Portland General Electric
121 SW Salmon Street • Portland, OR 97204
portlandgeneral.com

June 2, 2023

Email
puc.filingcenter@state.or.us

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

Attn: Commission Filing Center

Re: UM 1827 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 2021 and Winter 2021-22 demand response (DR) season. The evaluation provides impact estimates and process recommendations.

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

- **The pilot's core processes are working well, though market changes and shifts in pilot focus have added new challenges.** The Pilot has done well to address prior market challenges, forged strong relationships with key property managers in the region and includes refined processes. However, new challenges have emerged as the Pilot pivoted to recruitment of new construction, addressing connectivity challenges of the existing fleet, and CTA-2045 module availability.
- **Recruitment of new construction and full fleet replacement projects has been difficult.** Long lead times in new construction pose recruitment, logistical, and financial challenges in the market as the Pilot is currently designed.
- **Pilot staff are testing a new approach to improve connectivity of Wi-Fi switches, which require regular in-person maintenance.** To maintain connectivity, Wi-Fi requires regular maintenance every 6-7 months.
- **Demand reductions from events in Summer 2021 and Winter 2021-22 decreased on a per controlled device basis, relative to Summer 2020 (0.22 kW to 0.17 kW) and Winter 2020-21 (0.29 kW to 0.20 kW).** Connectivity decreased from Summer 2020 to Summer 2021 (88% to 75%), but increased between Winter 2020-21 and Winter 2021-22 (68% to 71%). Controllability increased relative to the prior season for both winter and summer (69% to 74% in summer and 60% to 71% in winter).
- **Evening events had greater hourly curtailment (and snapback) than morning events likely due to increased hot water usage in the evening.** The average hourly curtailment for evening events was greater than morning events. The major difference in curtailment occurred in the first two event hours.
- **Connectivity of Wi-Fi switches continues to lag behind the cellular switches.** Cellular switches had connectivity rates of around 85-90%, while Wi-Fi devices showed average connectivity of around 50-55%.

PGE has made significant changes to the pilot using the key findings identified in this evaluation. Noting the connectivity issues, declining seasonal performance along with the continual delays in transitioning to

CTA-2045, the Pilot has entered maintenance mode with the existing fleet of Wi-Fi and cellular signal connected switches and preparing for pilot redesign CTA-2045 enabled water heaters.

PGE intends to transition the Pilot to CTA-2045 enabled water heaters and communication devices and has discontinued the installation of retrofit water heaters with cellular signal connected switches and plans to engage PUC Staff on Pilot redesign at a later date.

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

- (1A) Consider shifting to the upfront midstream incentive model. **Update:** The Pilot will complete a full review of this recommendation in the redesign process.
- (1B) Consider reducing the unit count requirement. **Update:** The Pilot will complete a full review of this recommendation in the redesign process.
- (2A) Continue to work with property managers to encourage their maintenance staff to perform regular Wi-Fi router maintenance rather than sending in pilot staff to perform the maintenance. **Update:** Conducted a second maintenance plan effort in 2022 with 13 properties in which properties were responsible for performing the Wi-Fi router maintenance.
- (2B) Consider swapping out Wi-Fi switches for cellular in the properties with the most persistent connectivity issues. **Update:** The Pilot assessed the recommendation; however, with the conclusion of retrofits and transition to CTA-2045 delays the Pilot has transitioned into maintenance mode and will reengage these properties when the pilot has been redesigned.
- (3) Contact Pilot DRMS provider to see if device settings have changed. **Update:** The Pilot discussed with provider.
- (4) Consider future event design with longer hours. **Update:** The Pilot will complete a full review of this recommendation and use cases for longer and shorter events in the redesign process.

The Pilot's evaluation results have been instrumental in identifying program design and operational challenges, and opportunities for improvement. Shortly, PGE will be filing to extend the Pilot's term and participation and will continue to maintain the existing fleet, including seasonal dispatch. This resource is critical to PGE's decarbonization strategy as well as our commitment to better serve and offer opportunities to our multifamily customers.

If you have any questions or require further information, please Megan Stratman at megan.stratman@pgn.com. Please direct all formal correspondence and requests to the following e-mail address pge.opuc.filings@pgn.com.

Sincerely,

Robert Macfarlane
Manager, Pricing and Tariffs

Encls
cc: UM 1827 Service List and Peter Kernan, OPUC

Multifamily Residential Demand Response Water Heater Pilot Evaluation

Summer 2021 - Winter 2022 Report to the Oregon Public Utilities Commission

FINAL

Prepared for:

Submitted by:
Guidehouse Inc.
1375 Walnut Street, Suite 100
Boulder, CO 80302

303.728.2500
guidehouse.com

Reference No.: 219927
October 2022

Table of Contents

Table of Figures

Table of Tables

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

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:

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
    - retrofitted device 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 resource communication and control technologies
- Implementing different demand response dispatch strategies

This report describes the impact evaluation findings for PGE's Multifamily Residential Demand Response Water Heater Pilot for the Summer 2021 and Winter 2021-22 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, 2019-20, and 2020-21 evaluation reports, and a memo summarizing the impact evaluation of the Summer 2021 DR season.

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 2021 and Winter 2021-22 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 pilot's core processes are working well, 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.

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

Demand reductions from events in Summer 2021 and Winter 2021-22 decreased on a per controlled device basis, relative to Summer 2020 (0.22 kW to 0.17 kW) and Winter 2020-21 (0.29 kW to 0.20 kW). Connectivity decreased from Summer 2020 to Summer 2021 (88% to 75%),but increased between Winter 2020-21 and Winter 2021-22 (68% to 71%). Controllability increased relative to the prior season for both winter and summer (69% to 74% in summer and 60% to 71% in winter).

Evening events had greater hourly curtailment (and snapback) than morning events likely due to increased hot water usage in the evening. Average hourly curtailment for evening events, which ran from 5pm to 9 or 11pm, was approximately 20% greater than morning events, which ran from 5am to 9am. This increased curtailment in evening events was associated with greater snapback (-0.81 kW for PM events vs. -0.59 kW for AM events). The majority of the difference in curtailment occurred in the first two hours of events. Average first hour curtailment for evening events was double that of morning events, and average second hour curtailment for evening events was 50% greater than morning events. This was likely due to the difference in demand between 5am to 7am and 5pm to 7pm.

To understand the longevity of DR event impacts and the ability to mitigate snapback, PGE continued to call events of varying start times and length. **Relative to four-hour events, six-hour events showed similar, but slightly lower, demand reduction for the first four hours.** Curtailment then trailed off over the final hours of the event. Six-hour events showed a 50% increase in snapback relative to four-hour events in both seasons. However, **seven-hour events (only called in Summer) showed much lower snapback relative to both six and four-hour events.** Additional exploration of longer event periods could be useful to program managers to delay event snapback until after peak usage periods, and after other, shorter DR events have finished. This offers program managers additional flexibility as they seek to mitigate peak demand and avoid snapback from multiple DR programs coinciding.

Connectivity of Wi-Fi switches continues to lag behind the cellular switches. Cellular switches had connectivity rates of around 85-90%, while wifi devices showed average connectivity of around 50-55%. Aquanta, which consistents of both wi-fi and cell devices, had lower impact levels relative to Apricity which only consists of cell devices, was driven by this difference in connectivity.

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.

Table 1. Impact Results by Season

	Season Average Per Event						
Metric	**Summer 2019**	**Summer 2020**	**Summer 2021**	**Winter 2018-19[1]**	**Winter 2019-20**	**Winter 2020-21**	**Winter 2021-22**
Total Load Shifted (kW)	107	648	827	0	621	1,038	811
Total Enrolled Devices	3,284	7,354	10,416	1,396	6,536	9,705	11,258
Percent of Devices Connected	75%	88%	75%	64%	91%	68%[2]	71%
Percent of Devices Controlled	46%	69%	74%	36%	62%	60%	71%
Impact per Enrolled Device (kW)	0.07	0.13	0.13		0.22	0.17	0.14
Impact per Controlled Device (kW)	0.15	0.22	0.17	0.14[3]	0.30	0.29	0.20

Source: Guidehouse analysis

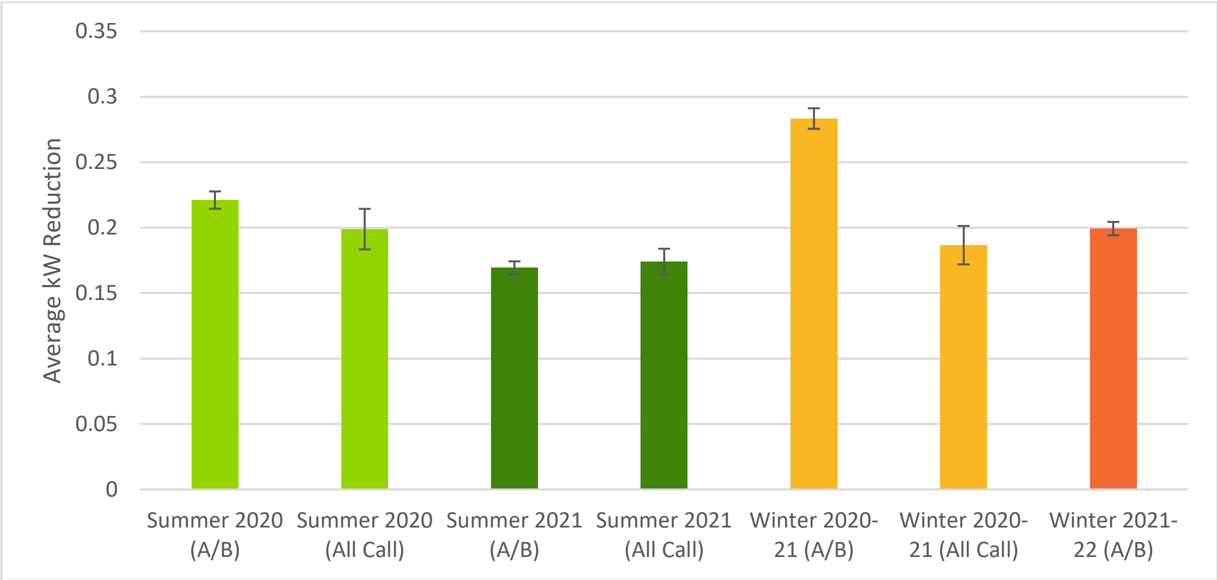
Figure 1 shows a comparison of the average impact per controlled device across the Summer 2020 to Winter 2021-22 seasons. The black lines on each bar in the graph represent the 90% margin of error of the estimate.

[1] 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.

[2] 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.

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

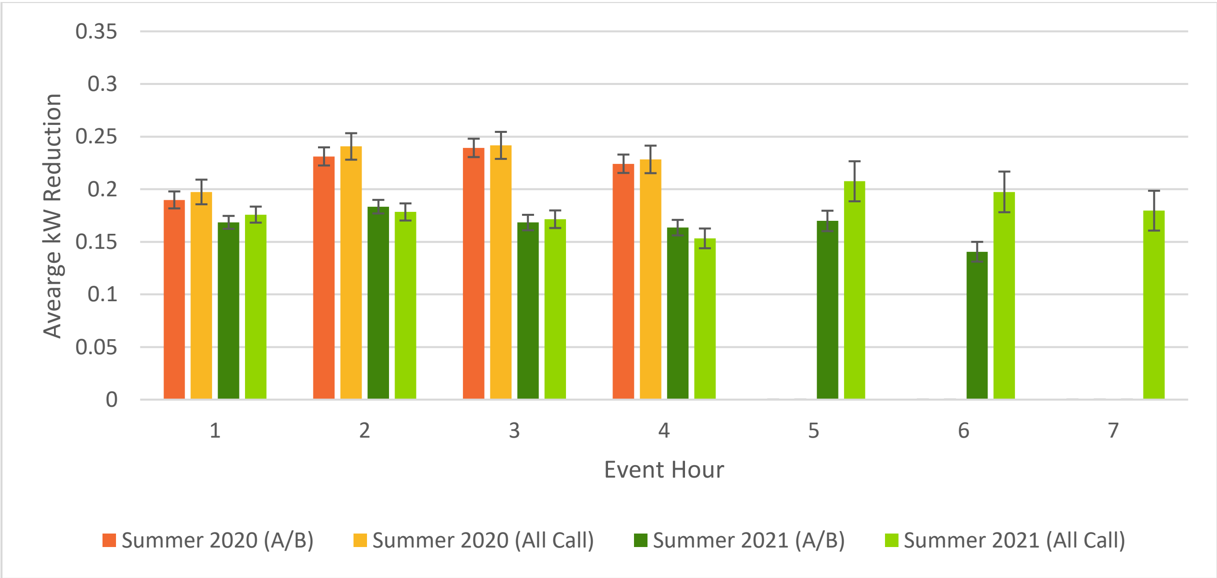
Figure 1 Average Hourly Event Impact per Controlled Device (Season Comparison)



Source: Guidehouse analysis

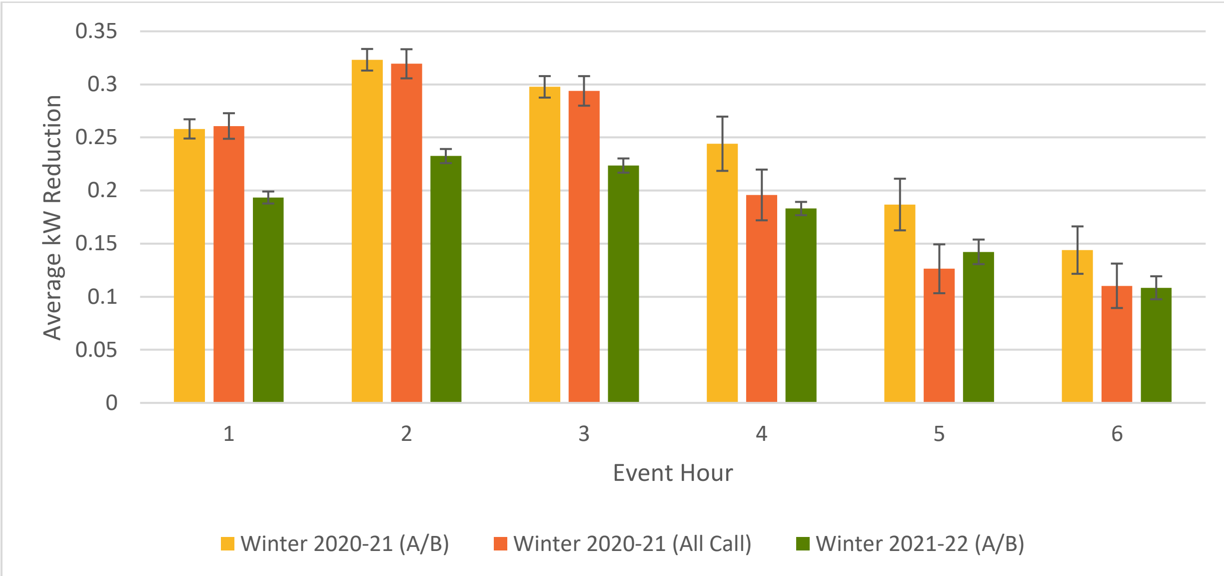
Figure 2 and Figure 3 show the comparison of average impact by hour of event per controlled device across the Summer and Winter seasons respectively. The black lines on each bar in the graph represent the 90% margin of error of the estimate.

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[4] (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. 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,[5] 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 (now Generac). As of *November 2021,* the pilot also offers 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 installs CTA-2045 communications modules to control the water heaters.

When events are called, any water heater that is actively heating and visible to Generac’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 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 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 used to receive Chinook Book coupons, 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

[4] 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/

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

- 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[6]
- Summer 2021: June 1st, 2021 through September 30th, 2021
- Winter 2021-22: December 7th through February 28th, 2022

The pilot has flexibility to call multiple events at varying times up to eight hours each on all non-holiday weekdays. In Winter 2018-19, events started at varying times of day, twice a day, and lasted for varying lengths of time. In Summer 2020, 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. During Winter 2020-2021, PGE continued to use three-hour events to curtail demand (6AM to 9AM or 5PM to 8PM). In addition, PGE also set six-hour events to study curtailment decay and mitigate snapback. These events were either 4PM to 10PM or 5PM to 11PM. In Summer 2021, only one event was called per day. Events started at varying points in the afternoon to evening and lasted for varying lengths of time. In Winter 2021-22, all events started at either 5AM or 5PM. All morning events were four hours in length (5AM to 9AM). Approximately half of evening events were 4 hours long (5PM to 9PM), while the other half were 6 hours in length (5PM to 11PM).

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.[7]
- 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.
- 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.

1.3 Pilot Objectives

Specific pilot objectives include:

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

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

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

2.1.1 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, 2022 (from PGE)
Event log containing event start and end times for each test group[8] 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"
- Assets without an installation date (when an asset was installed at the premise[9]), 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

2.1.2 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.

2.1.2.1 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.

[8] 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.

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

The 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 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

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

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.

2.1.2.2 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[10] for estimating net savings from energy efficiency programs. RPPM follows Ho et al. (2007)[11] 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.

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

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

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.

[10] *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*

[11] *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*

$Snapback_{it}$	=	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[12].

For the 2021-22 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.

[12] 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 three types of communications protocols to control water heaters: Wi-Fi (manufactured by Aquanta), cellular (manufactured by Aquanta and Generac, formerly known as Apricity), and CTA-2045 (manufactured by Generac). This section discusses the pilot's use of these three technologies.

3.1.1 Wi-Fi Switches

The Aquanta Wi-Fi switches comprise approximately 37% 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 is pursuing 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 is intended to improve connectivity in a cost-effective manner and is focused on the 13 participating properties with the lowest connectivity. As of August 4, 2022, eight out of the 13 targeted properties have agreed to have their maintenance staff go into units and reset the Wi-Fi routers.

