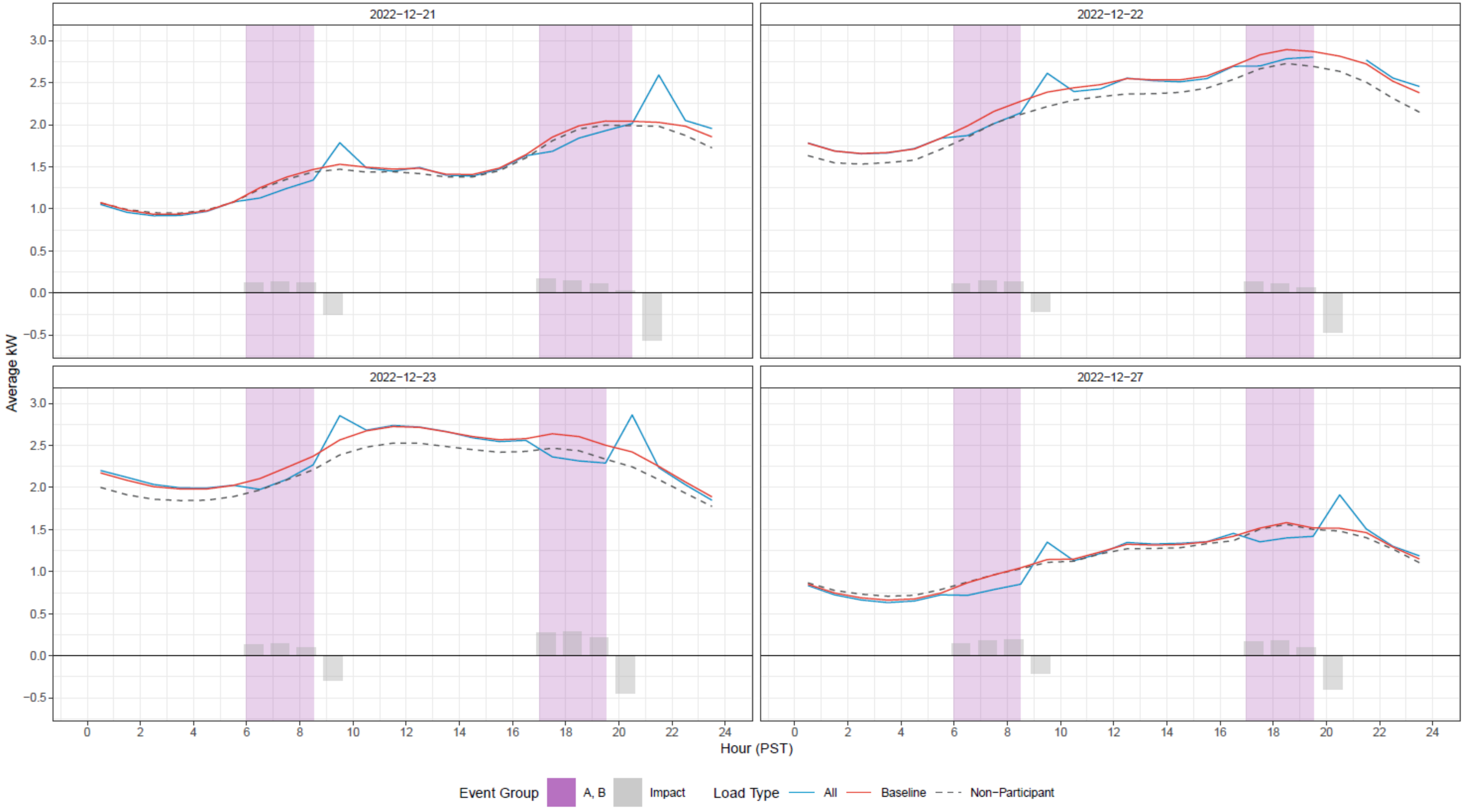

2022-09-07
2022-09-08
2022-09-19
2022-09-20
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour Starting
Event Group
A
B
Impact
Load Type
A
B
Baseline