3.1.2 Cellular Switches

Currently the pilot uses both Generac and Aquanta cellular switches, though they are only currently installing Aquanta cellular switches because they have installed their target number of Generac cellular switches. After the current inventory of Aquanta cellular switches is installed, they will not order any more. The cellular switches comprise approximately 63% of the fleet and have the highest connectivity of any of the technologies currently in use by the pilot.

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

PGE is currently offering an incentive to owners of new construction multifamily properties to install CTA-2045-enabled water heaters and to participate in the pilot. The incentives cover the incremental cost of a CTA-2045-enabled water heater above a standard electric resistance tank water heater. Pilot staff report that the incremental cost has been 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.

The pilot previously completed one installation of CTA-2045 modules manufactured by Generac, but the modules were later determined to be faulty and there are currently no functional CTA-2045 modules available in the market. The pilot is working closely with manufacturers, including Generac and others, to monitor the availability of these modules, and is continuing to recruit new construction projects for future installations. Pilot staff expect to be able to purchase functional CTA-2045 modules in 2023 at the earliest.

The continued delay in the planned code change to make CTA-2045-enabled water heaters the baseline is affecting the market for CTA modules because companies are not eager to create devices for a communications protocol that is extremely rare. The effective date for this code change has been pushed three times thus far. When the code finally goes into effect (currently planned for July 2023), there will likely be new companies entering this market and competing to develop effective CTA-enabled devices.

3.2 Recruitment

The pilot is now focusing on recruiting owners of new construction multifamily properties into the pipeline for installing CTA-2045 devices when they become available. Pilot staff continue to report 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. One new recruitment strategy is partnerships with other entities implementing new construction programs in the area, including Energy Trust of Oregon and Earth Advantage. Both of these programs are primarily focused on persuading customers to install heat pump water heaters, but when they encounter customers who are set on electric resistance water heaters, they encourage those customers to participate in PGE's pilot. The pilot has received several warm leads through these avenues. The pilot is also working with NAIOP (a commercial real estate development association) and ULI (Urban Land Institute) to attend events where potential pilot participants could learn more about the program.

Pilot staff are also conducting outreach to the construction code and architect communities, which are still coming up to speed on the new CTA-2045 technology, and to investment property owner organizations. This outreach consists mainly of cold calls and maintaining a presence at relevant industry events.

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. The current incentive approach requires subcontractors to wait until project completion to receive reimbursement for the additional cost of the CTA-2045-enabled water heaters, which puts additional financial burden on the subcontractors since project lead times can be very long. Subcontractors don't want to reveal the pricing that they're receiving because it's part of their competitive bidding process; different subcontractors receive better prices based on their relationship with distributors. One of the goals of the pilot is ensuring that participating property owners are able to install CTA-enabled devices at the same price point that they would pay for a standard "dumb" water heater, but the current incentive model is making that difficult to ensure because of upcharges added by middlemen. 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, CLEAResult and PGE are still considering this approach but have not made a decision about shifting to a midstream incentive model. 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.

3.3 Installation

Pilot staff have well-honed procedures for installing switches at existing properties. They report good relationships with the electrician subcontractors and high satisfaction from the property managers. The only devices currently being installed are Aquanta cellular switches, and when the existing stock of those switches is installed, there will be no more installations at retrofit properties.

The installation of CTA-2045 modules at new construction properties will begin when the defective devices have been replaced. The currently available CTA-2045-enabled water heaters (manufactured by A.O. Smith) require the installation of two devices to enable communication with the pilot, but A.O. Smith is developing a new type of CTA-2045-enabled water heater that will only require a one-device installation, which will simplify installation procedures.

One potential benefit of moving to a midstream incentive model would be that distributors could install the CTA-2045 communications modules prior to delivering the water heaters to construction sites, further streamlining installation procedures.

3.4 Data Tracking and Reporting

Pilot staff have been working on some additional reporting capabilities to enable easier monitoring and analysis for the PGE pilot manager. CLEAResult has developed a new dashboard that tracks connectivity by device type (i.e., Aquanta Wi-Fi, Aquanta cellular, Generac cellular, and Generac CTA-2045). Generac has created a post-event season export that has 11 points of data.

Pilot staff report some frustration with working with data in the EDM system; however, they also note that changing data systems can be a lengthy and challenging process.

4. Impact Evaluation Findings

This section discusses the findings from Guidehouse's impact evaluation of the Summer 2021 and Winter 2021-22 DR seasons.

4.1 Summer 2021 Impact Results

The Summer 2021 DR season lasted from June 1st, 2021 through September 30th, 2021. 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 2021 DR events, including the season average and the minimum and maximum values by event.

Table 2. Summer 2021 Impacts per Event

Metric	Season Average (per Event)	Minimum	Maximum
Total Demand Reduction (kW)	826.78	222.64	1,873.14
Percent of Devices Controlled	74%	37%	88%
Impact per Controlled Device (kW)	0.17	0.06	0.26
Snapback per Controlled Device (kW)	-0.53	-1.12	-0.16

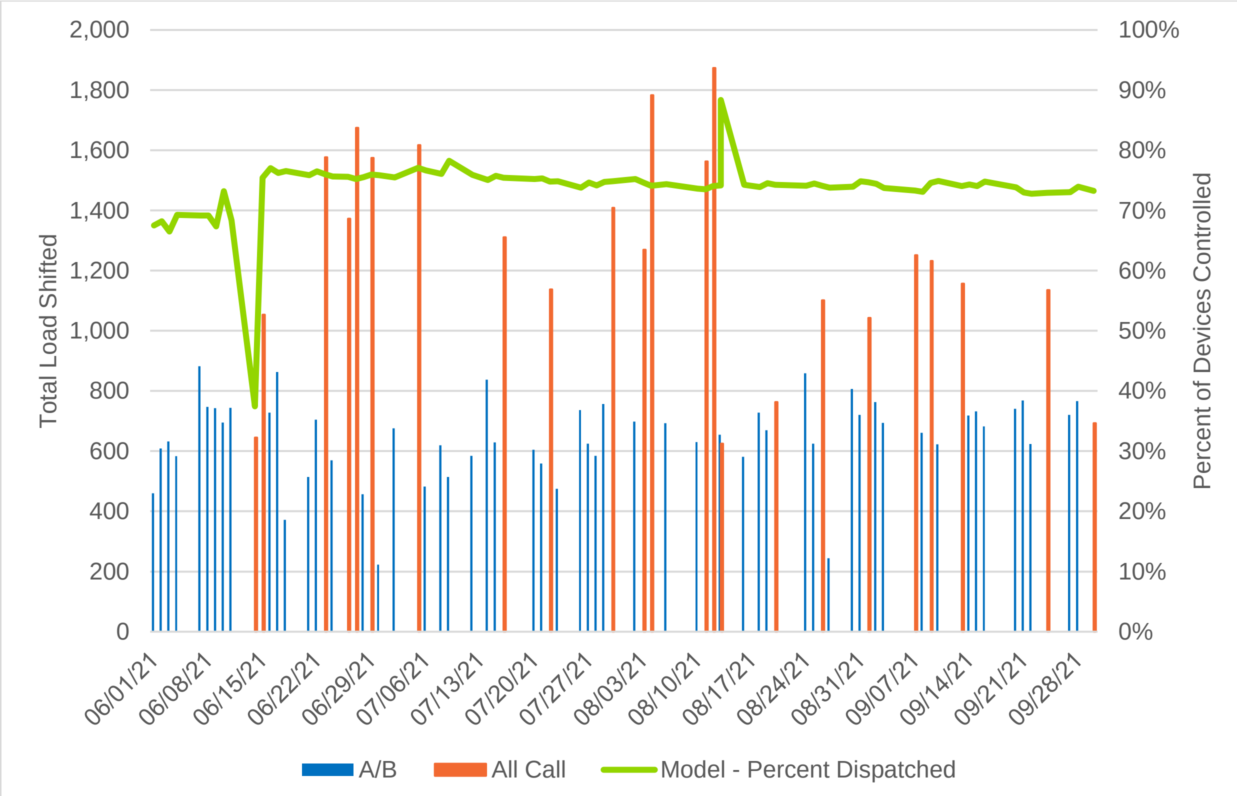
Source: Guidehouse analysis

The program called a total of 78 events during the Summer 2021 season. The **total demand reduction per event** averaged 827 kW. As shown by the filled columns[13] 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 625 kW to 1,873 kW whereas for A/B design events, load shifted per event was between 223 kW and 883 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 29% to 63% for Aquanta devices and 45% to 91% 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 66% to 88%, whereas the percent of devices controlled for all-call events ranged from 37% to 77%. Fourth, the total number of enrolled devices increased from the beginning to the end of the season to

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

the end.[14] For A/B design events, the number of devices enrolled increased from 4,939 to 5,202 from the beginning to the end of the season, and from 9,893 to 10,416 for all-call events.

Figure 4. Total kW Reduction and Percent Controlled per Event (Summer 2021)



Source: Guidehouse analysis

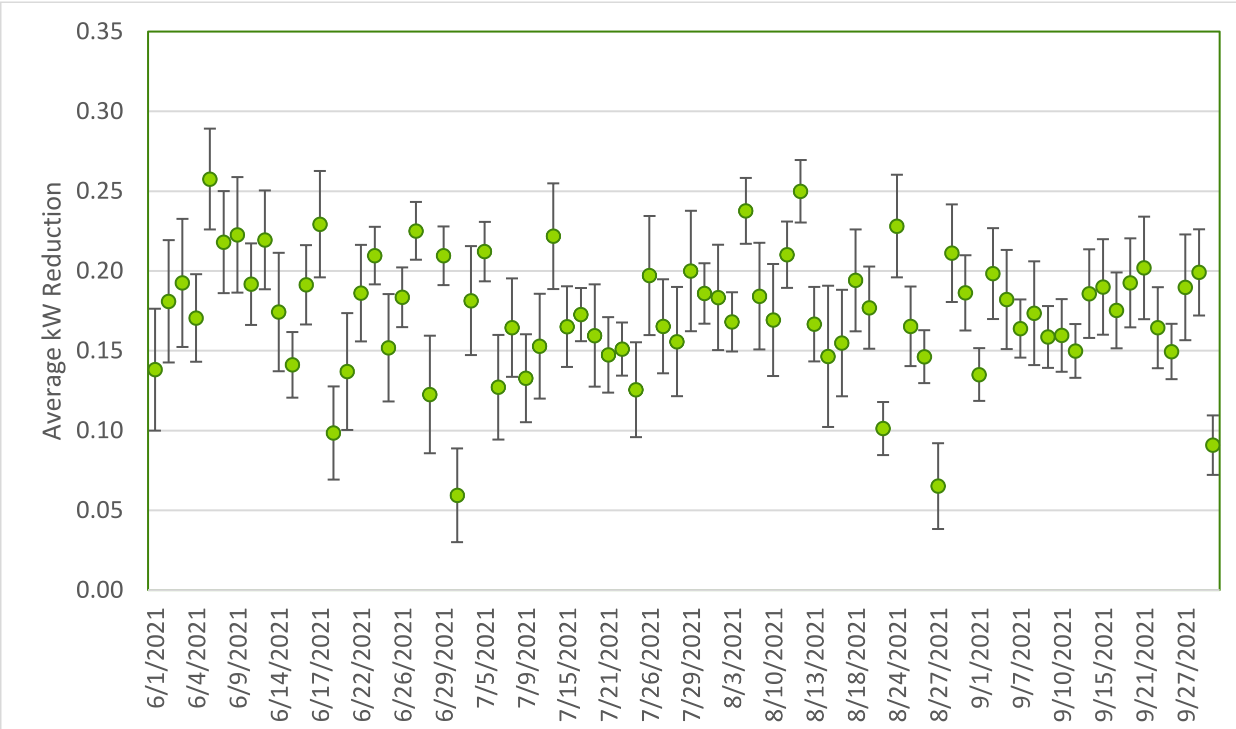
The **average load shifted per controlled device** was 0.17 kW per controlled device, with a range of 0.06 to 0.26 kW (shown in .). The impact estimates were statistically significant (i.e., statistically different from zero) for all events. These averages were calculated by dividing the total event impact (shown in the previous graphic) by the number of controlled devices[15] for that event, which is a function of water heater connectivity, heating status, and tank level.[16] The whisker bars around each dot represent the 90% margin of error in the estimate.

[14] 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.

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

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

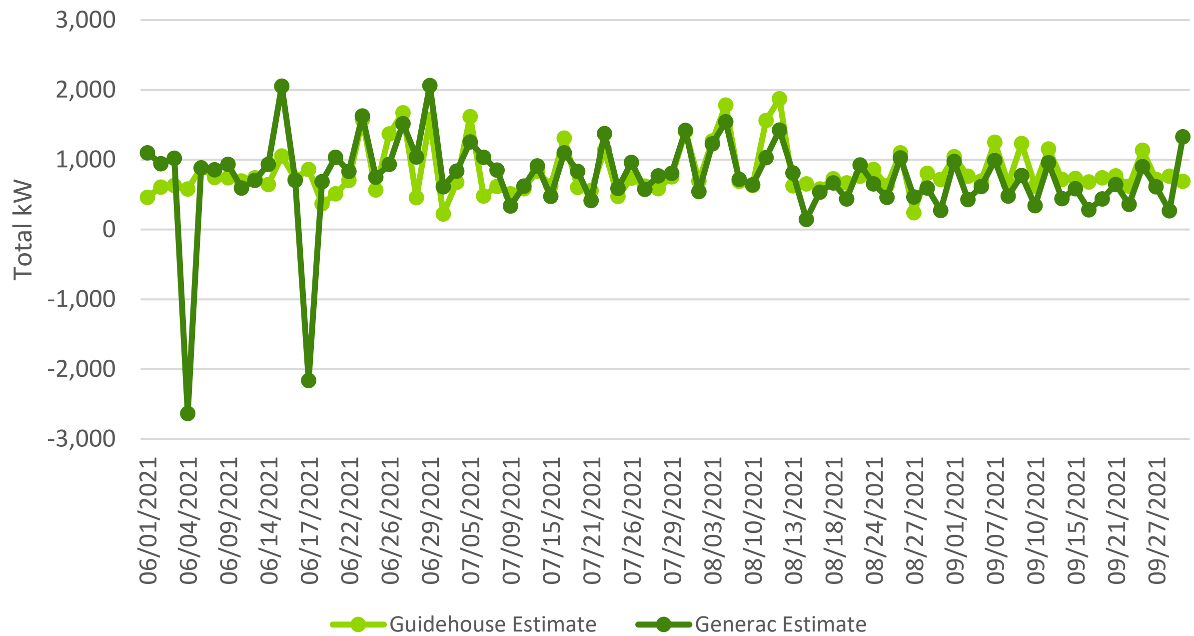
Figure 5. Average kW Reduction per Controlled Device by Event (Summer 2021)



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 2021 events had similar estimates between Guidehouse's and Generac's results, except for two events where Generac's estimates were significantly lower (-2,000 kW or less). This was caused by an error within Generac's internal processes, and they are currently working on resolving the issues for these two events so it will not arise again in future DR events.

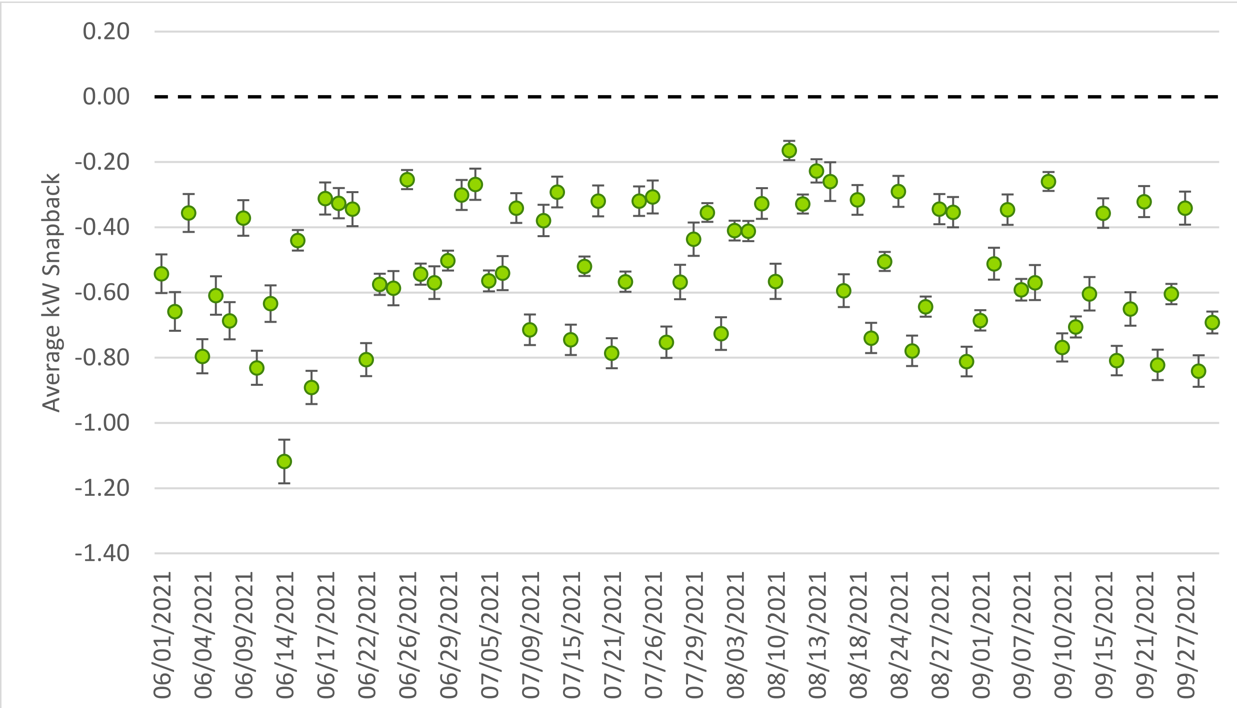
Figure 6. Total kW Impact: Guidehouse and Generac Comparison (Summer 2021)



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 -0.53 kW, meaning that on average the participating households were using 0.53 kW *more* than the control group households during the period after the events. Average per-device snapback ranged from -0.16 kW to -1.12 kW.

Figure 7. Average Snapback per Controlled Device by Event (Summer 2021)



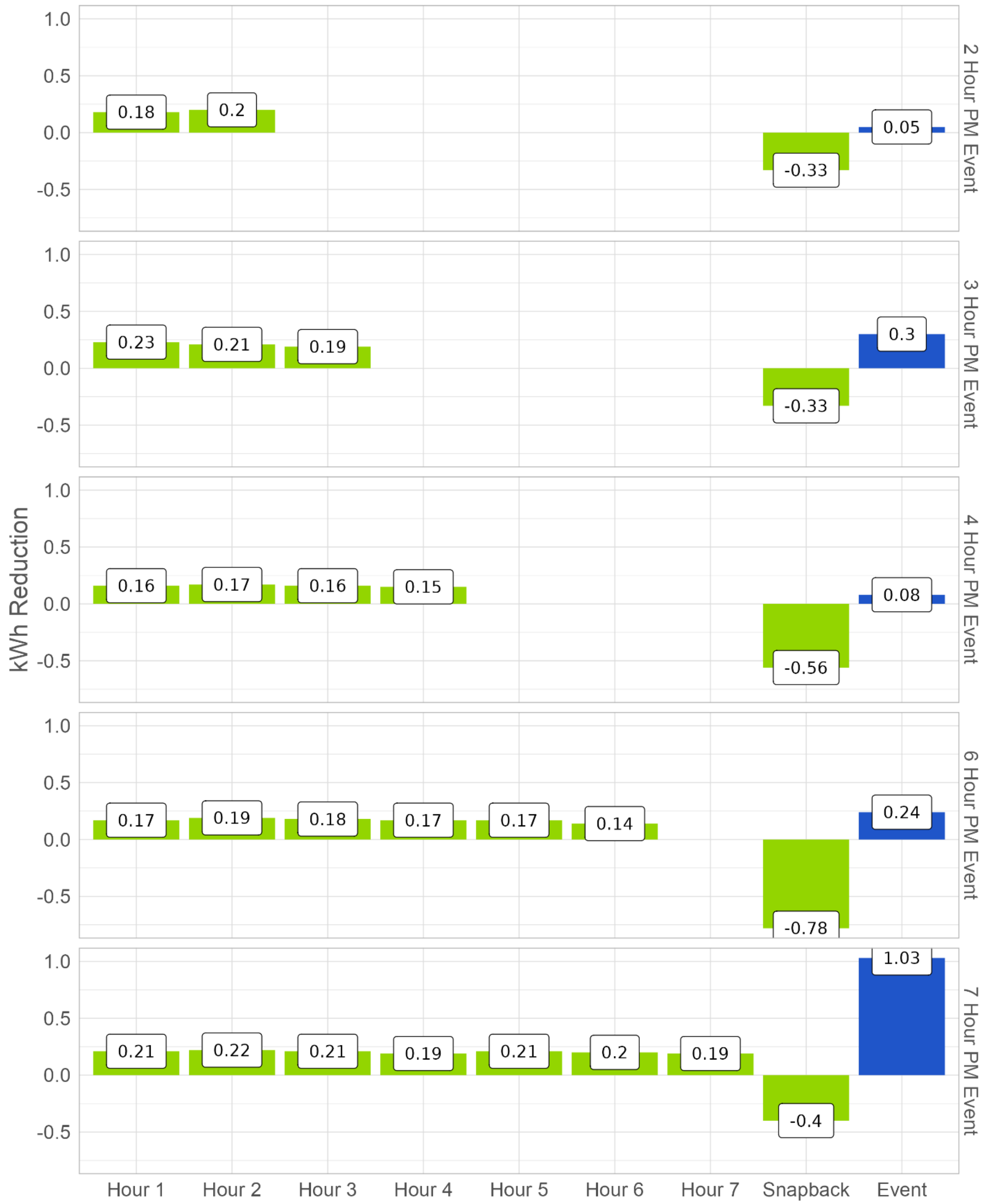
Source: Guidehouse analysis

During Summer 2021, 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 four-hour evening events showed the lowest savings per controlled device, 0.05 and 0.08 kWh savings respectively. Three-hour and six-hour evening events showed 0.30 and 0.24 kWh savings per controlled device[17], respectively, and seven-hour evening events showed the highest savings at 1.03 kWh savings per controlled device.

Hourly impacts per controlled device ranged from 0.14 to 0.23 kWh savings. Hourly impacts generally stayed consistent across each hour of an event, with a slight decrease in the final hour. Snapback per controlled device increased with event length, except for seven-hour events which had lower snapback, likely a major contributer to having the highest net savings.

[17] 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 Energy Impact by Event Length (Summer 2021)



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 2021 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[18]**:** a device that was actively heating, but was not dispatched

Override, Not Dispatched: a device that entered override mode[19] 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.

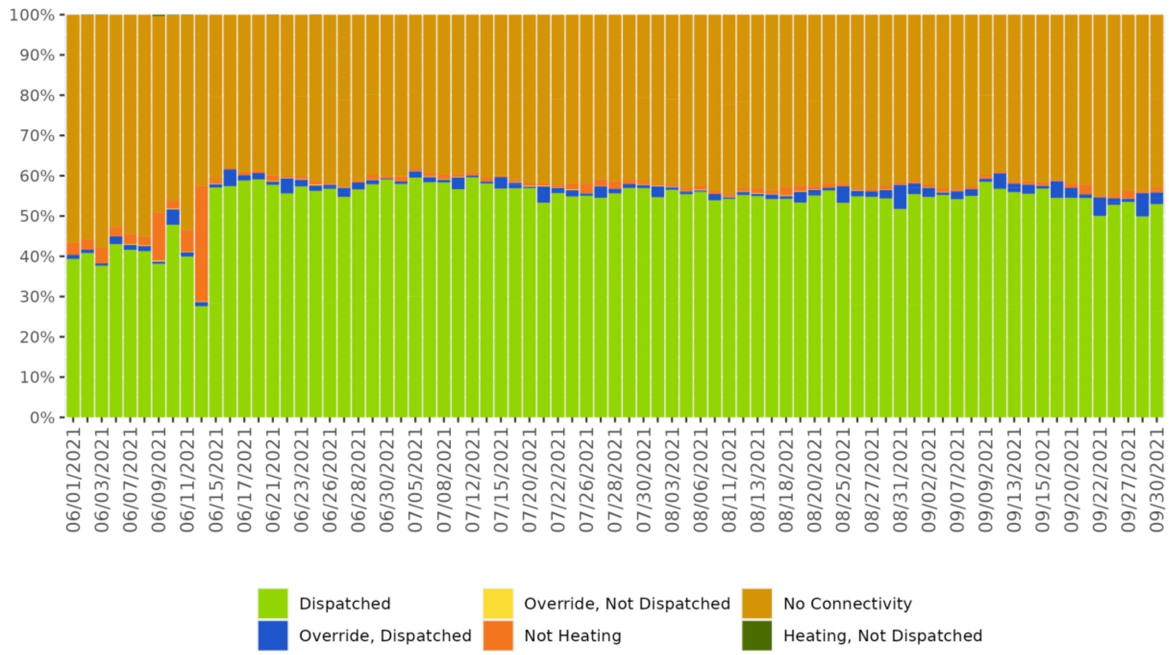
During Summer 2021, connectivity rates were higher than the previous winter, at 75% on average for the summer 2021 season. As noted previously, the percent of devices controlled (dispatched) varied from event to event, averaging 74% (an increase over the Winter 2020-2021 season's 60% and the Summer 2020 season's 69%). Nearly 99% of devices across all events were either in *Dispatch*, *Override, Dispatch,* or *No Connectivity* mode, which is why the average connectivity and controlled rates are so similar for the summer 2021 DR season.

The connectivity rates varied greatly across the two devices. Throughout the summer events, connectivity rates for Apricity devices did not fall below 88% for any event, whereas connectivity rates for Aquanta devices did not go above 62% for a single event.

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

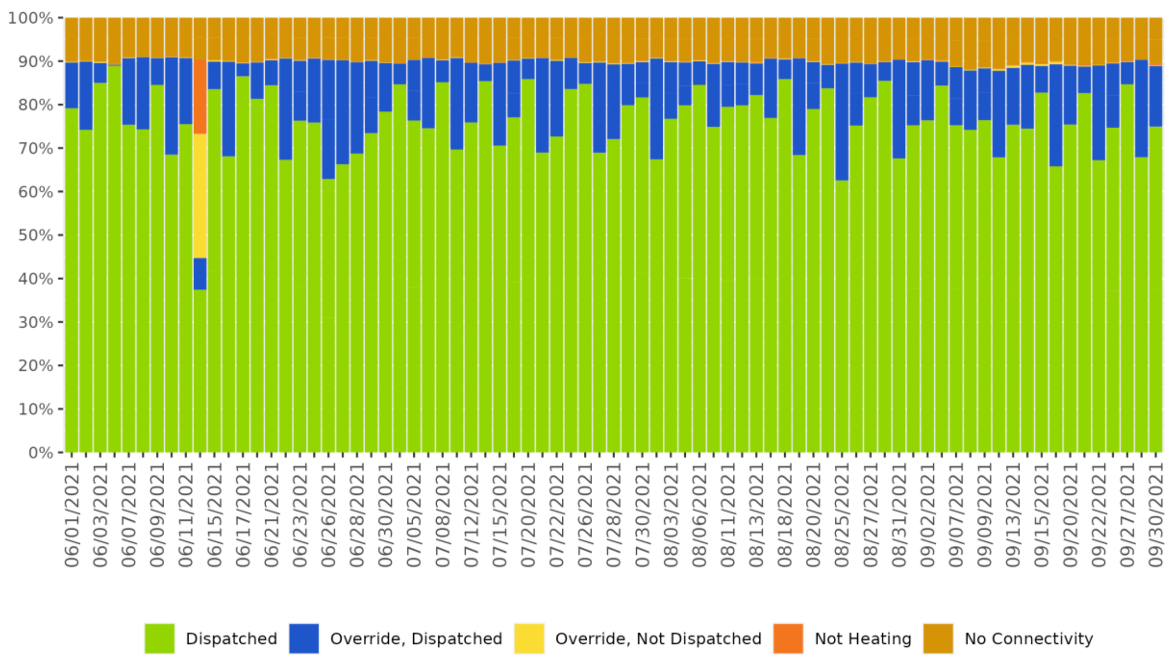
[19] Devices enter override mode when its tank drains more than 30 percent and cannot be curtailed until the tank refills.

Figure 9. Aquanta Device Dispatch Status by Event (Summer 2021)



Source: Guidehouse analysis

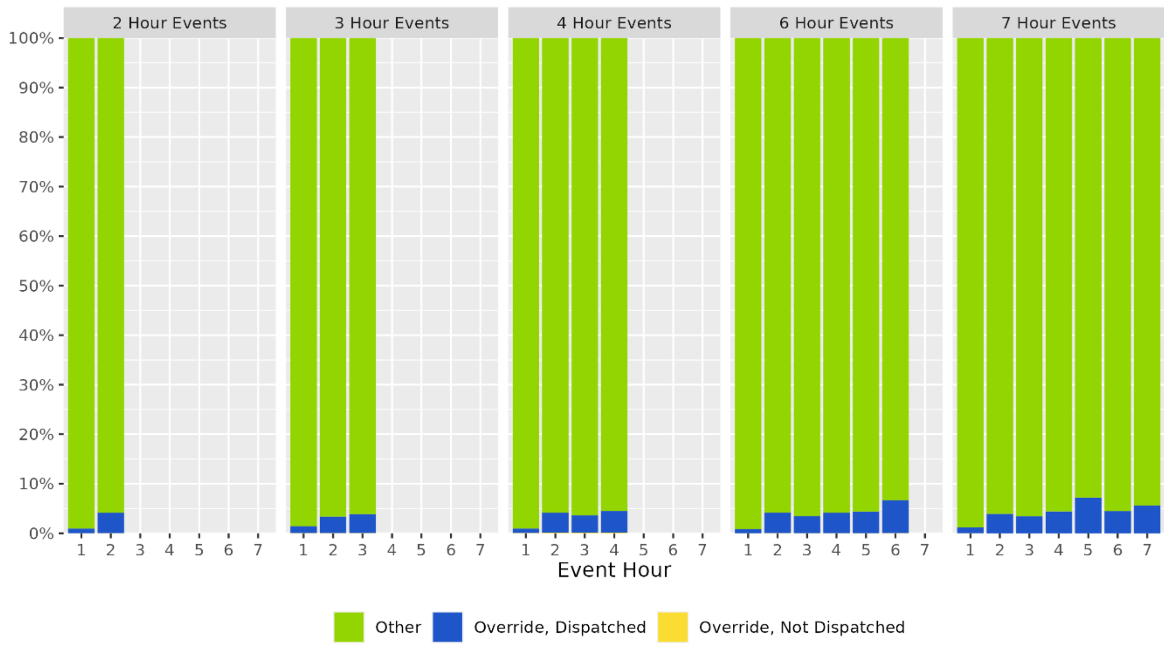
Figure 10. Apricity Device Dispatch Status by Event (Summer 2021)[20]



Source: Guidehouse analysis

Figure 11 and Figure 12 show the percent of devices in **Override** status (includes devices in **Override, Dispatched** and **Override, Not Dispatched** statuses) by event length and event hour. Across the events, there was a small trend of increasing Apricity devices going into Override status each subsequent hour of the event. For example, during three-hour events, the percent of Apricity devices in Override status increased from 1.4% in event hour one to 3.4% in event hour two to 3.9% in event hour three. This trend shows that as the length of the event increased, the percent of devices moving to Override status also increased. The longer the event length, the more likely the event coincided with a daily activity that used hot water, thereby triggering an Override status. For Aquanta devices, there were very few that went into Override status throughout the event season, which is likely due to their low connectivity rate.

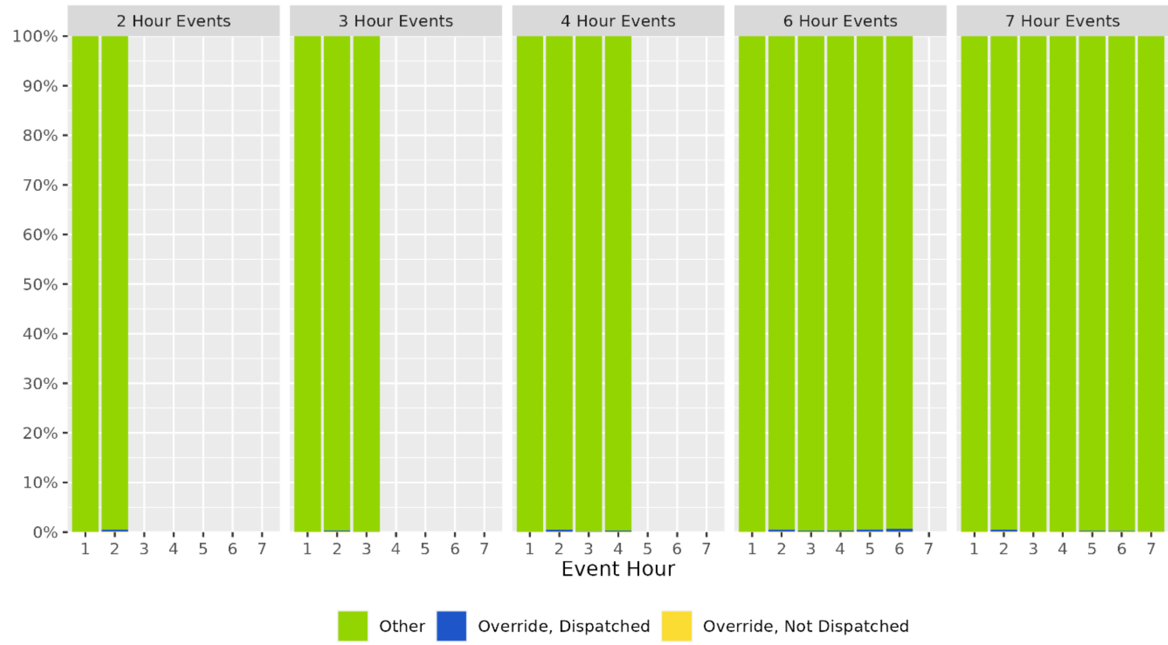
Figure 11. Apricity Override Status by Event Length and Hour (Summer 2021)



Source: Guidehouse analysis

[20] For the June 14th event, the Concerto system indicated it was a Group A event, but Group B also showed impacts. CLEAResult opened a ticket (CS-1151) to investigate this issue. This issue likely resulted in the inconsistent event device status for that event day.

Figure 12. Aquanta Override Status by Event Length and Hour (Summer 2021)



Source: Guidehouse analysis

4.2 Winter 2021-22 Impact Results

This section discusses the findings from Guidehouse's impact evaluation of the Winter 2021-22 DR season, which lasted from December 7, 2021 through February 28, 2022. 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**Error! Reference source not found.** summarizes the key metrics for the Winter 2021-22 DR events, including the season average and the minimum and maximum values by event.

Table 3. Winter 2021-22 Impacts per Event

Metric	Season Average (per Event)[21]	Minimum	Maximum
Event Demand Reduction (kW)	811	387	1,196
Percent of Devices Controlled	73%	70%	74%
Impact per Controlled Device (kW)	0.20	0.10	0.29
Snapback per Controlled Device (kW)	-0.70	-0.98	-0.35

[21] Season Average includes only A/B events, as no All Call events were deployed during the Winter 2021-22 season.

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 each metric (event impacts, percent of controlled devices, impacts per controlled device, and snapback per controlled device).