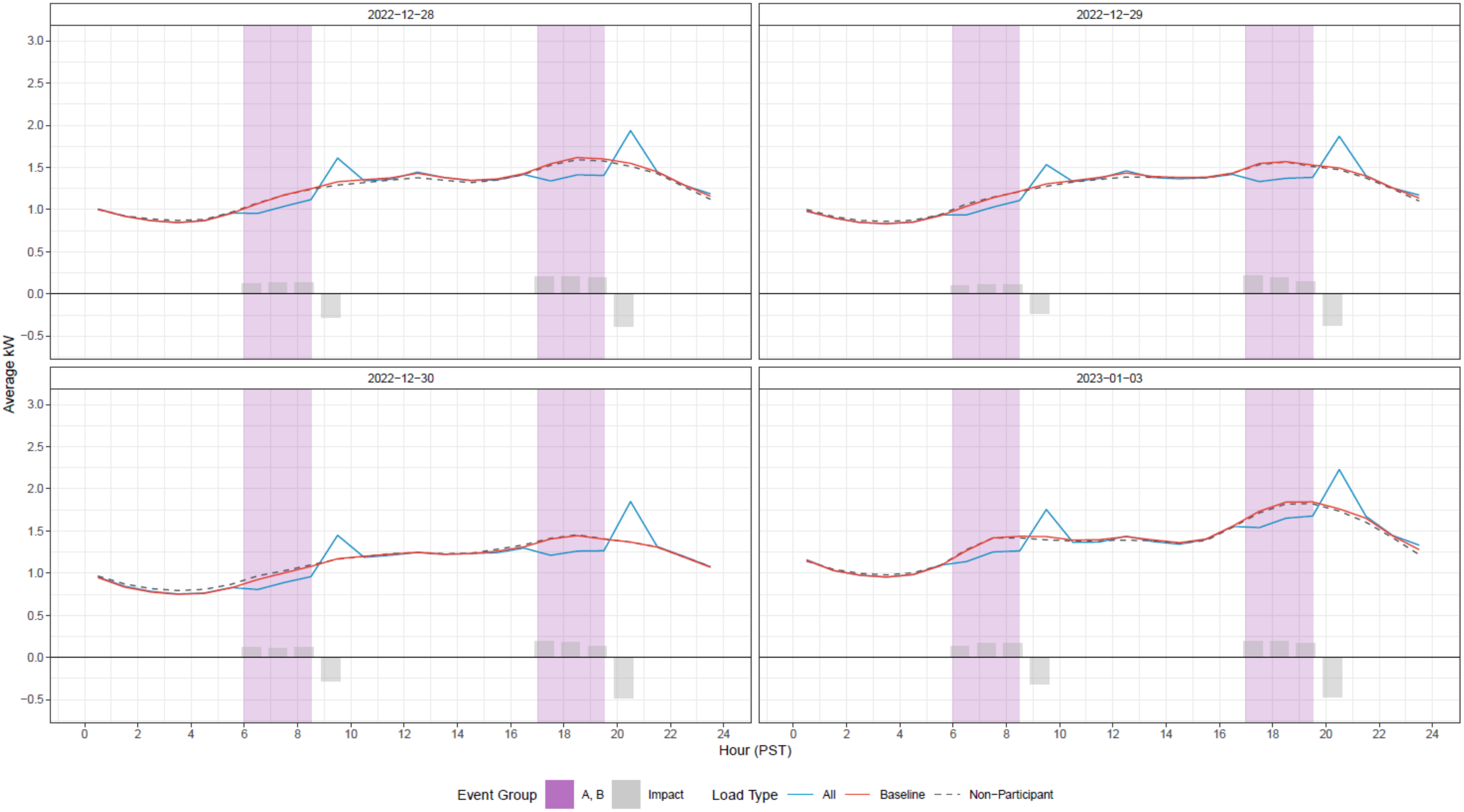
Appendix B. Winter 2022-23 Event Plots

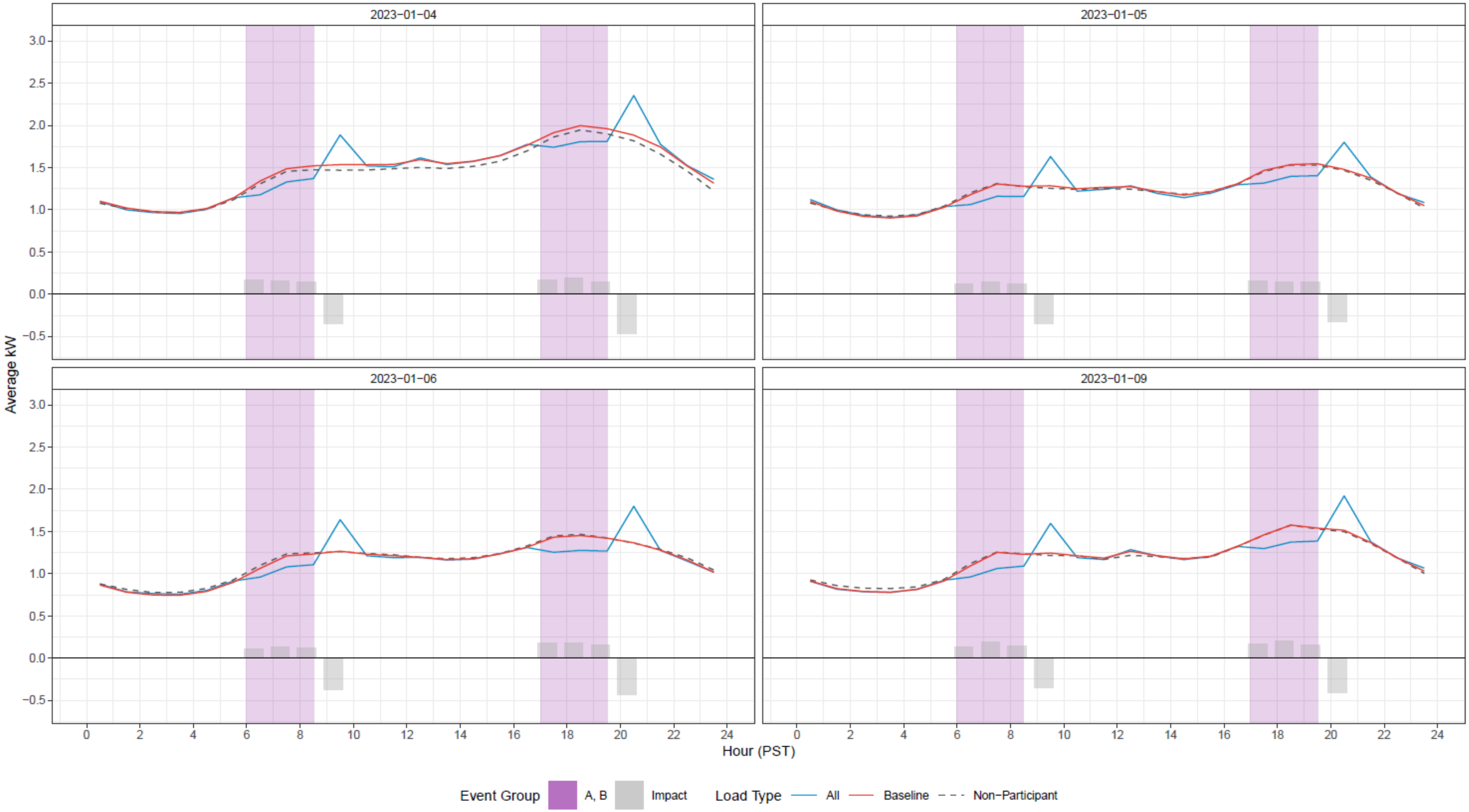

2022−12−01
2022−12−02
2022−12−05
2022−12−06
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
A
Impact
Load Type
All
Baseline
Non−Participant

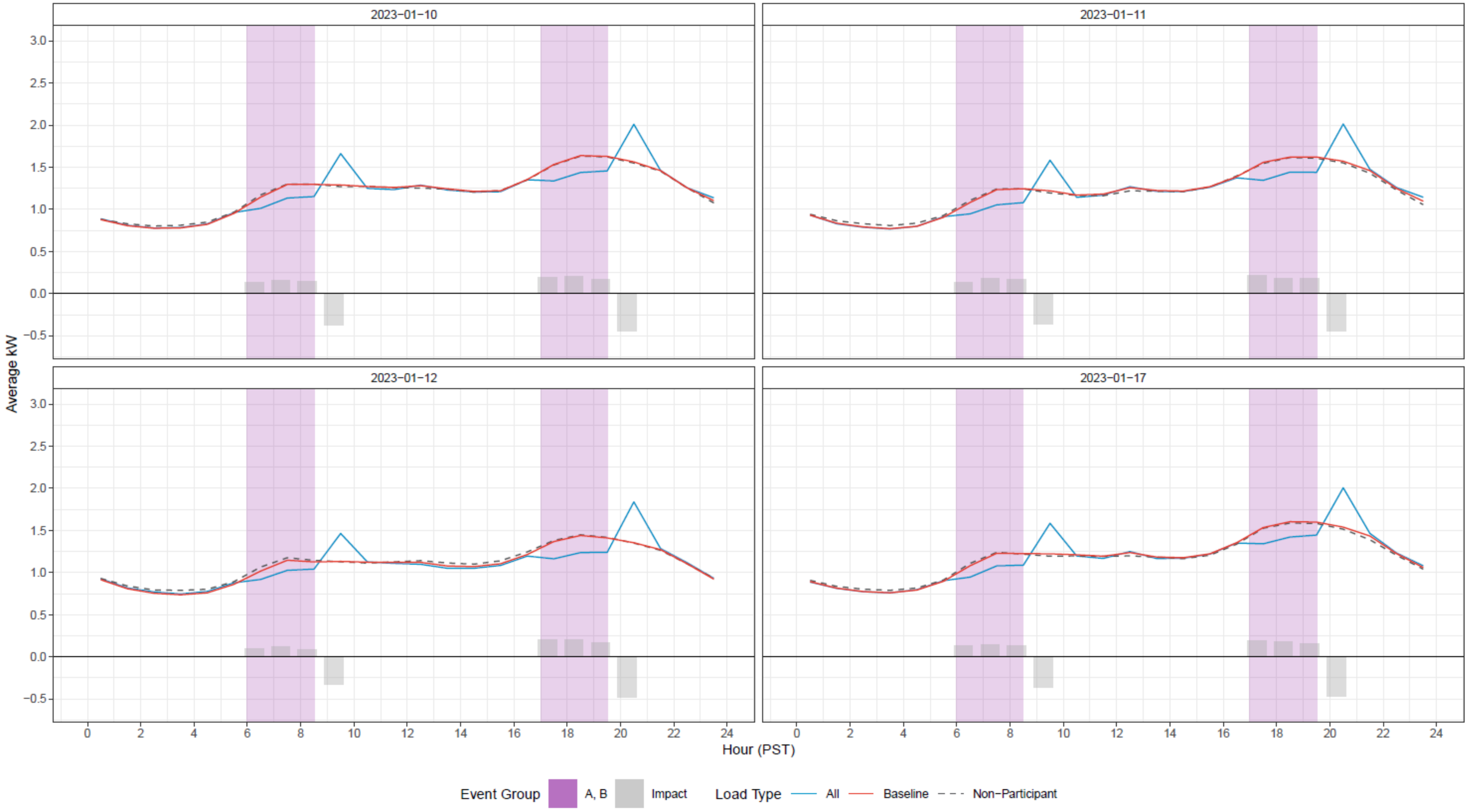

2022−12−07
2022−12−09
2022−12−12
2022−12−13
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

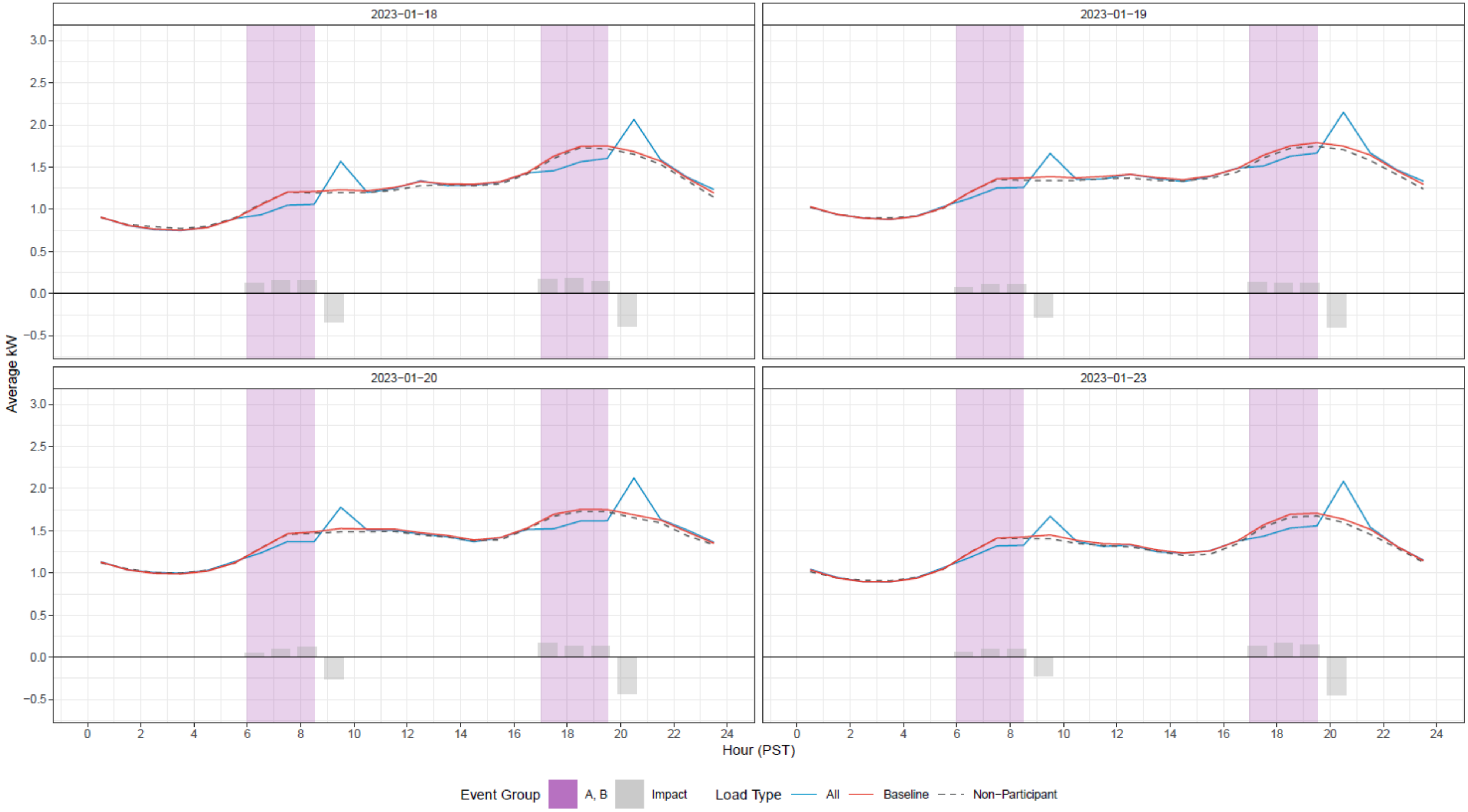

2022−12−14
2022−12−15
2022−12−16
2022−12−19
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