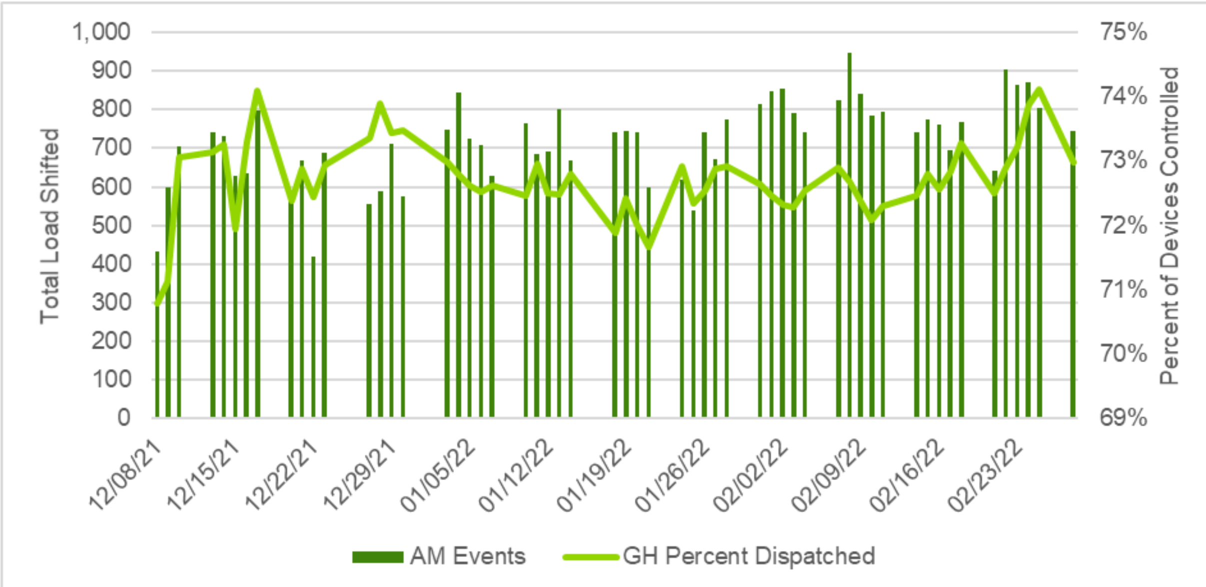
Table 4. Winter 2021-22 Impacts per Event by Time of Day

Metric	Daytime	Season Average (per Event)	Min	Max
Total Demand Reduction (kW)	AM	719	418	948
	PM	901	387	1,196
Percent of Devices Controlled	AM	73%	71%	74%
	PM	73%	70%	74%
Impact per Controlled Device (kW)	AM	0.18	0.10	0.23
	PM	0.22	0.10	0.29
Snapback per Controlled Device (kW)	AM	-0.59	-0.73	-0.35
	PM	-0.81	-0.98	-0.38

Source: Guidehouse analysis

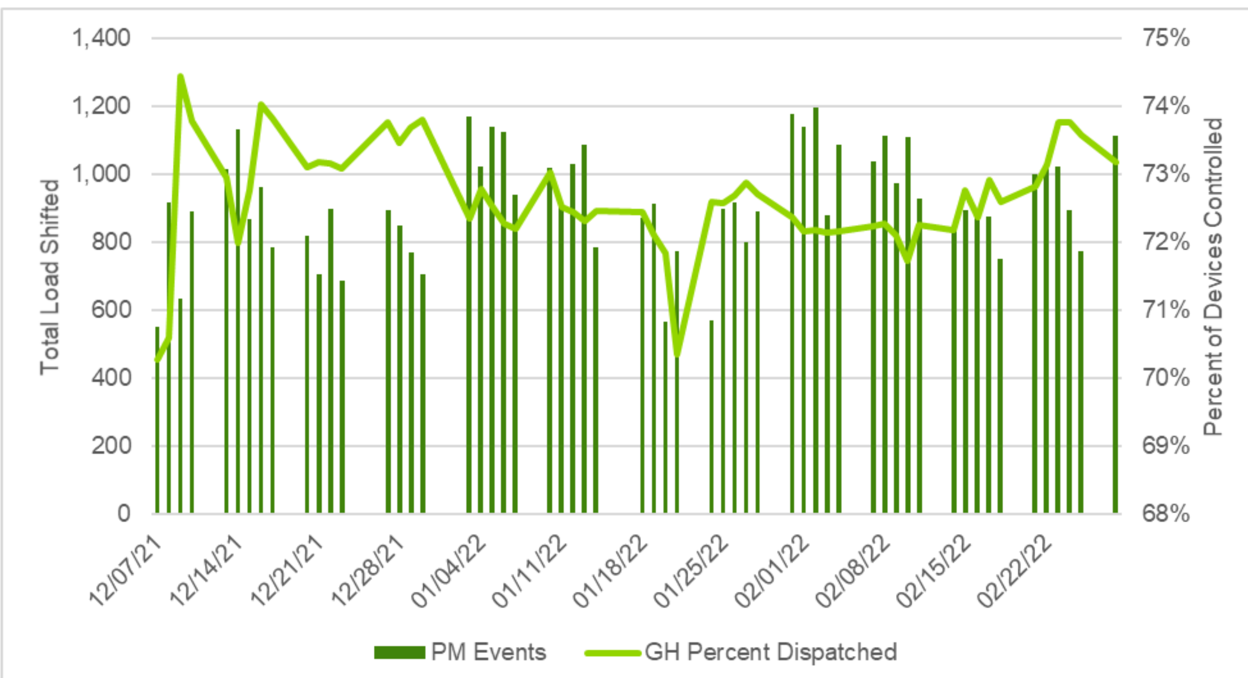
The program called a total of 113 events during the Winter 2021-22 season. The **total demand reduction per event** averaged 719 kW for AM events and 901 kW for PM events. As shown in the green bars in Figure 13 and Figure 14 impacts varied from event to event, with a range of 418 to 948 kW during AM events and 387 to 1,196 for PM events. The **percent of devices controlled** ranged from 71% to 74% for AM events and 70% to 74% for PM events.

Figure 13. Total AM kW Reduction and Percent Controlled per Event (Winter 2021-22)



Source: Guidehouse analysis

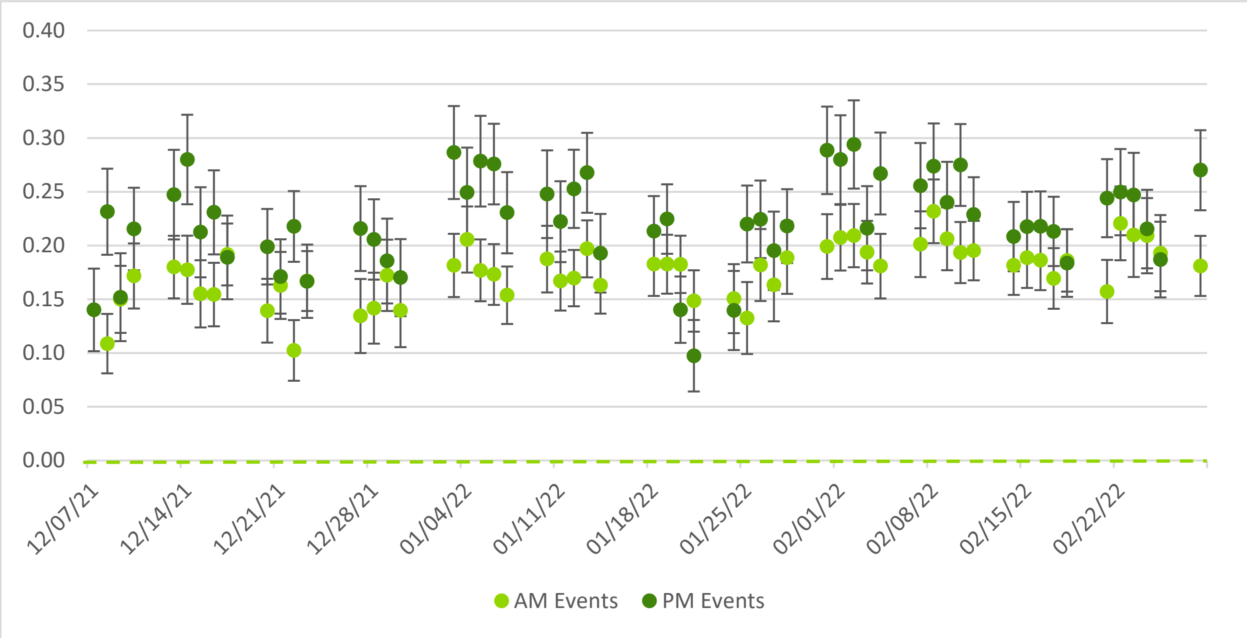
Figure 14. Total PM kW Reduction and Percent Controlled per Event (Winter 2021-22)



Source: Guidehouse analysis

The **average impact per controlled device** was 0.20 kW per controlled device (shown in Figure 15), with a range of 0.10 to 0.29 kW. The impact estimates were statistically significant (i.e., statistically different from zero) for all events.

Figure 15. Average kW Reduction per Controlled Device by Event (Winter 2021-22)

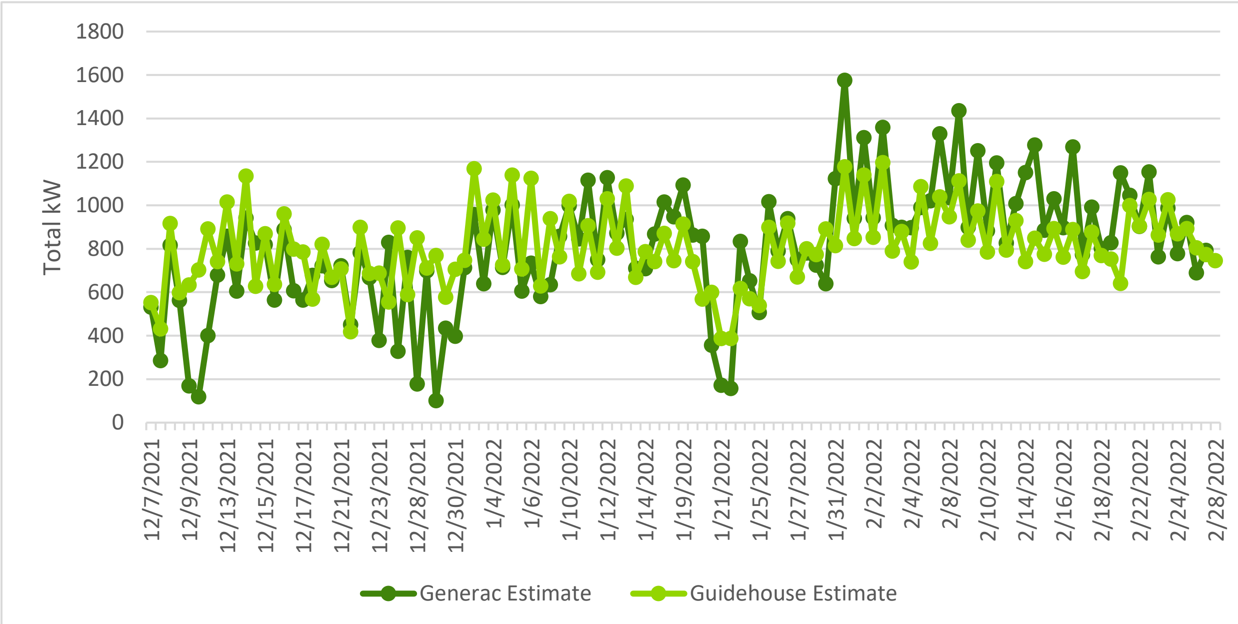


Source: Guidehouse analysis

To support the program's interest in real-time reporting tools, Figure 16 presents a **comparison of evaluated impacts to customer baseline load estimates from Generac[22]**. On average, the Generac estimated impacts were 21% higher than the evaluated impacts. This represents a slight increase from Winter 2020-2021, where the differences Generac estimates were only 17% higher.

[22] The February 28th PM event is excluded from the Generac estimate comparison due to lack of Generac data. February 28th impacts were still estimated by Guidehouse and included in the rest of analysis.

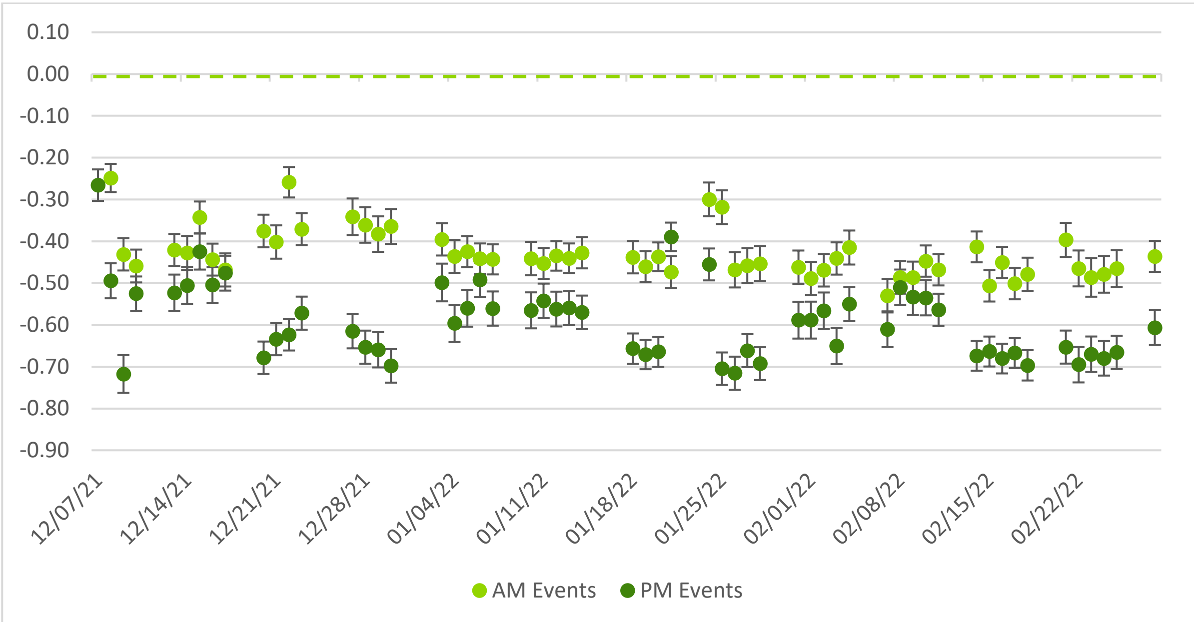
Figure 16. Total kW Impact: Guidehouse and Generac Comparison (Winter 2021-22)



Source: Guidehouse analysis

Figure 17 presents the average **snapback per controlled device** for events. The average snapback per controlled device for events was -0.70 kW, meaning that on average the participating households were using 0.70 kW *more* than the control group households during the one-hour period after the events. Snapback per controlled device ranged from -0.35 kW to -0.98 kW.

Figure 17. Average Snapback per Controlled Device by Event (Winter 2021-22)



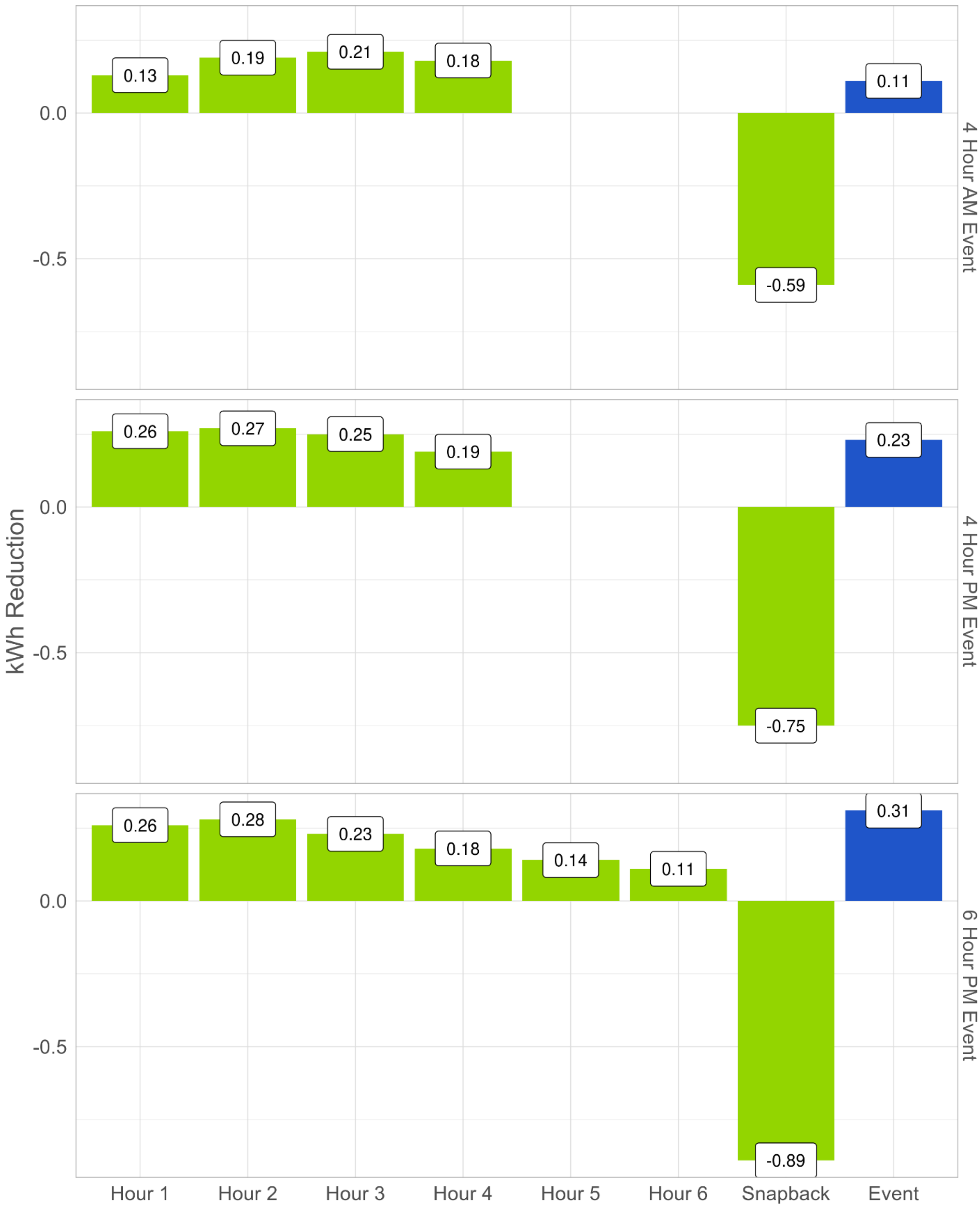
Source: Guidehouse analysis

During Winter 2021-22, events resulted in a net energy impact, as illustrated in Figure 18. The total energy reduction across events varied according to time of day and event length. After incorporating hourly curtailment and snapback, four-hour morning events showed 0.11 kWh savings per controlled device, while four-hour and six-hour evening events showed 0.23 and 0.21 kWh savings per controlled device[23], respectively. Evening events provided higher savings relative to morning events. Six-hour events demonstrated similar hourly demand reduction for the first four hours of four-hour PM events, which decreased over the second half of the event. Snapback levels were in-line with total savings, and morning events showed the lowest value while six-hour PM events displayed the highest snapback and highest net impact.