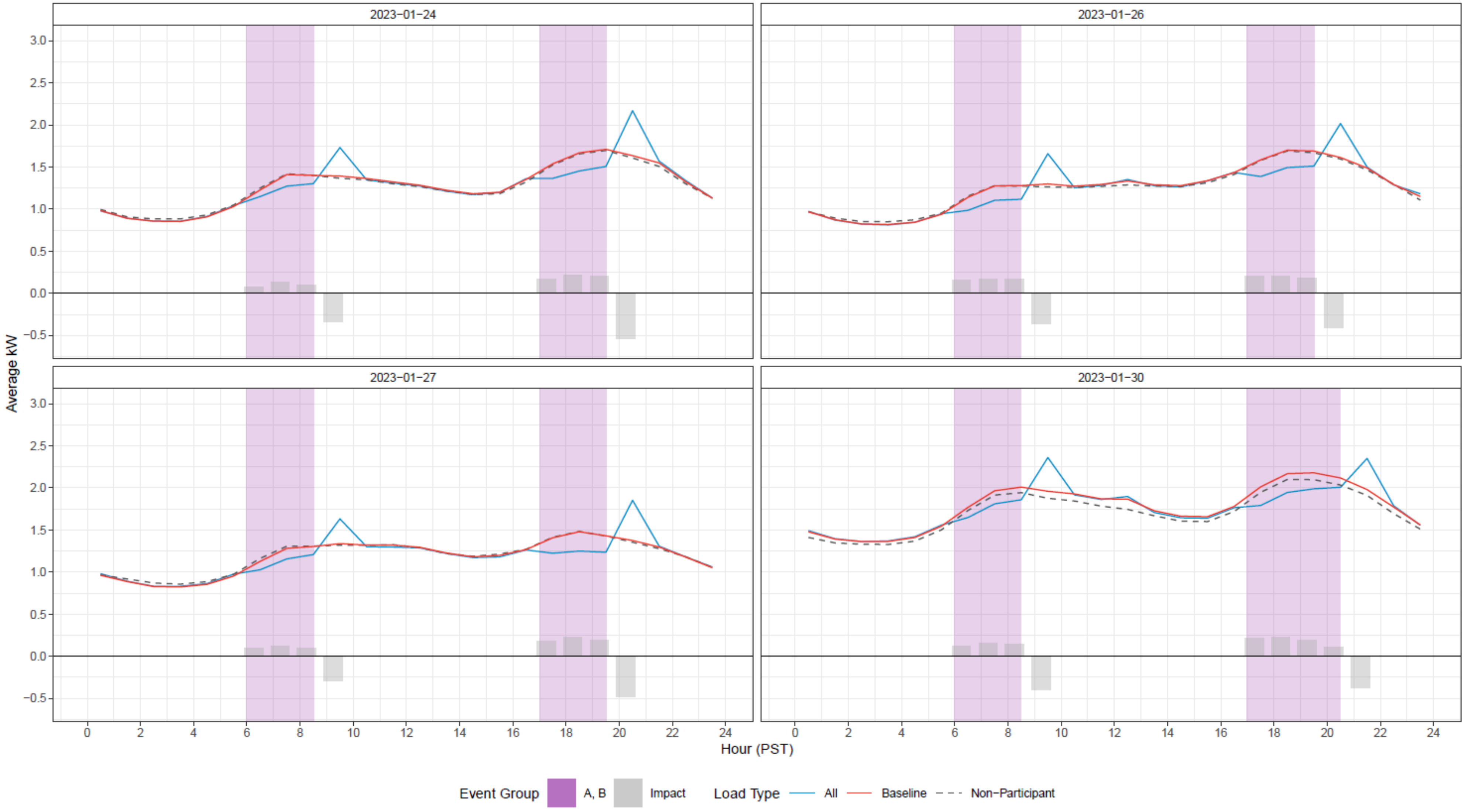

2022−12−21
2022−12−22
2022−12−23
2022−12−27
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

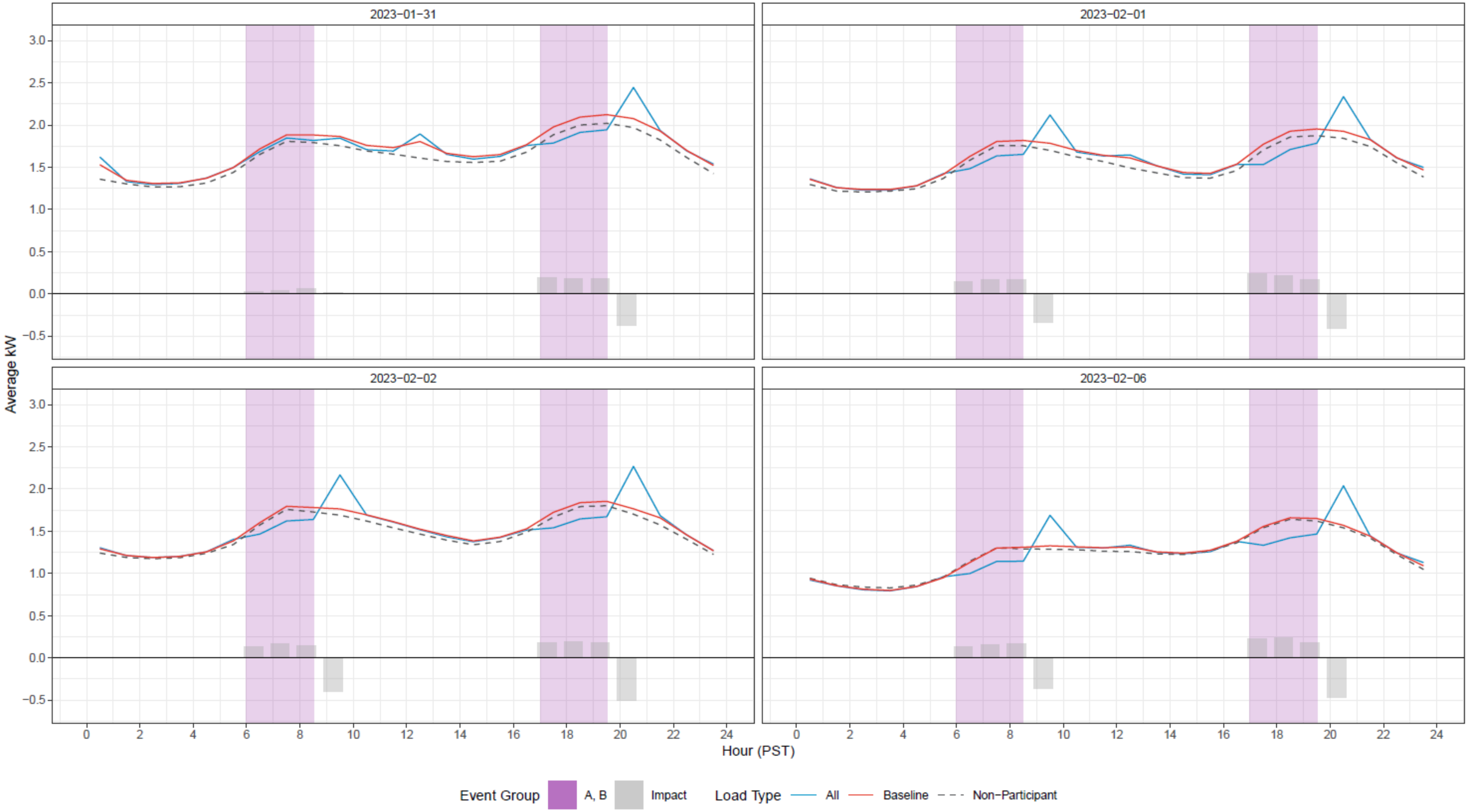

2022−12−28
2022−12−29
2022−12−30
2023−01−03
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

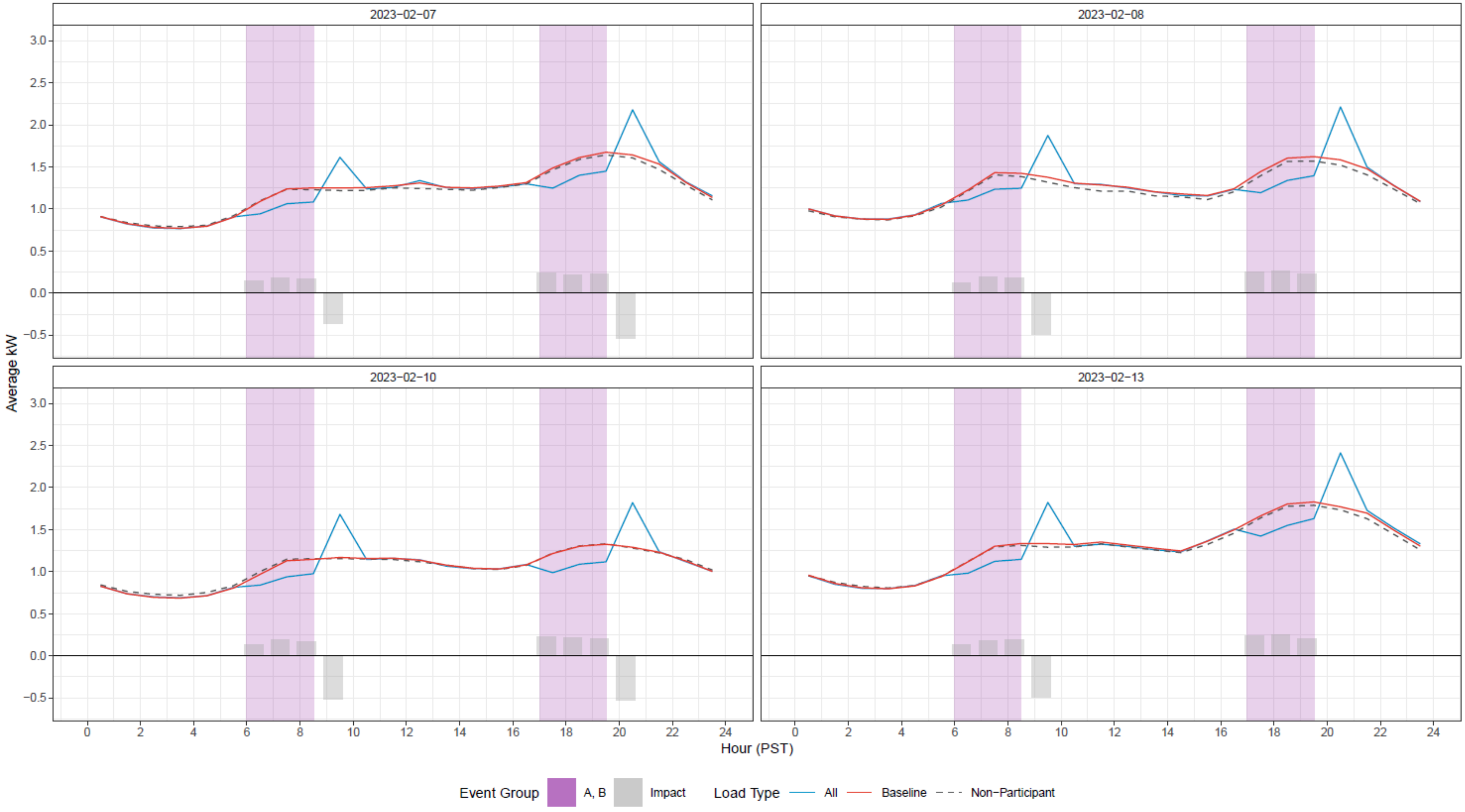

2023−01−04
2023−01−05
2023−01−06
2023−01−09
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

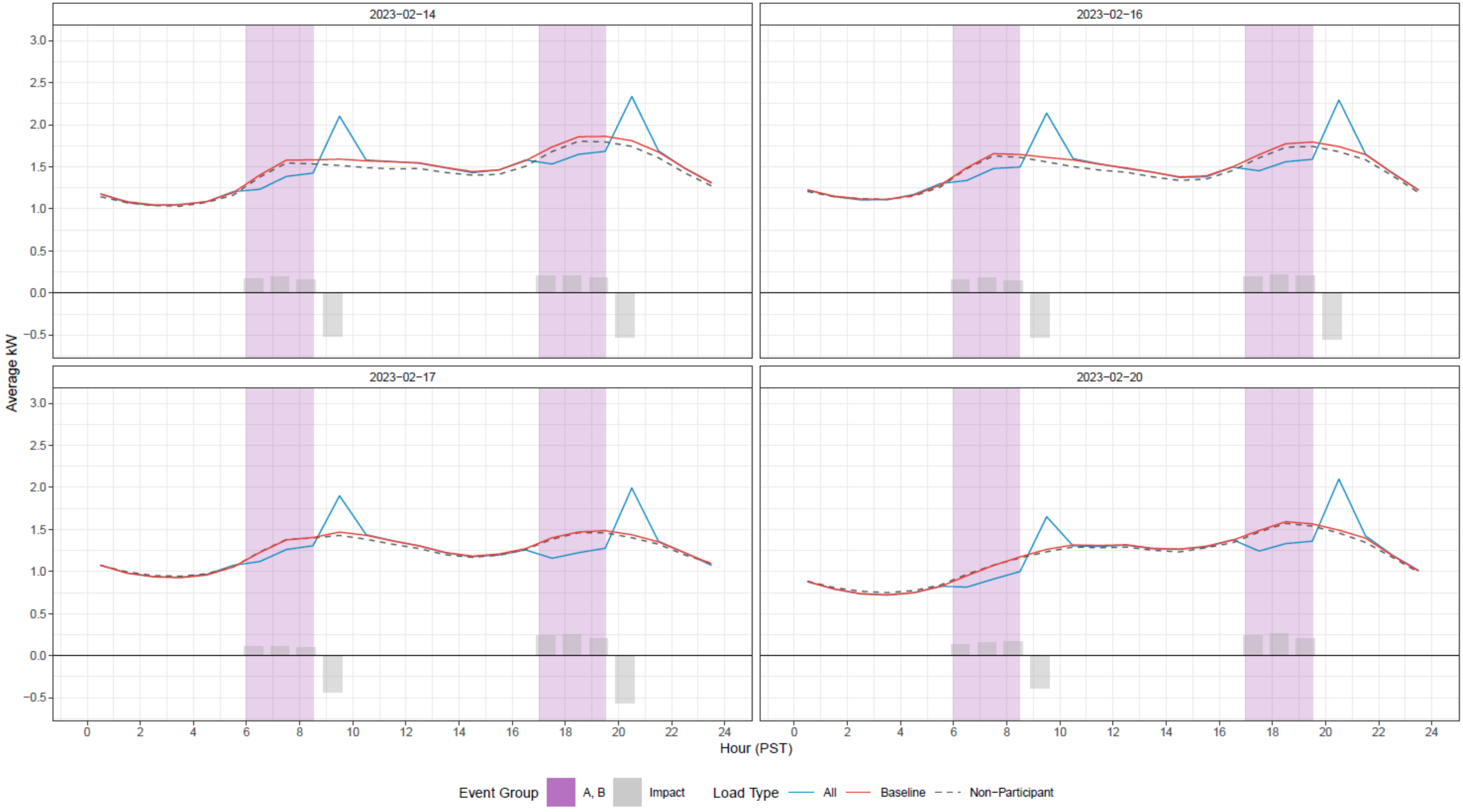

2023−01−10
2023−01−11
2023−01−12
2023−01−17
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
Hour (PST)
0
2
4
6
8
10
12
14
16
18
20
22
24
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