Events showed an increase in curtailment from the first to second hour of the event, with a slow decrease as the event continued. While this analysis did not seek to determine why curtailment differed from hour to hour, there are some possibilities. The increase in demand reduction in hour two is likely due to higher baseline demand. Higher baseline demand can lead to higher savings because there is more potential for loadshifting or reduction. The decrease in hourly impacts overtime is likely due to overrides occurring throughout the event, as well as decreasing demand as peak AM and PM periods pass.

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

Figure 18. Hourly and Event Energy Impact by Event Length (Winter 2021-22)

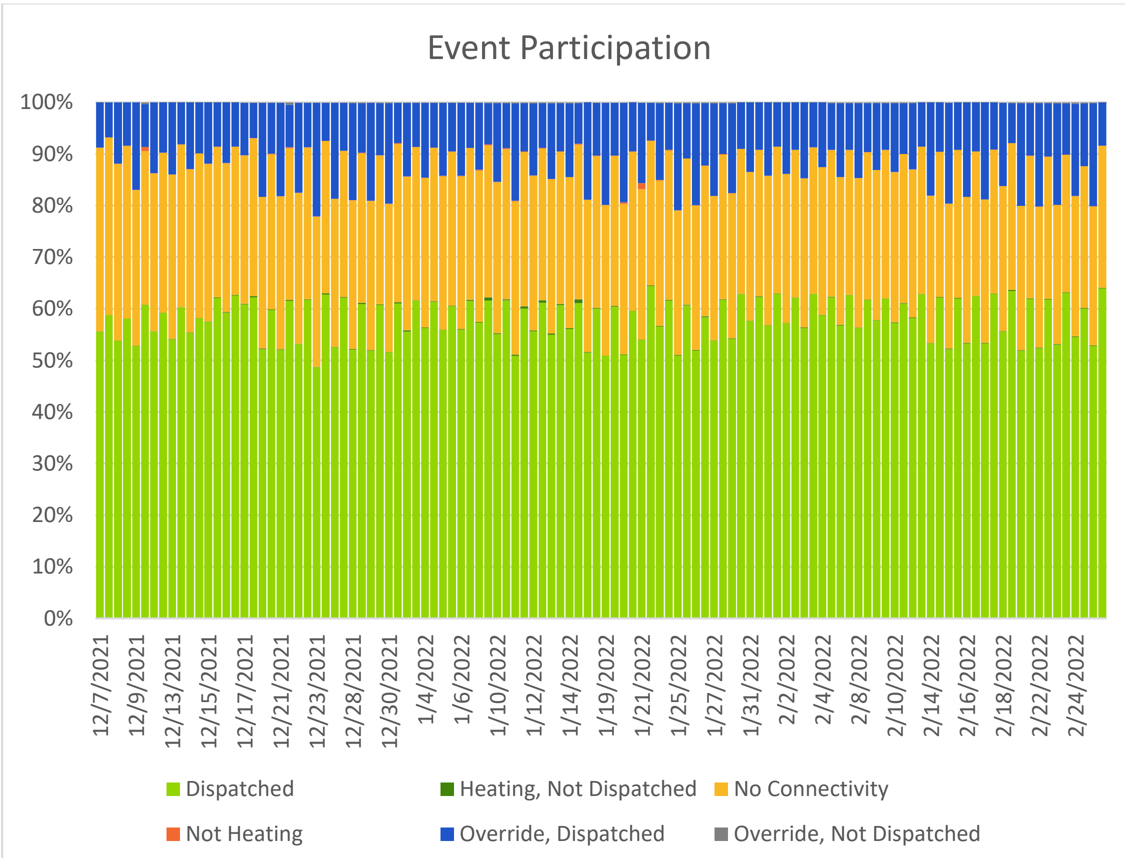


Source: Guidehouse analysis

4.2.2 Device Statuses: Connectivity and Overrides

Figure 19 shows device dispatch status by event.[24] 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.

Figure 19. Device Dispatch Status by Event (Winter 2021-22)



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 (67% vs. 49%). However, Apricity devices showed an increased likelihood of being overridden after being dispatched (19% vs. 6%). Even though Apricity devices had a higher dispatch rate, some of this curtailment was reduced because it was overridden.

[24] The large number of events during this DR season made the horizontal axis difficult to read. This figure presents device dispatch status sequentially by event. Status for specific events are available in the AM/PM plots below or the accompanying workbook.

The last event (February 28th from 5pm to 9pm) was excluded due to lack of data.

Table 5. Average Device Dispatch Status by Device Type (Winter 2021-22)

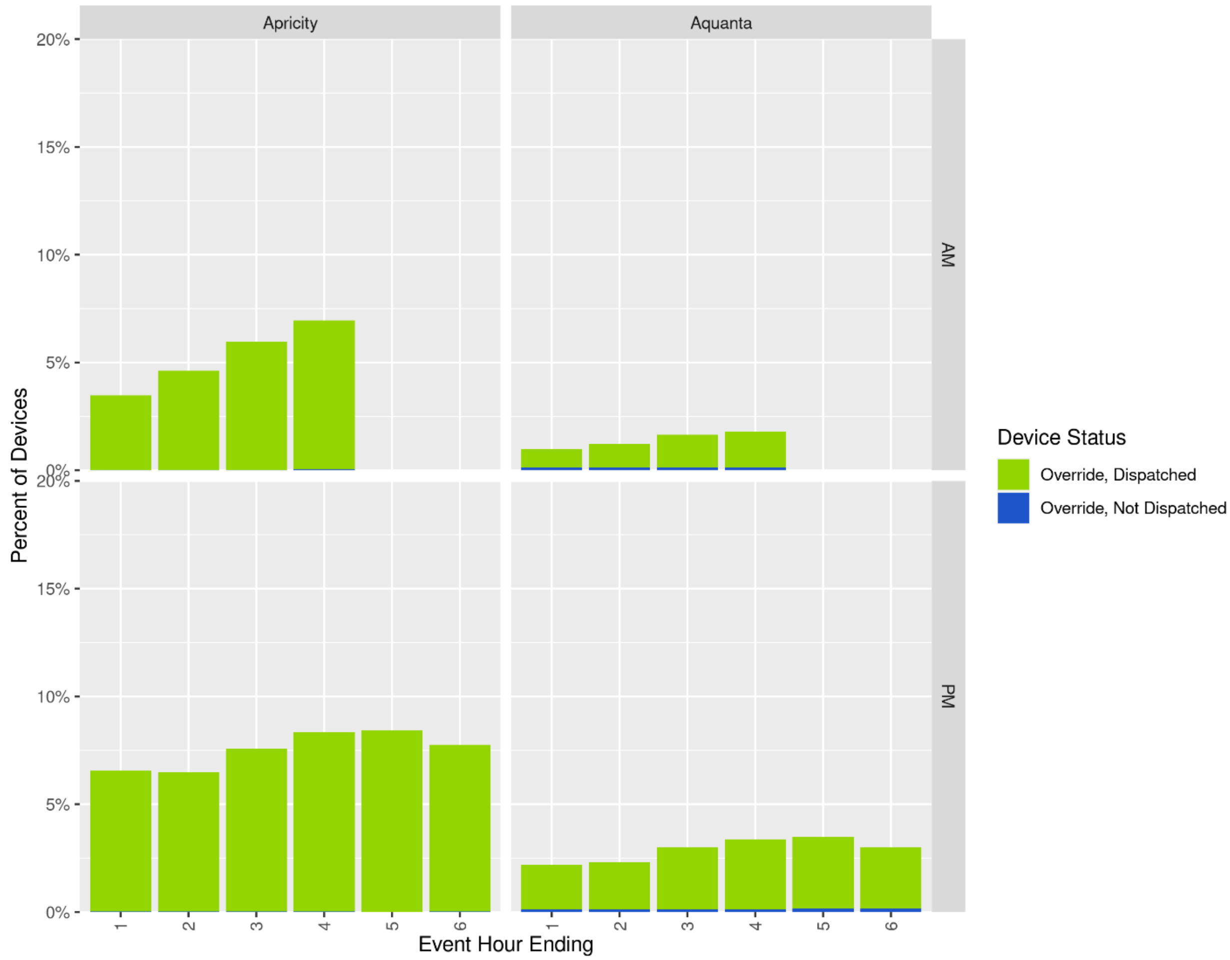
Device Status	Apricity	Aquanta
Dispatched	67%	49%
Heating, Not Dispatched	0%	0%
No Connectivity	14%[25]	44%
Not Heating	0%	0%
Override, Dispatched	19%	6%
Override, Not Dispatched	0%	0%

Source: Guidehouse analysis

Figure 20 shows the percent of devices in **Override** status (includes devices in **Override, Dispatched** and **Override, Not Dispatched** statuses) by device type, event hour, and time-of-day. Across the events, there was a small trend of increasing devices going into Override status each subsequent hour of the event, peaking at hours 4 and 5, then decreasing again (if longer than 4 hours). The longer the event length, the more likely the event coincided with a daily activity that used hot water, thereby triggering an Override status. Additionally, the periods with the highest Override status percentage generally coincided with higher demand periods. Nearing the end of the event, more devices have had a chance to return to Dispatch status, and demand decreased, reducing the percentage of devices in Override status.

[25] Half of Apricity devices with No Connectivity status were persistently offline due to a known issue.

Figure 20. Hourly Overrides by Device Type and Time of Day (Winter 2021-22)



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: 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 project development, as well as logistical challenges and resistance from contractors who are relucant to bear the upfront of costs of the more expensive CTA-2045-enabled water heaters while waiting for reimbursement.

> **Recommendation #1a:** Consider shifting to the upfront midstream incentive model to engage distributors in the recruitment process and mitigate some of the logistical and financial challenges of new construction projects.

> **Recommendation #1b:** Consider reducing the unit count requirement for new construction and fleet replacement projects to allow smaller properties and properties that do not conduct full fleet replacement to participate in the pilot.

Finding #2: Connectivity of Wi-Fi switches continues to lag behind the cellular switches and to degrade over time. To maintain a relatively high level of connectivity, the Wi-Fi switches require periodic maintenance that must be conducted in person. This maintenance has been infrequent due to cost, resulting in properties with Wi-Fi switches to frequently have a status of *not connected* duing events.

> **Recommendation #2a:** Continue to work with property managers to encourage their maintenance staff to perform regular Wi-Fi router maintenance rather than sending in pilot staff to perform the maintenance.

> **Recommendation #2b:** Consider swapping out Wi-Fi switches for cellular in the properties with the most persistent connectivity issues if property maintenance staff are unable to help improve connectivity rates.

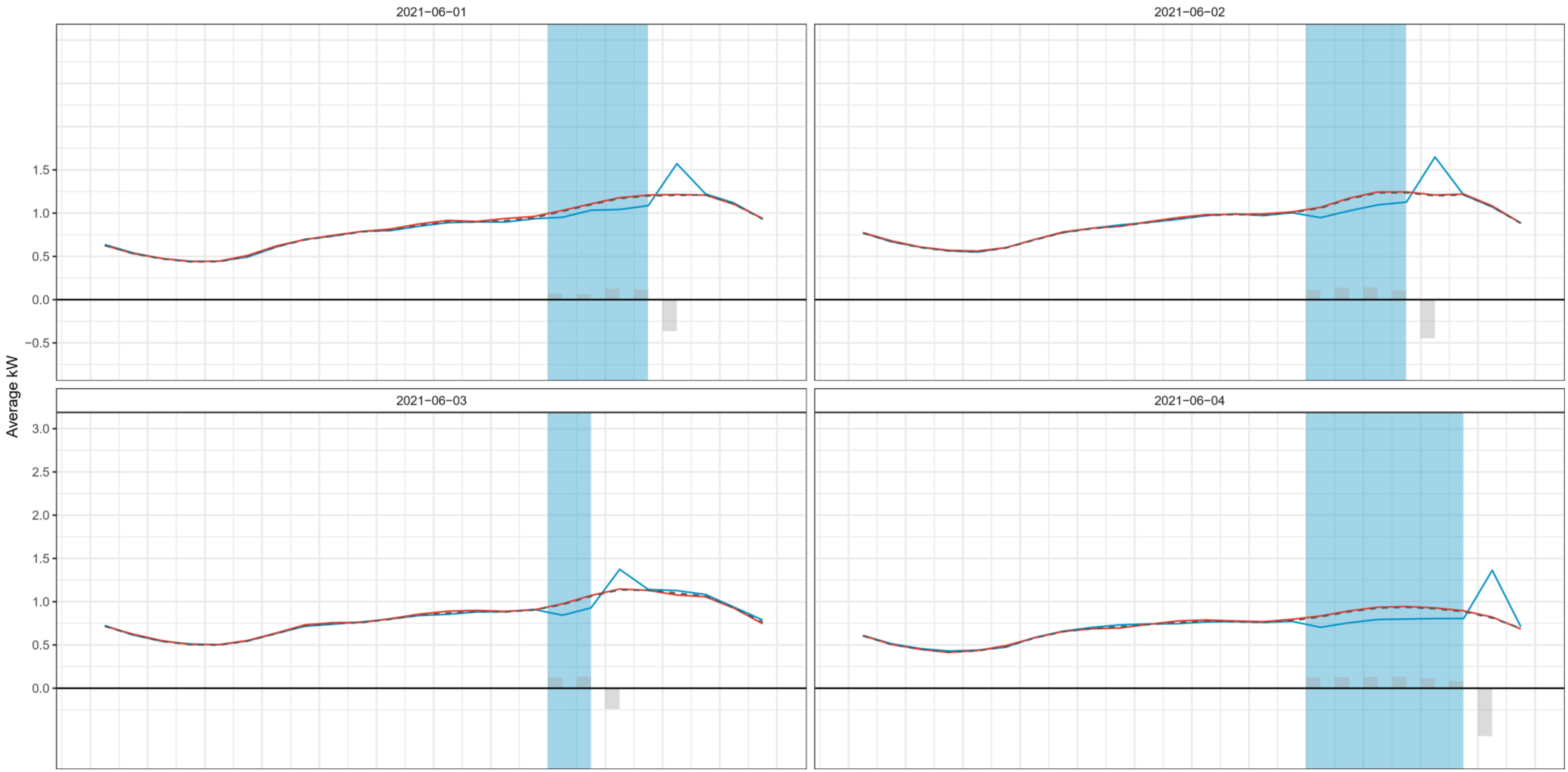
Finding #3: Relative to the Winter 2020-2021 evaluation season, the 2021-2022 impact per enrolled device decreased almost 18%. This continues a trend over winter season evaluations, which have seen a steady drop in impacts since the 2019-2020 evaluation, while the summer season impacts held steady for 2021 and 2022 evaluation seasons.

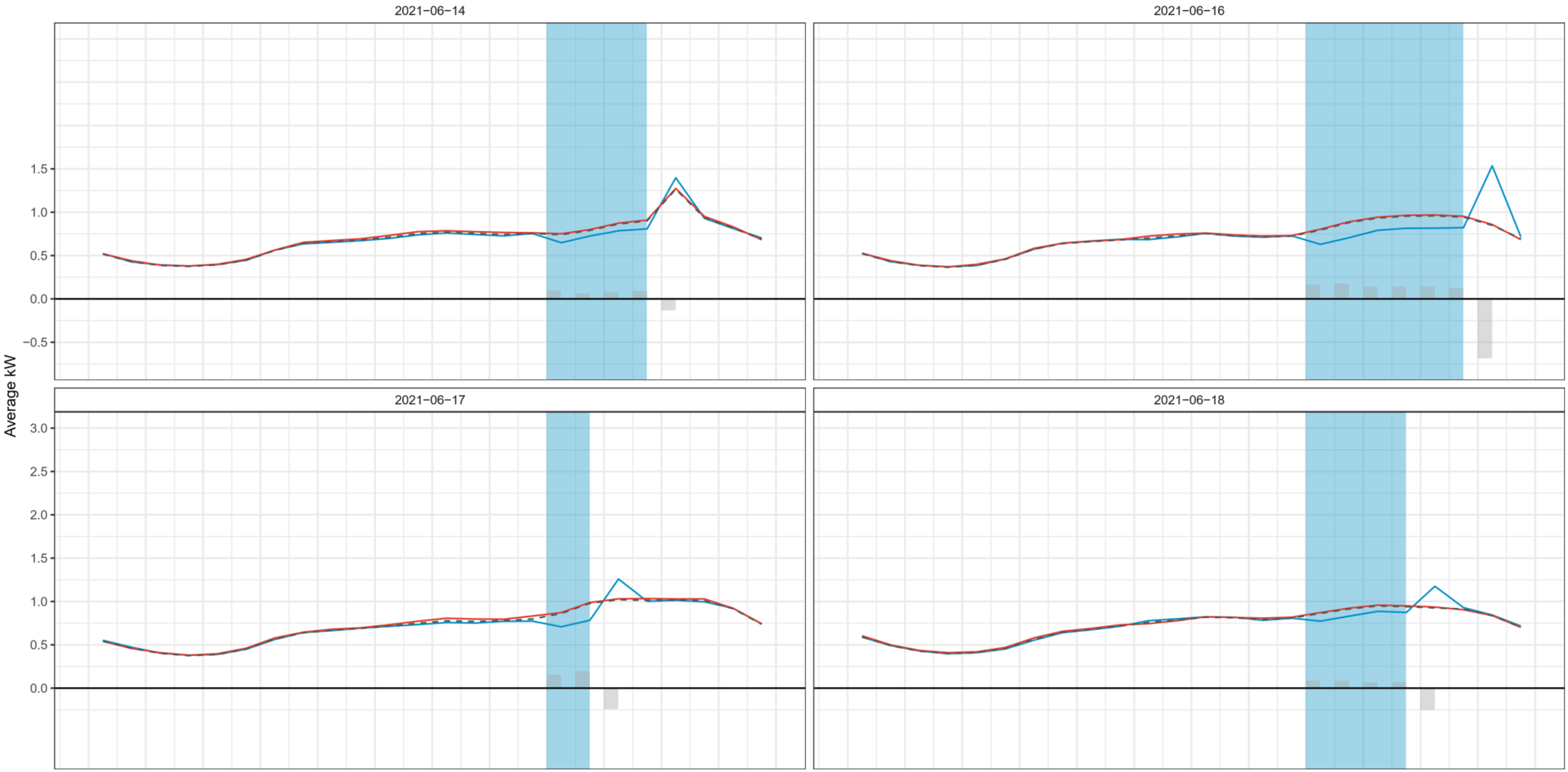
> **Recommendation #3:** Contact Generac to see if anything changed in device settings to explain this decrease in impacts.