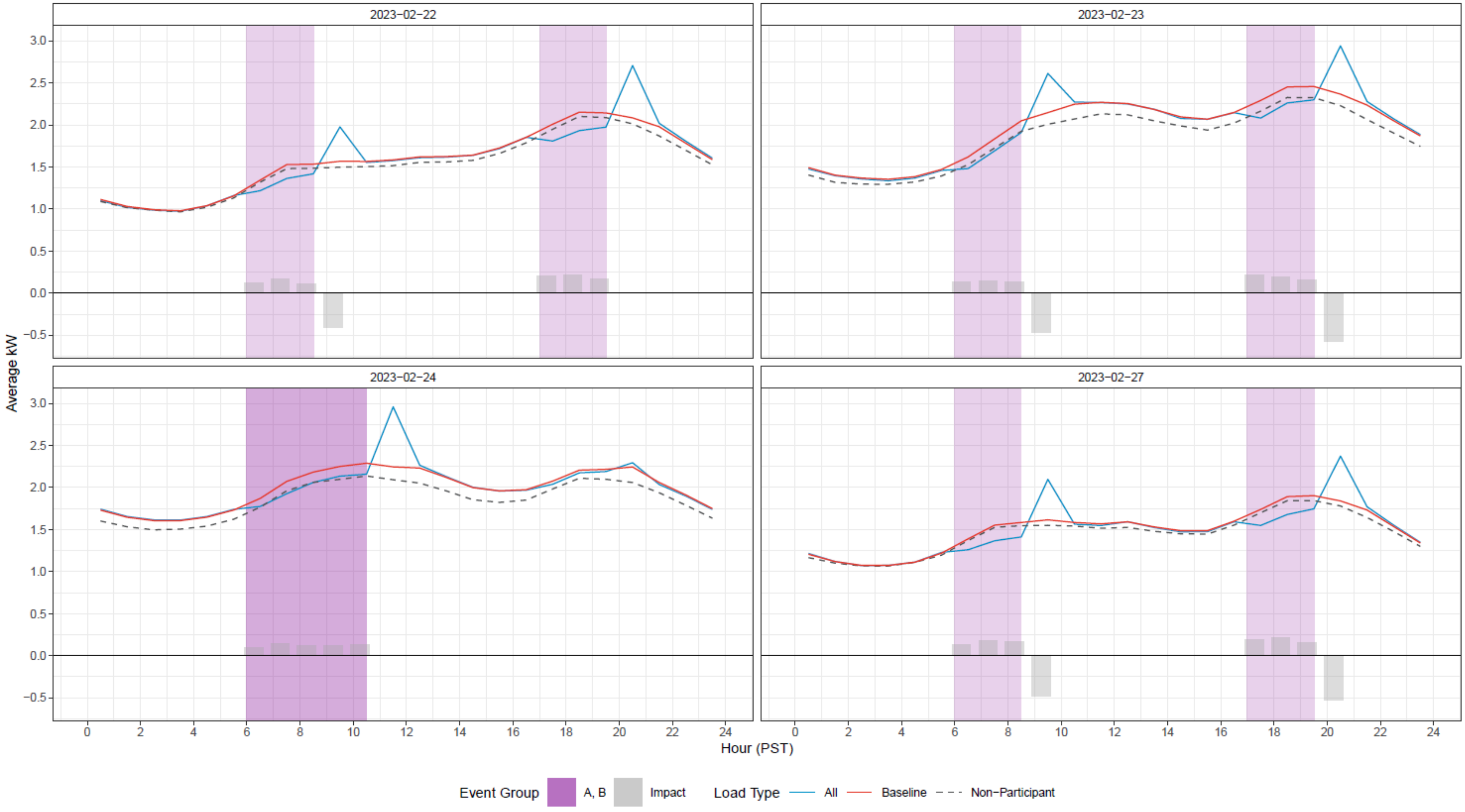

2023−01−18
2023−01−19
2023−01−20
2023−01−23
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

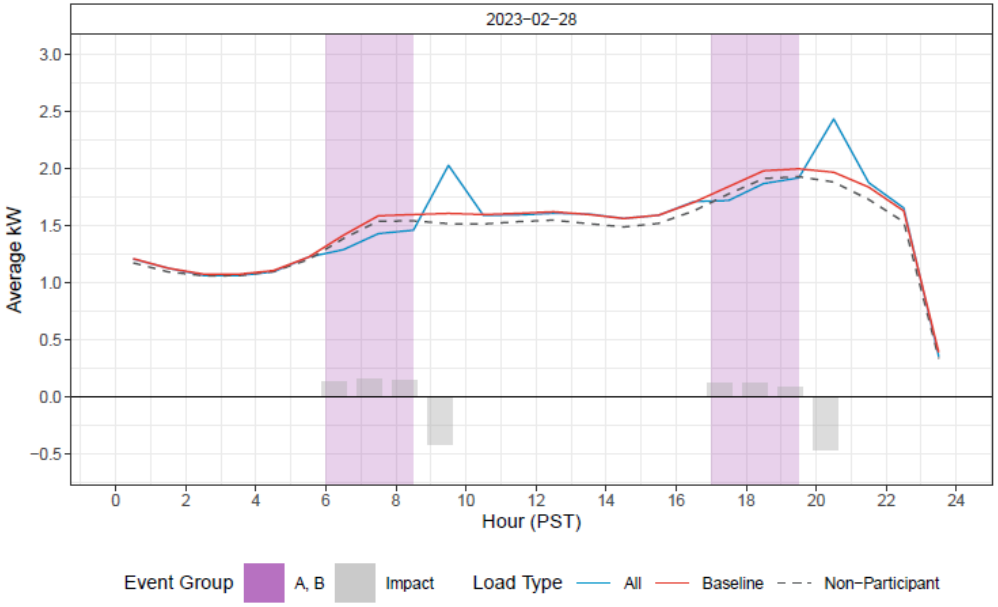

2023-01-24
2023-01-26
2023-01-27
2023-01-30
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant


2023−01−31
2023−02−01
2023−02−02
2023−02−06
Average kW
3.0
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
All
Baseline
Non−Participant

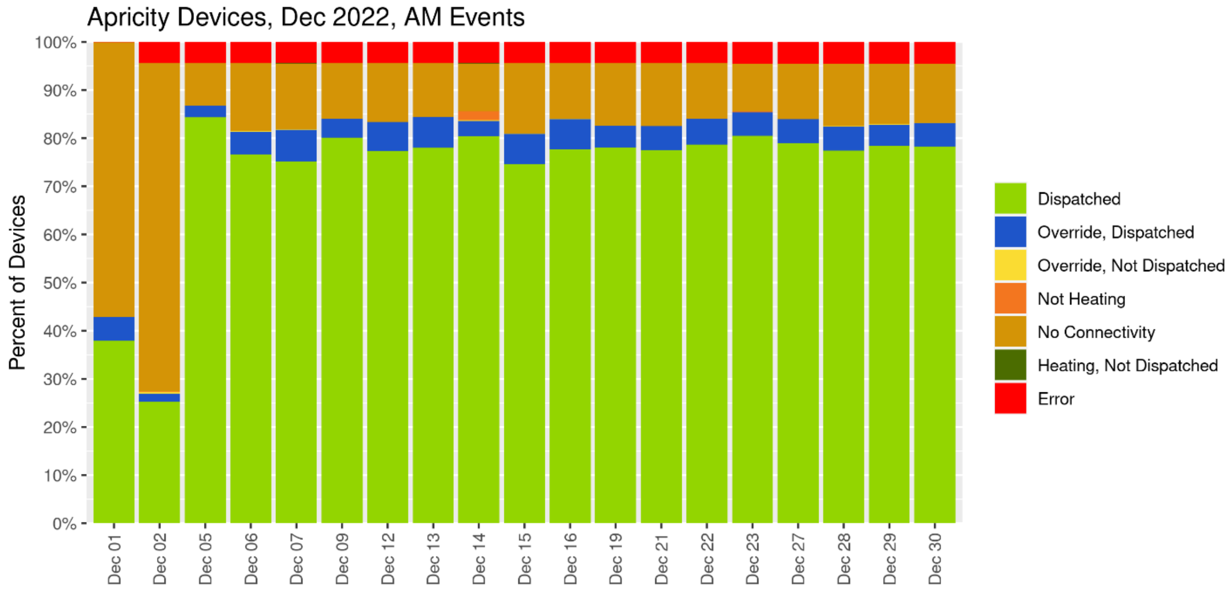

2023−02−07
2023−02−08
2023−02−10
2023−02−13
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

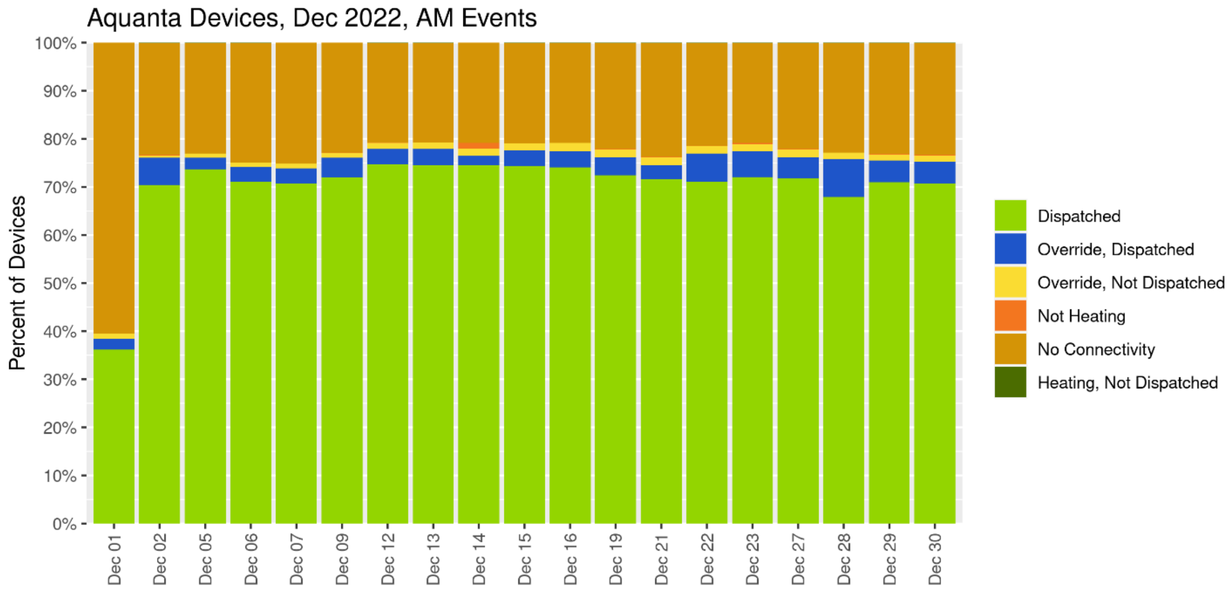

2023−02−14
2023−02−16
2023−02−17
2023−02−20
Average kW
Hour (PST)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

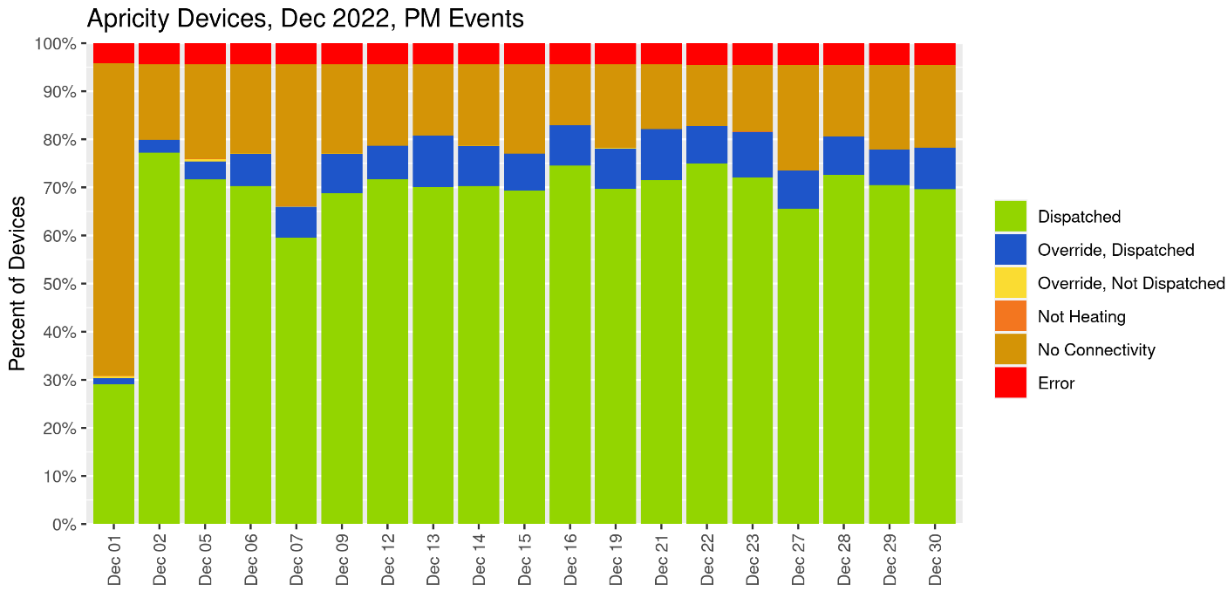

2023−02−22
2023−02−23
2023−02−24
2023−02−27
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

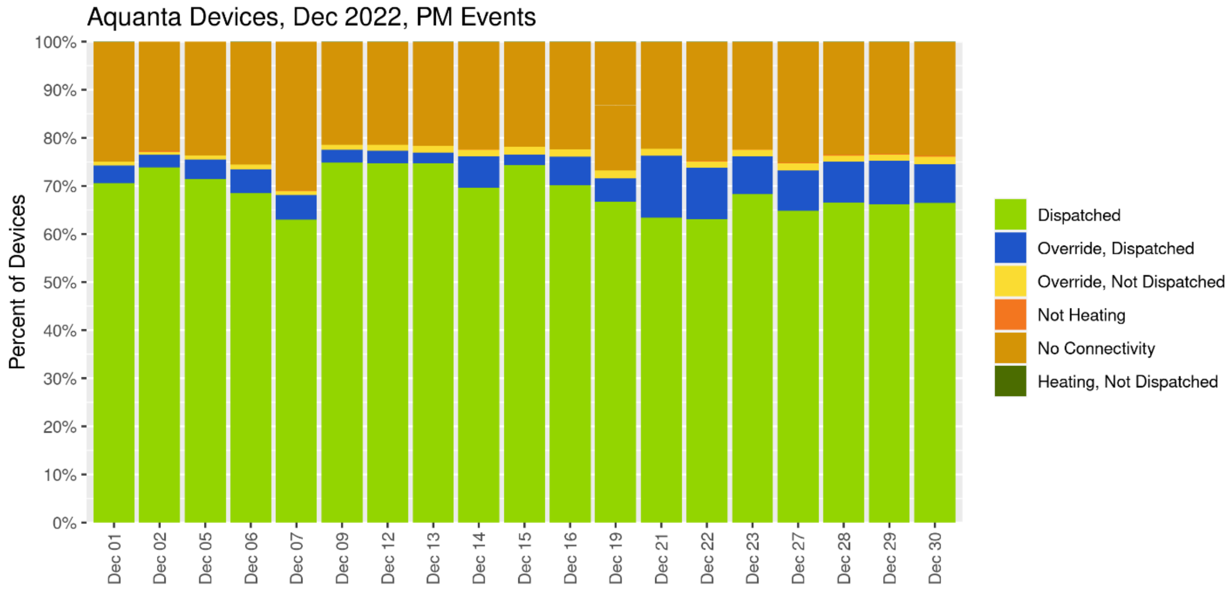

2023−02−28
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour (PST)
Event Group
A, B
Impact
Load Type
All
Baseline
Non−Participant

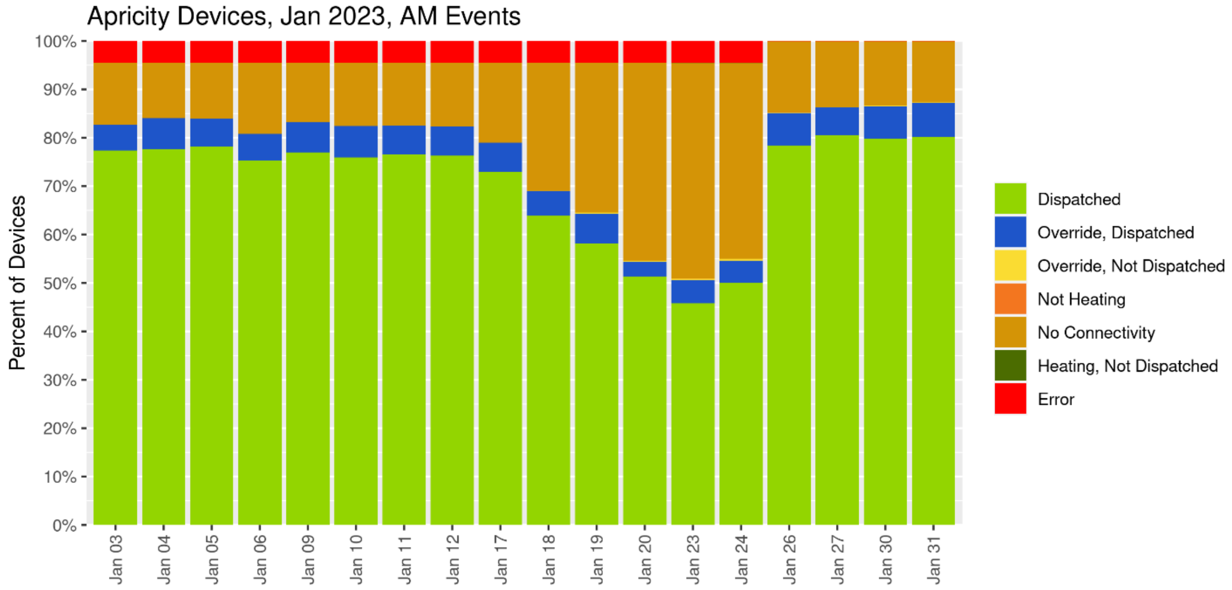
Appendix C. Event Device Status Plots by Time of Event (Winter 2022-23)