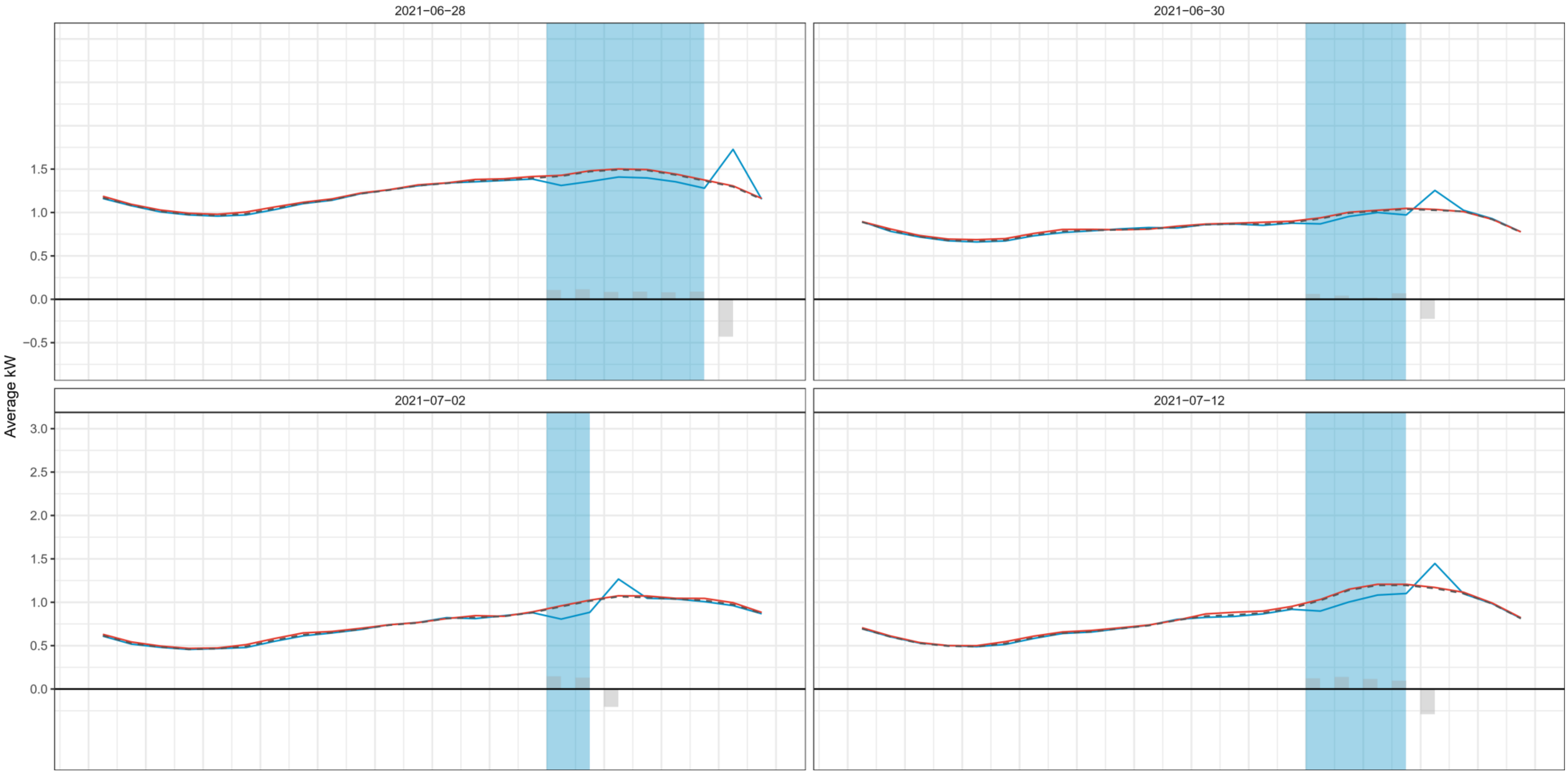
Finding #4: Relative to shorter events, six-hour and seven-hour events showed similar levels of demand reduction during the early event hours, and trailed off during the final hours. Snapback was also generally greater for longer events. The benefit of more hours of dispatch generally outweighs the increase in snapback.

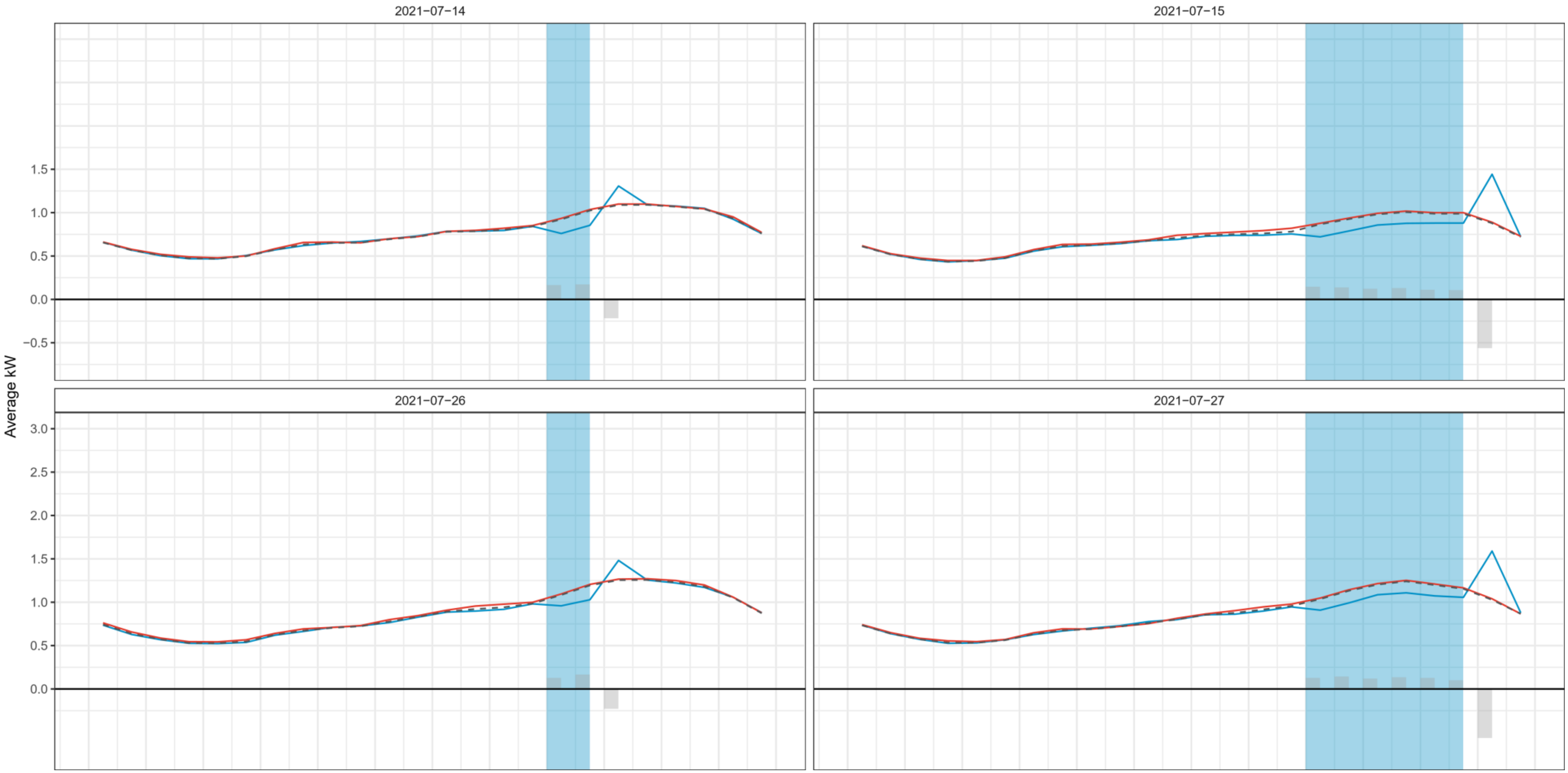
Recommendation #4: PGE should consider these results in future event design. Delaying snapback later in the day by extending the event length may be valuable even if it results in a higher magnitude of snapback. However, we found that depending on when the event ended, longer events sometimes had lower snapback than short events which ended during an hour of higher use.

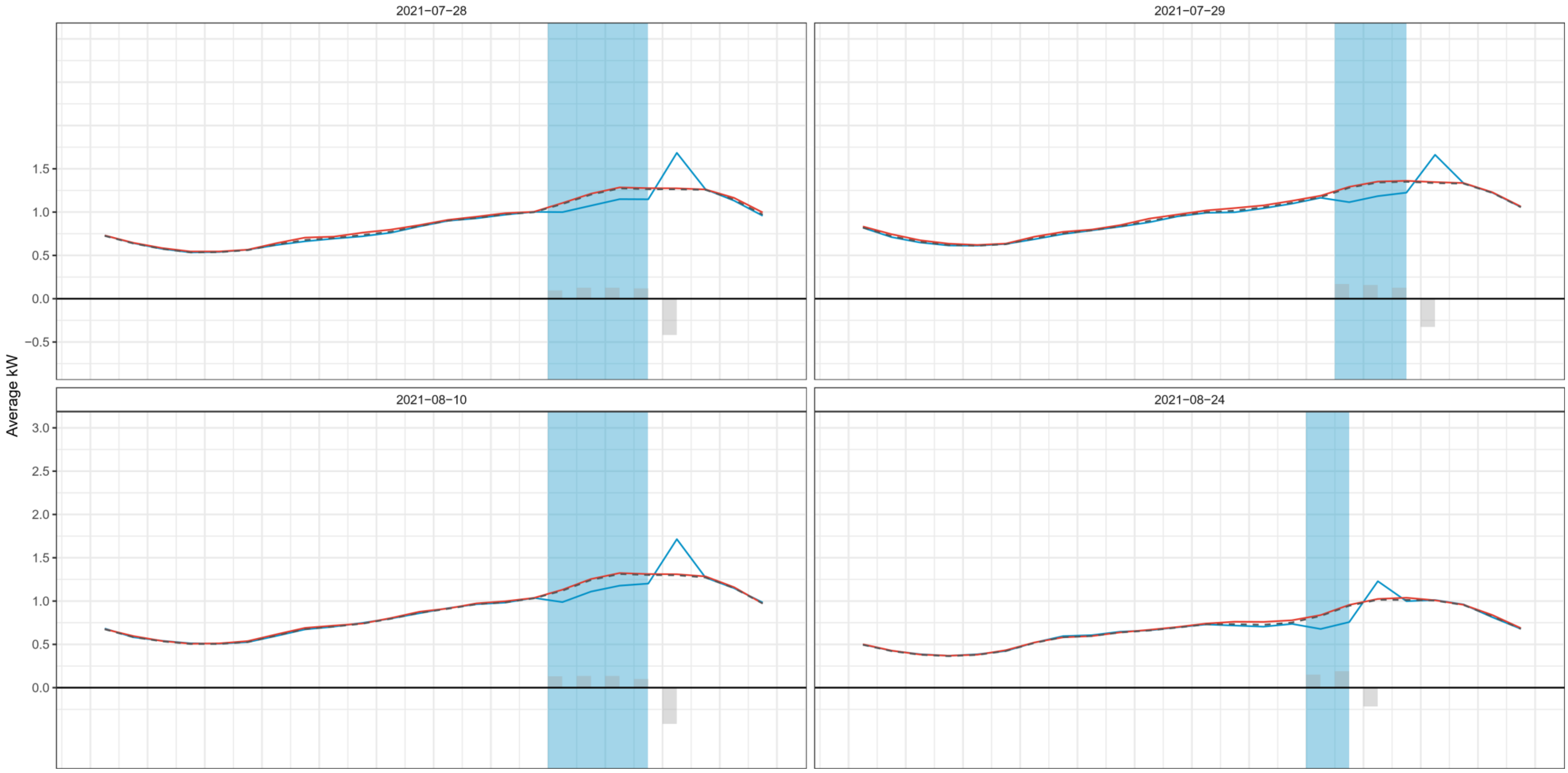
Appendix A. Summer 2021 Event Plots

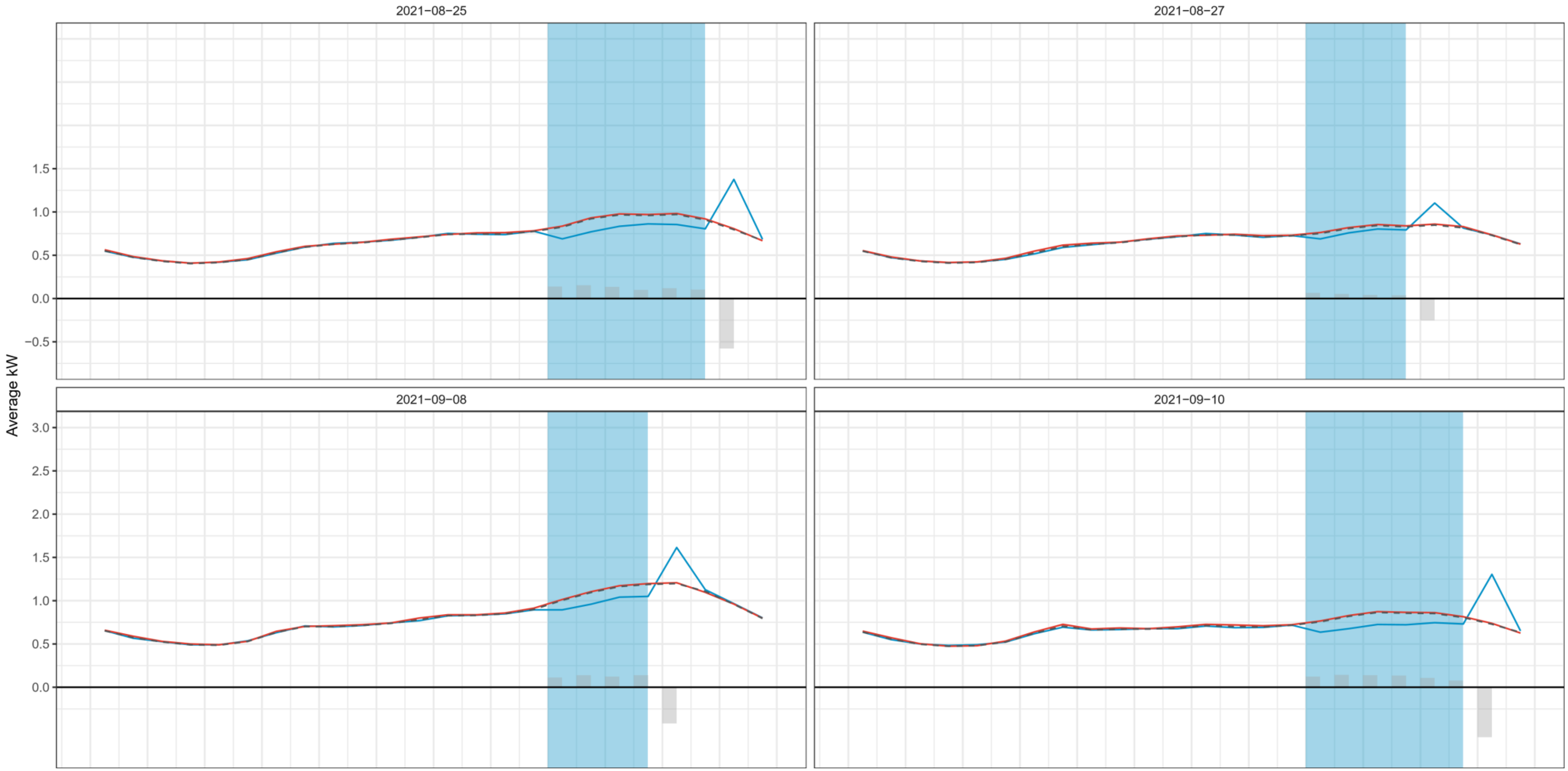

2021−06−01
2021−06−02
2021−06−03
2021−06−04
Average kW
1.5
1.0
0.5
0.0
−0.5
3.0
2.5
2.0

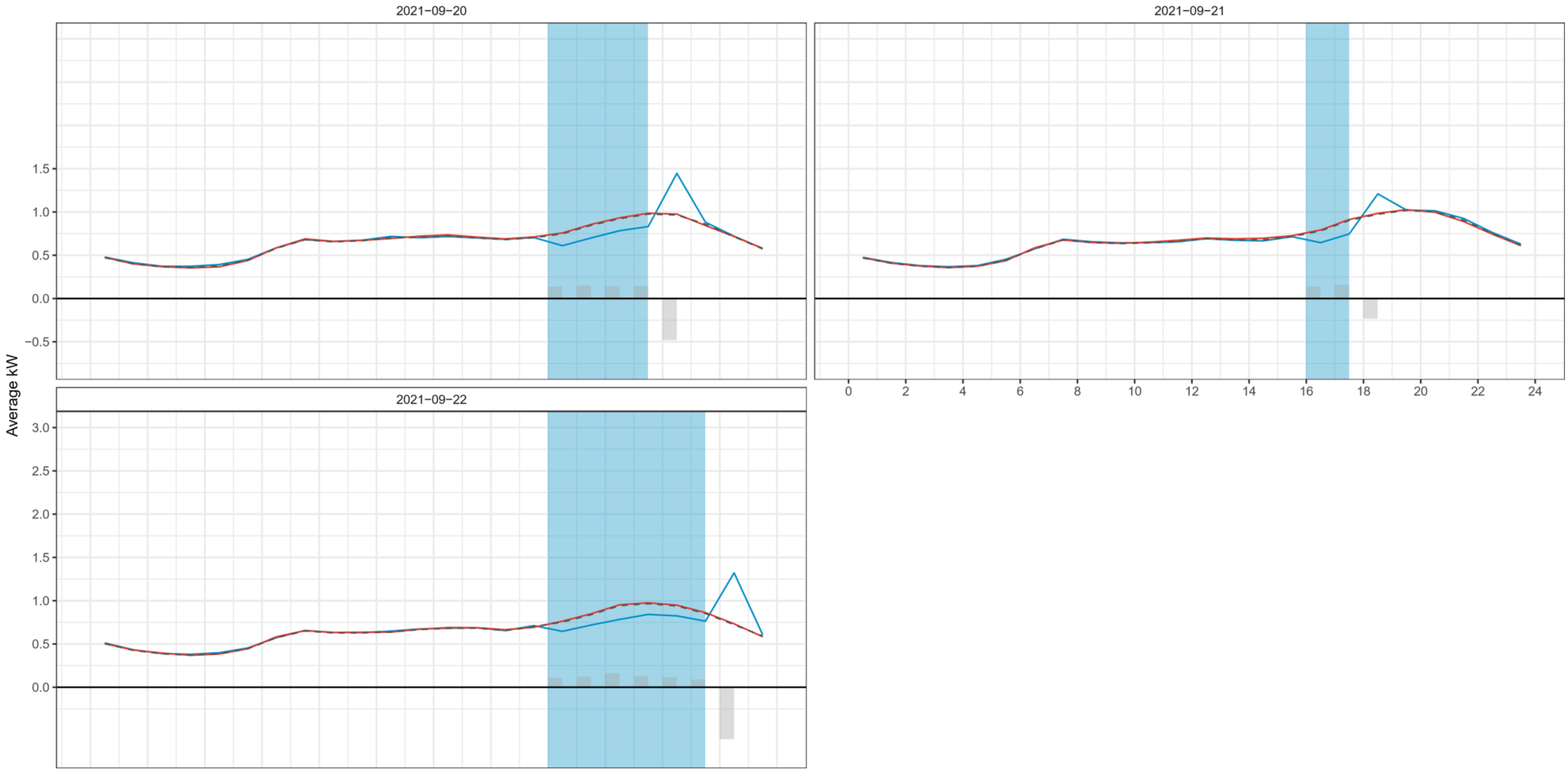

2021−06−14
2021−06−16
2021−06−17
2021−06−18
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

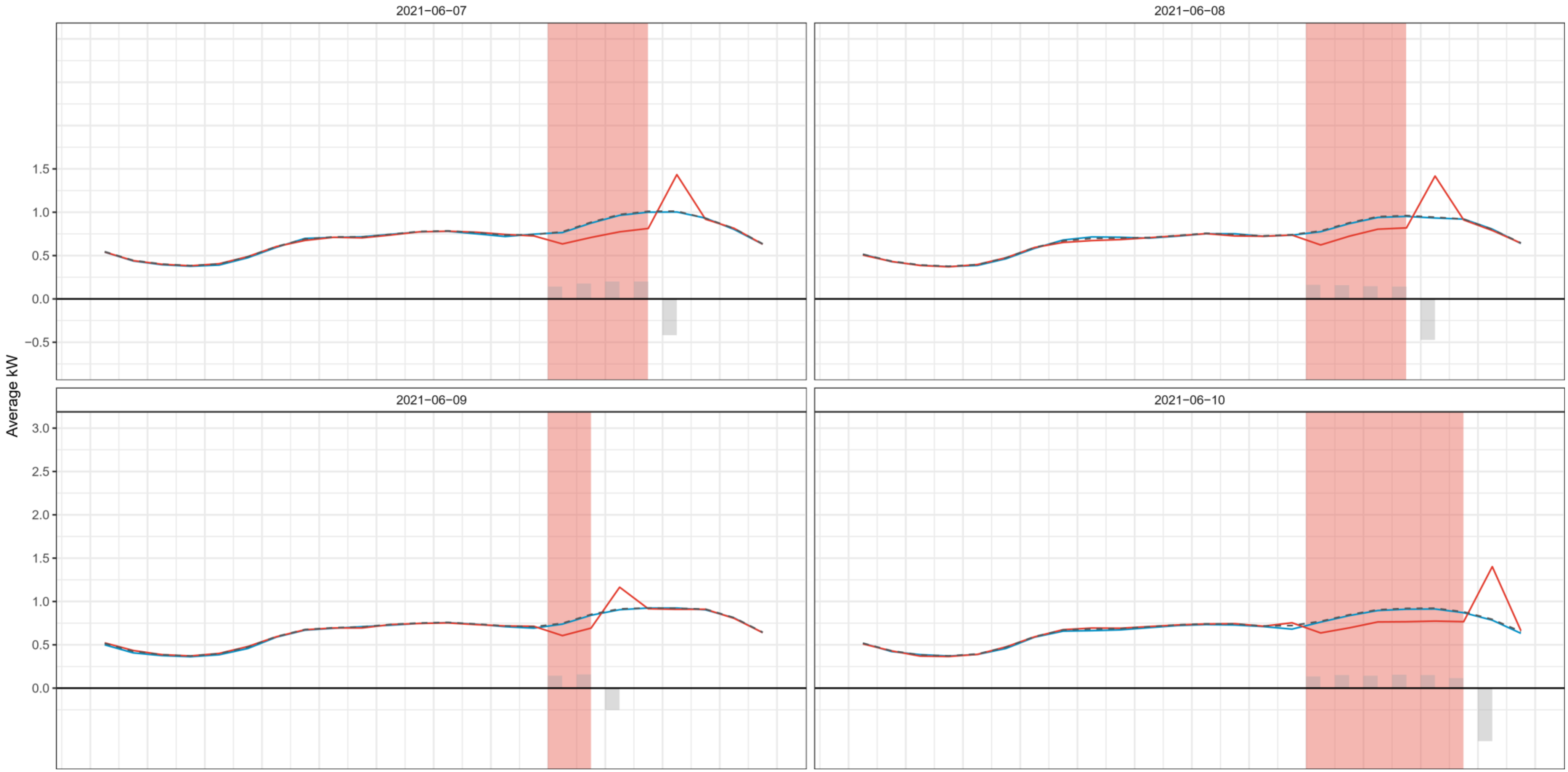

2021−06−28
2021−06−30
2021−07−02
2021−07−12
Average kW
1.5
1.0
0.5
0.0
−0.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

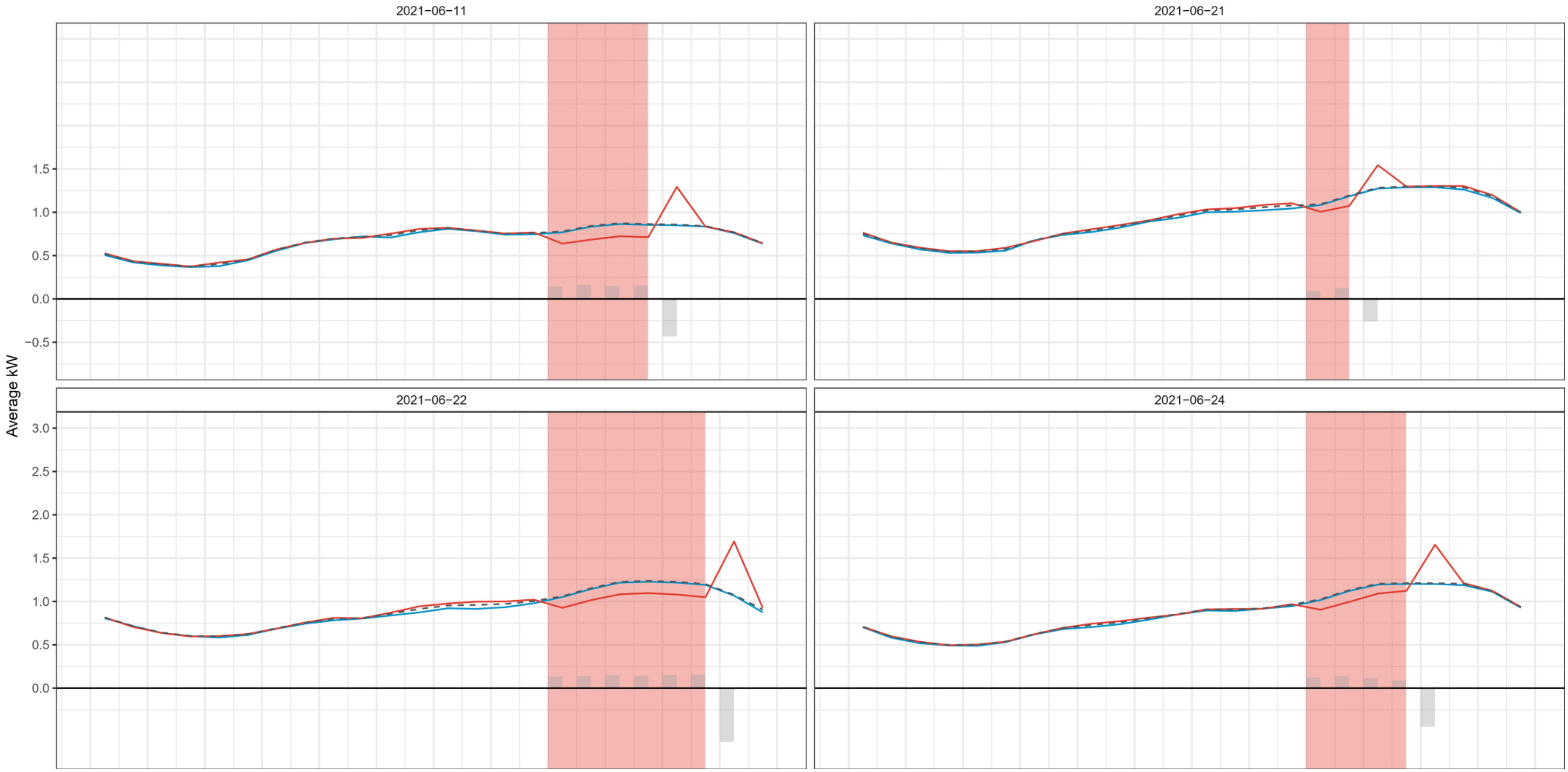

2021−07−14
2021−07−15
2021−07−26
2021−07−27
Average kW
1.5
1.0
0.5
0.0
−0.5
3.0
2.5
2.0

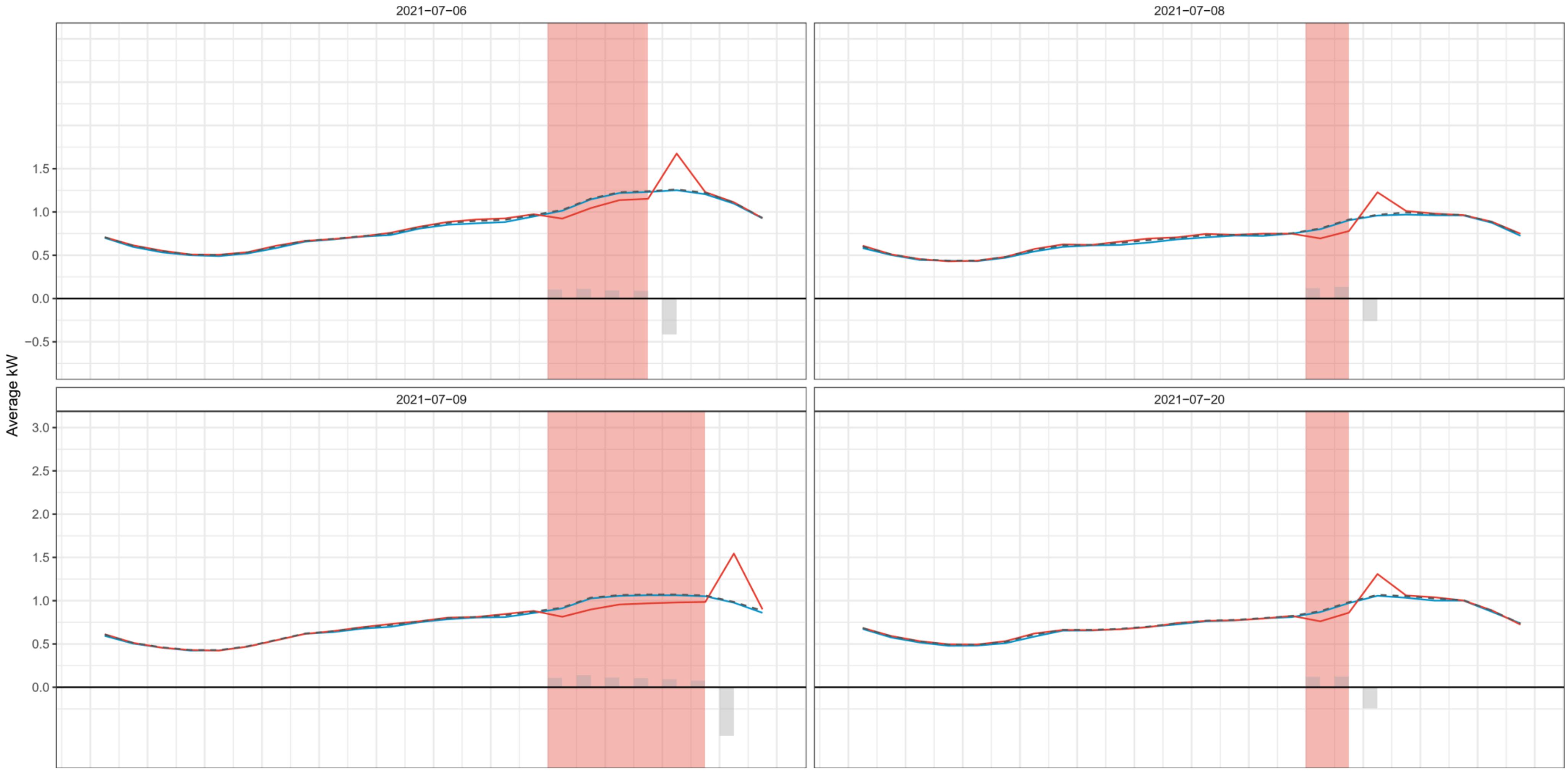

2021−07−28
2021−07−29
2021−08−10
2021−08−24
Average kW
1.5
1.0
0.5
0.0
−0.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

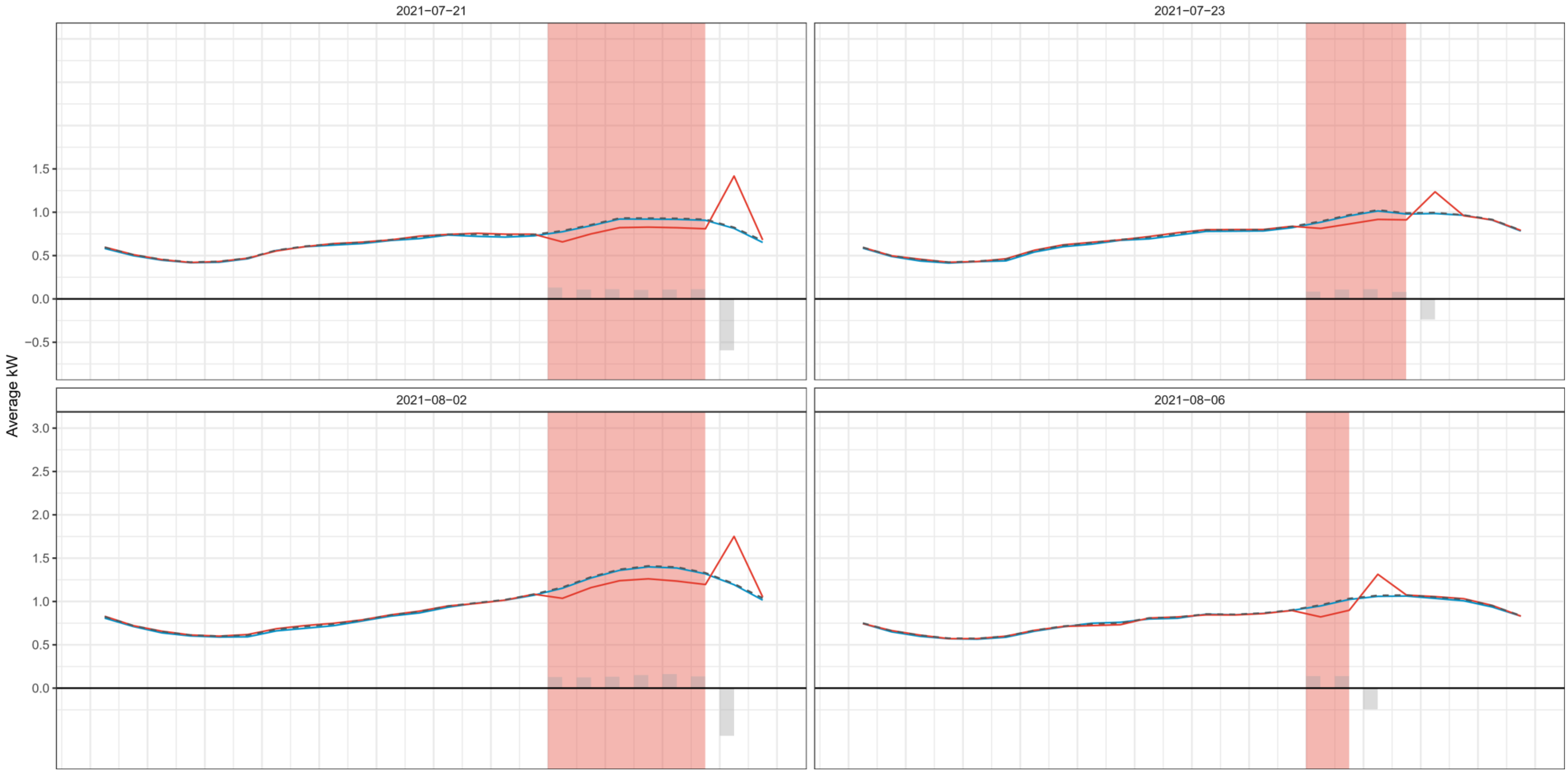

2021−08−25
2021−08−27
2021−09−08
2021−09−10
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