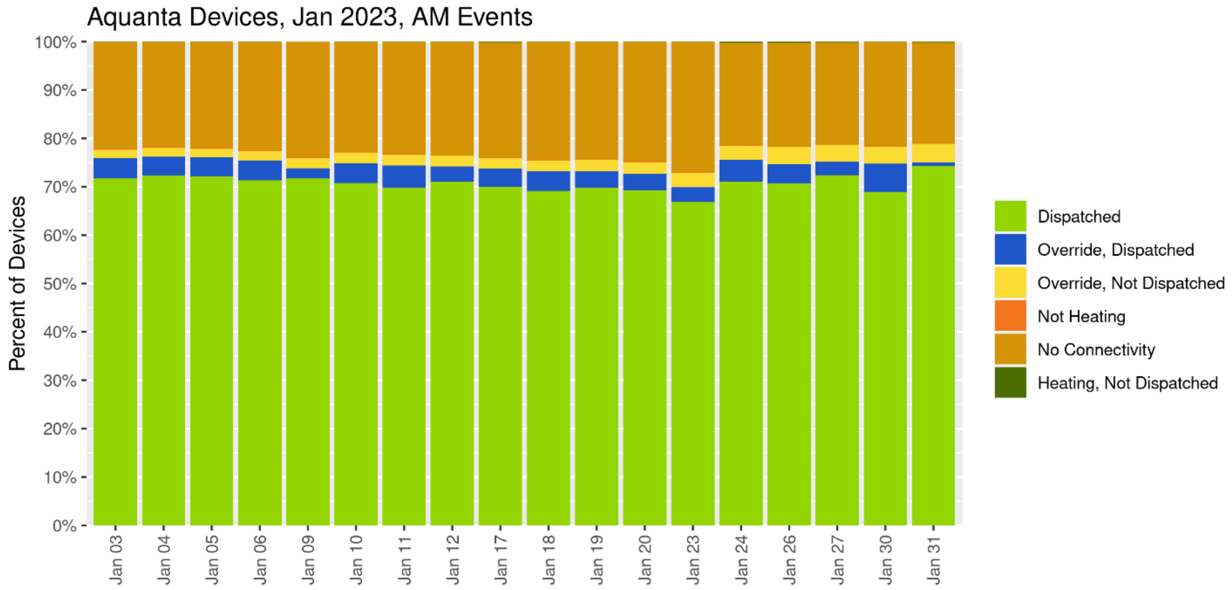


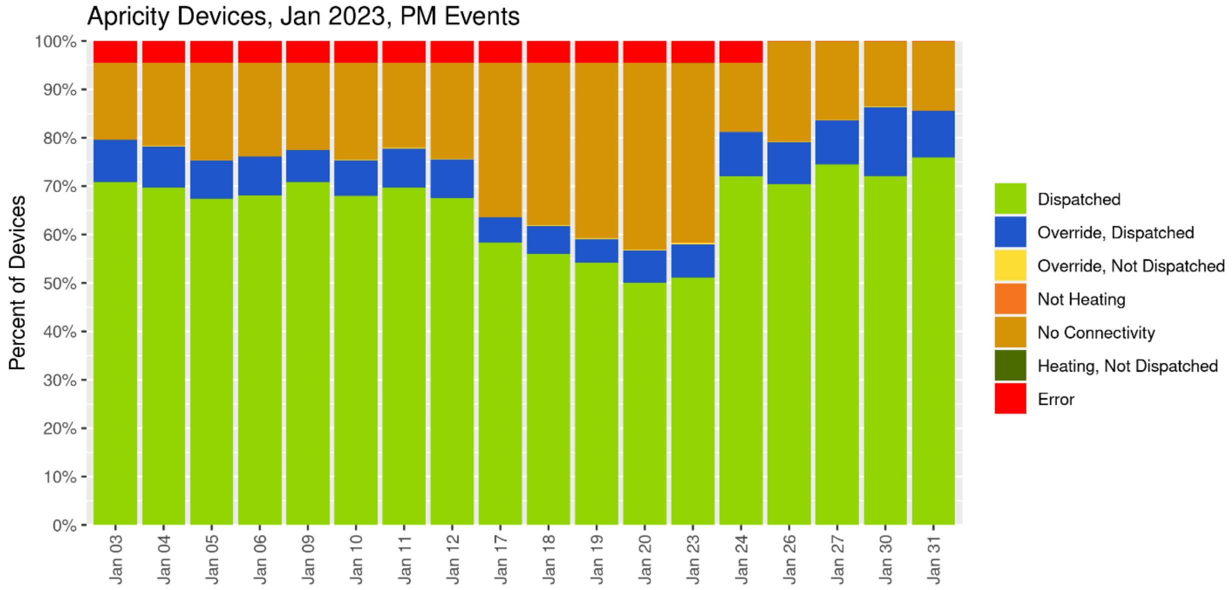



Apricity Devices, Dec 2022, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Dec 01
Dec 02
Dec 05
Dec 06
Dec 07
Dec 09
Dec 12
Dec 13
Dec 14
Dec 15
Dec 16
Dec 19
Dec 21
Dec 22
Dec 23
Dec 27
Dec 28
Dec 29
Dec 30
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Error


Aquanta Devices, Dec 2022, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Dec 01
Dec 02
Dec 05
Dec 06
Dec 07
Dec 09
Dec 12
Dec 13
Dec 14
Dec 15
Dec 16
Dec 19
Dec 21
Dec 22
Dec 23
Dec 27
Dec 28
Dec 29
Dec 30
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched


Apricity Devices, Jan 2023, AM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan 03
Jan 04
Jan 05
Jan 06
Jan 09
Jan 10
Jan 11
Jan 12
Jan 17
Jan 18
Jan 19
Jan 20
Jan 23
Jan 24
Jan 26
Jan 27
Jan 30
Jan 31
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched
Error


Aquanta Devices, Jan 2023, AM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan 03
Jan 04
Jan 05
Jan 06
Jan 09
Jan 10
Jan 11
Jan 12
Jan 17
Jan 18
Jan 19
Jan 20
Jan 23
Jan 24
Jan 26
Jan 27
Jan 30
Jan 31
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched


Apricity Devices, Jan 2023, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan 03
Jan 04
Jan 05
Jan 06
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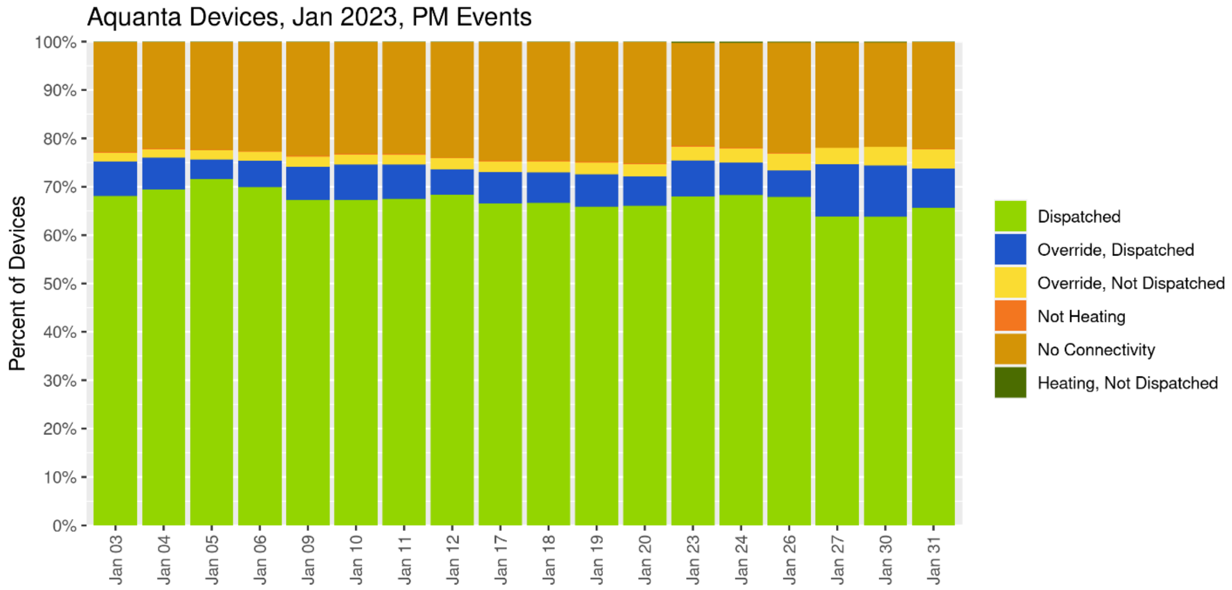
Jan 10
Jan 11
Jan 12
Jan 17
Jan 18
Jan 19
Jan 20
Jan 23
Jan 24
Jan 26
Jan 27
Jan 30
Jan 31
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched
Error


Aquanta Devices, Jan 2023, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan 03
Jan 04
Jan 05
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Jan 20
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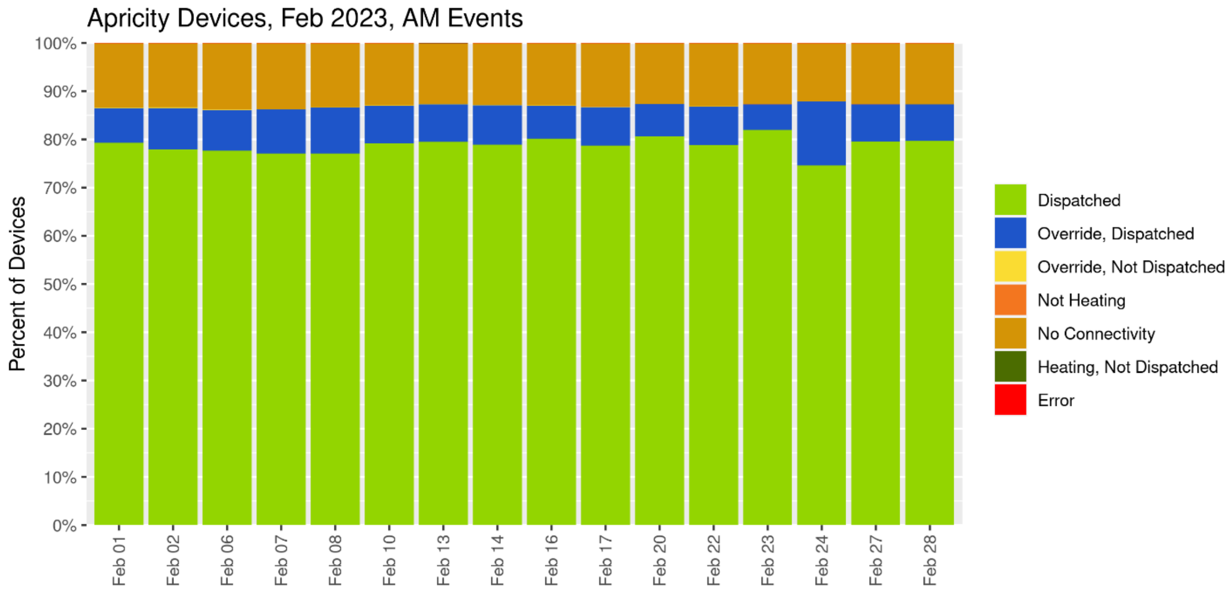
Jan 27
Jan 30
Jan 31
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched


Apricity Devices, Feb 2023, AM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Feb 01
Feb 02
Feb 06
Feb 07
Feb 08
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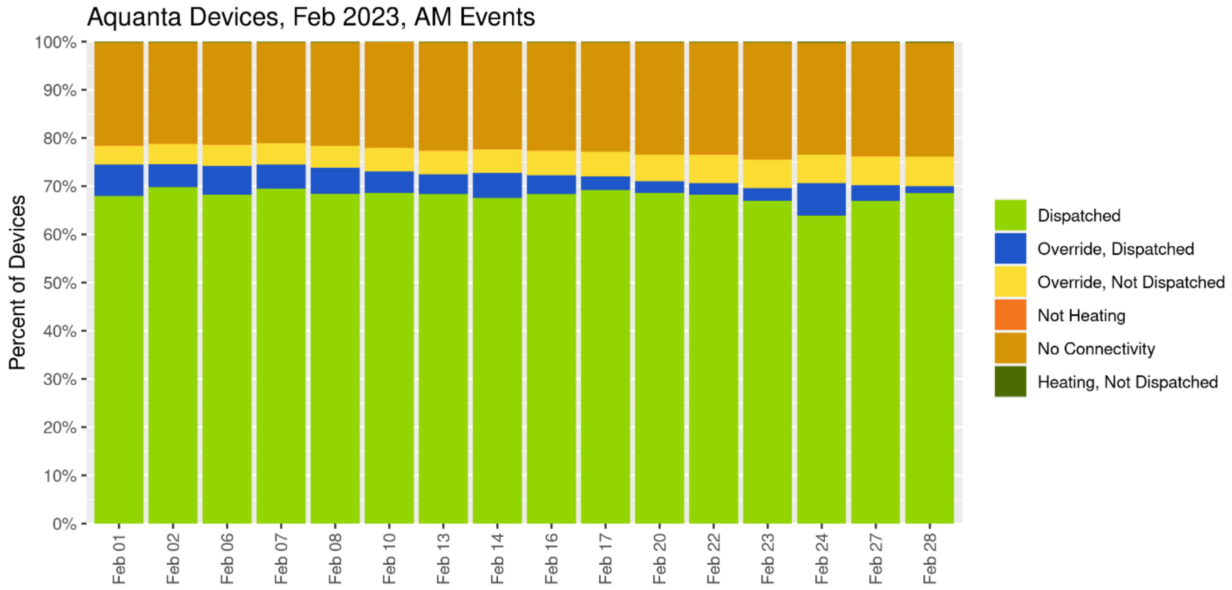
Feb 24
Feb 27
Feb 28
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched
Error


Aquanta Devices, Feb 2023, AM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
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20%
10%
0%
Feb 01
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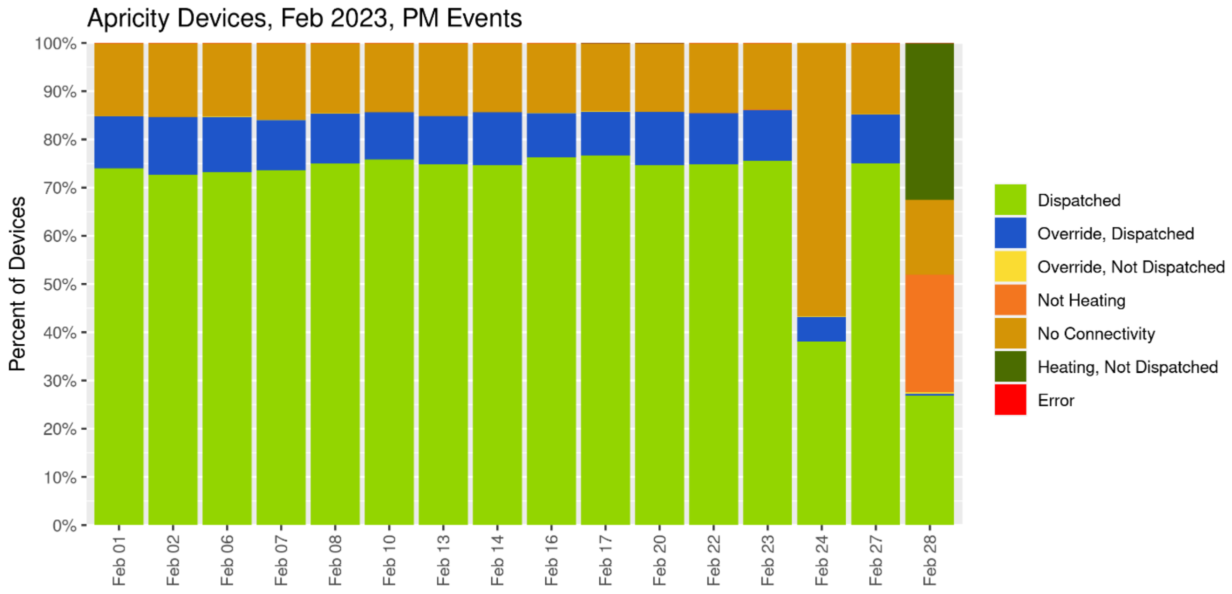
Feb 28
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched


Apricity Devices, Feb 2023, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Feb 01
Feb 02
Feb 06
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Feb 08
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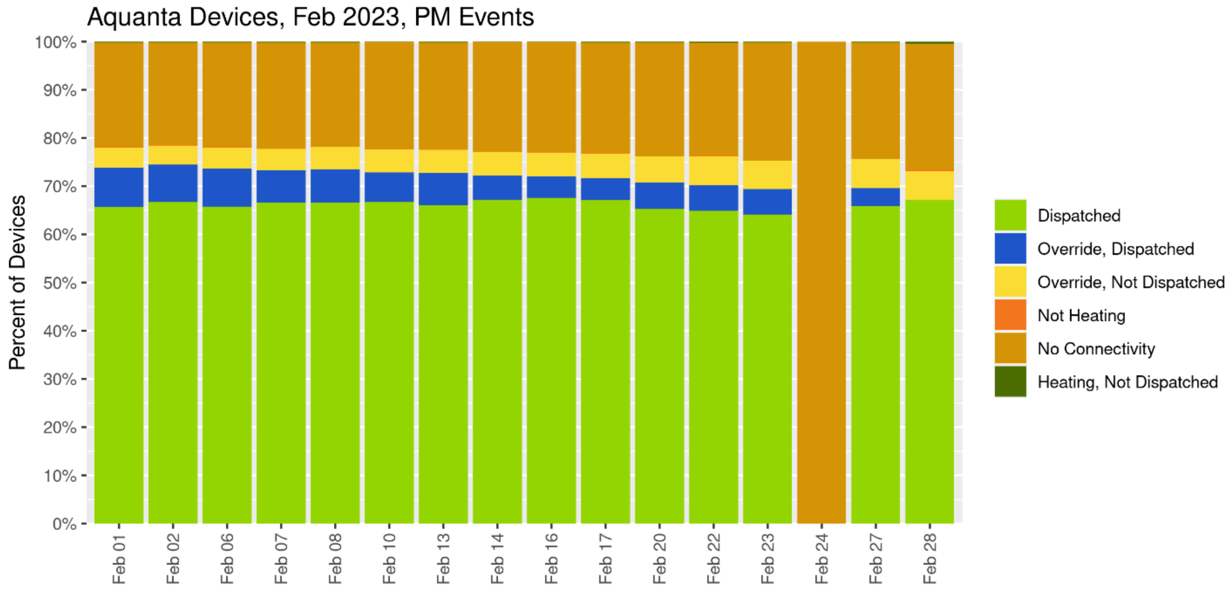
Feb 24
Feb 27
Feb 28
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched
Error


Aquanta Devices, Feb 2023, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Feb 01
Feb 02
Feb 06
Feb 07
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Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched

Appendix D. Program Season Comparison Caveats

Due to changes in event type, data structure, and event hours, readers should use caution when comparing results across seasons, especially in Table 1. These event type and data structure differences resulted in discrepancies between seasons that do not reflect individual device performance.

During the Summer 2020 season, the pilot began testing an “all-call” dispatch strategy whereby all enrolled and enabled devices were targeted for an event. This resulted in the number of devices called for individual events increasing and a jump in load shifted per event. For example, the Summer 2020 load shifted per event jumped by almost 5x even though the number of devices only increased by 2x. This increase was due to two factors (1) improved connectivity (i.e., increasing the proportion of devices able to reduce power) **and** (2) the implementation of all-call events – raising the total number of devices called per event.

The data structure changed for the Winter 2020-2021 evaluation, which resulted in an updated method for determining device connectivity, and subsequently an aritificial drop in connectivity from the Winter 2019-2020 evaluation season. This drop was due to the way the data was analyzed, not a meaningful change in device connectivity. Connectivity results from the Summer 2021 evaluation season onward reflect a more detailed data set and increased accuracy in estimating connectivity than used in previous evaluations.

Winter 2021-2022 AM events started at 5AM. This early start period likely contributed to lower impacts during the first hour of AM events relative to Winter 2020-2021 AM events, which started at 6AM. Also, since event impacts slowly degrade over time, longer events have lower average load shifted. Winter 2020-2021 events were for three or six hours, while Winter 2021-2022 events were for four or six hours. Lower impacts during the fourth event hour decreased average event impacts across the two seasons.

Event length varied by season. In the Winter 2022-2023 season, 94% of events were three hours. That means the results for impacts in hours 4-6 are less robust than in other seasons which had a greater number of longer events.