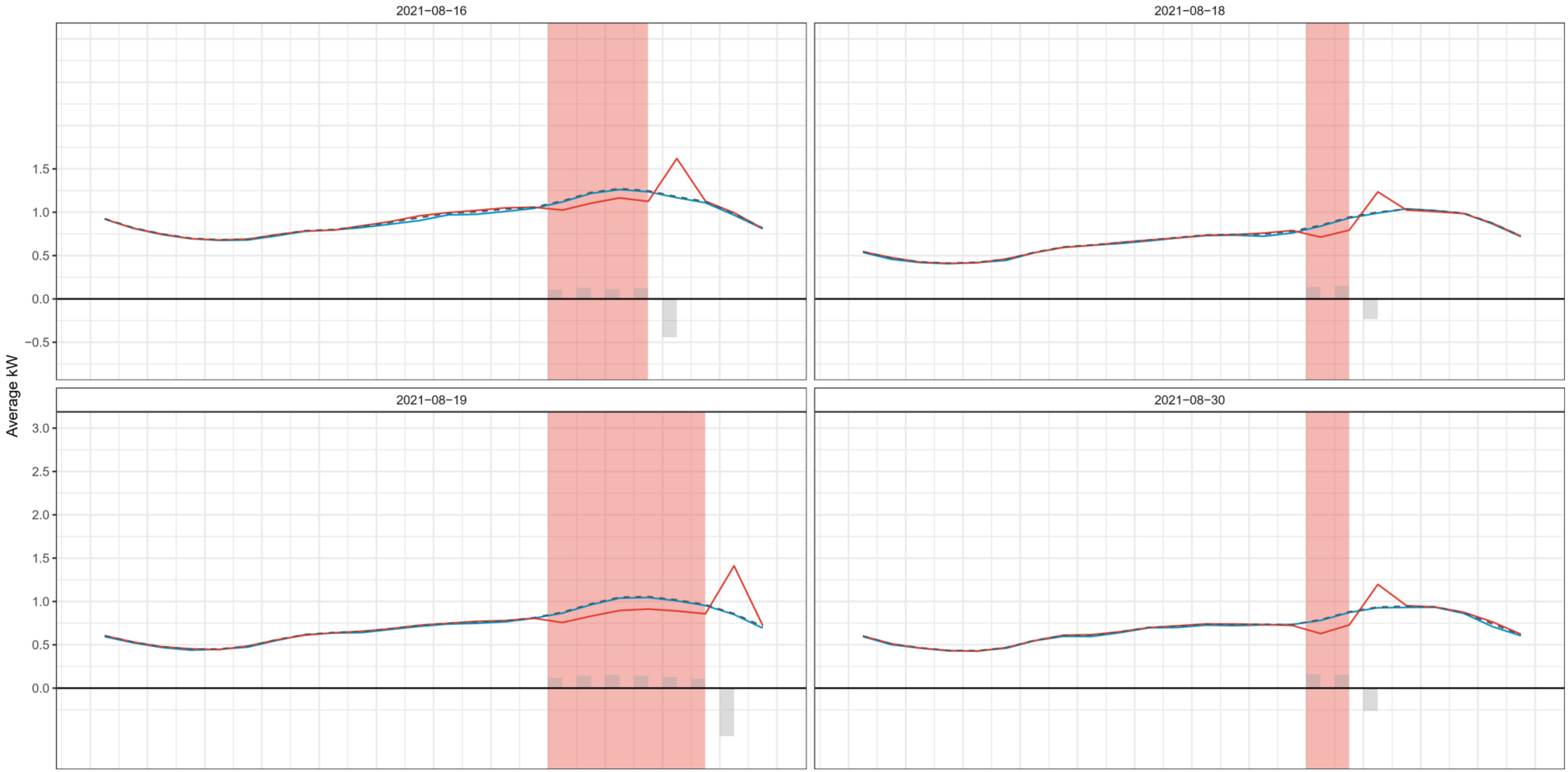

2021-09-20
2021-09-21
2021-09-22
Average kW
1.5
1.0
0.5
0.0
-0.5
3.0
2.5
2.0
0
2
4
6
8
10
12
14
16
18
20
22
24

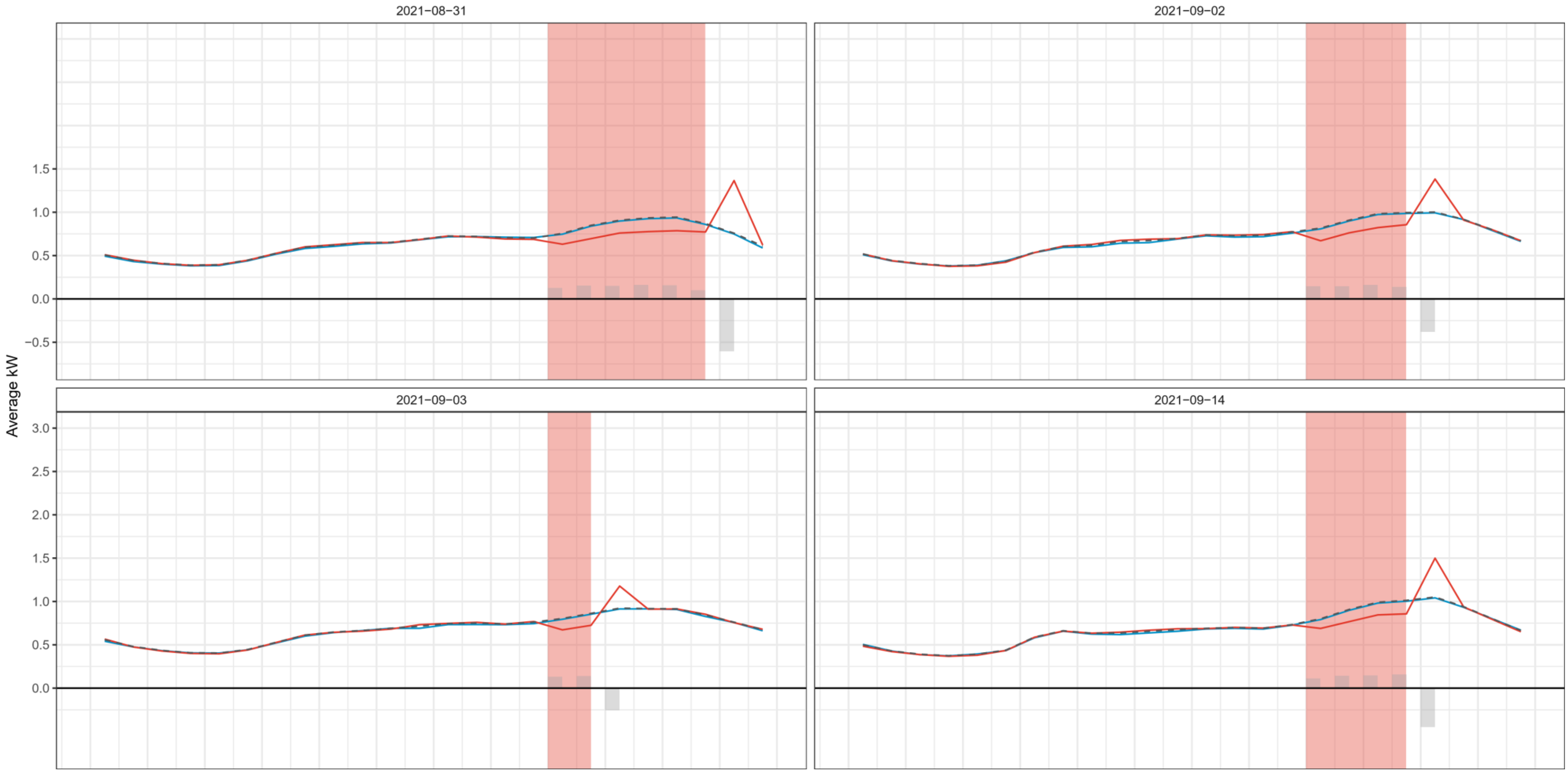

2021−06−07
2021−06−08
2021−06−09
2021−06−10
Average kW
1.5
1.0
0.5
0.0
−0.5
3.0
2.5
2.0

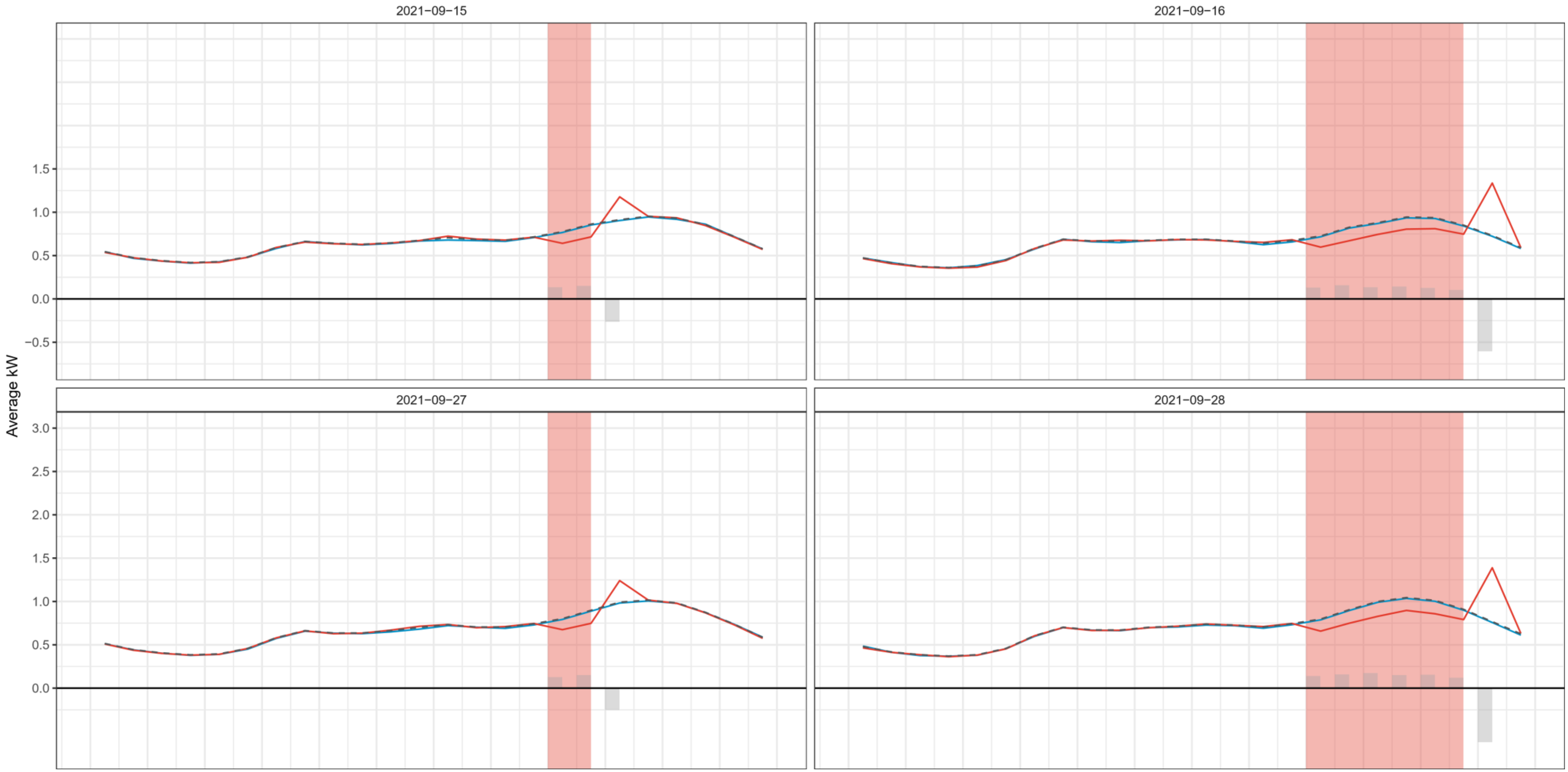

2021−06−11
2021−06−21
2021−06−22
2021−06−24
Average kW
1.5
1.0
0.5
0.0
−0.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0


2021−07−06
2021−07−08
2021−07−09
2021−07−20
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

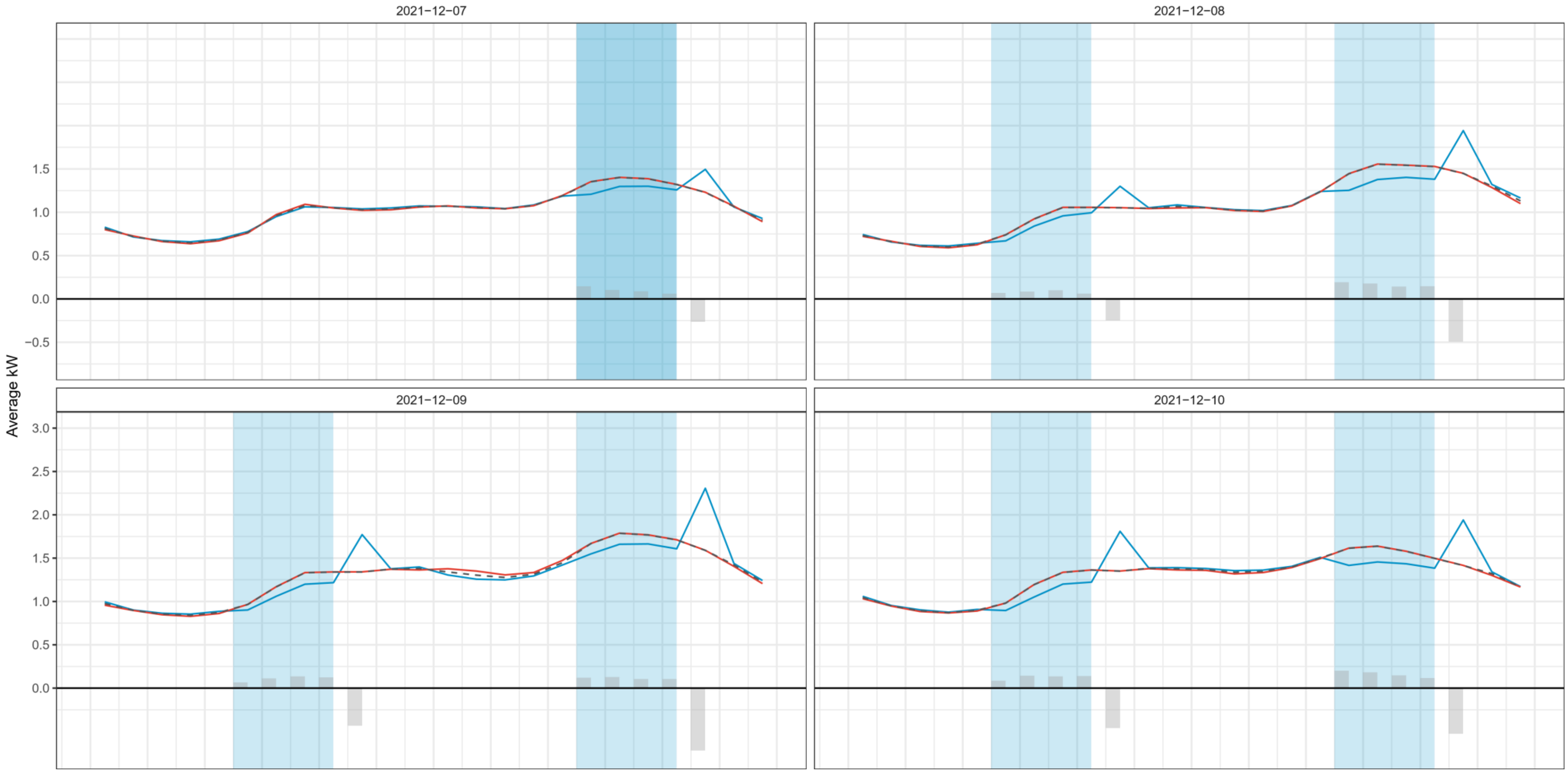

2021−07−21
2021−07−23
2021−08−02
2021−08−06
Average kW
1.5
1.0
0.5
0.0
−0.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

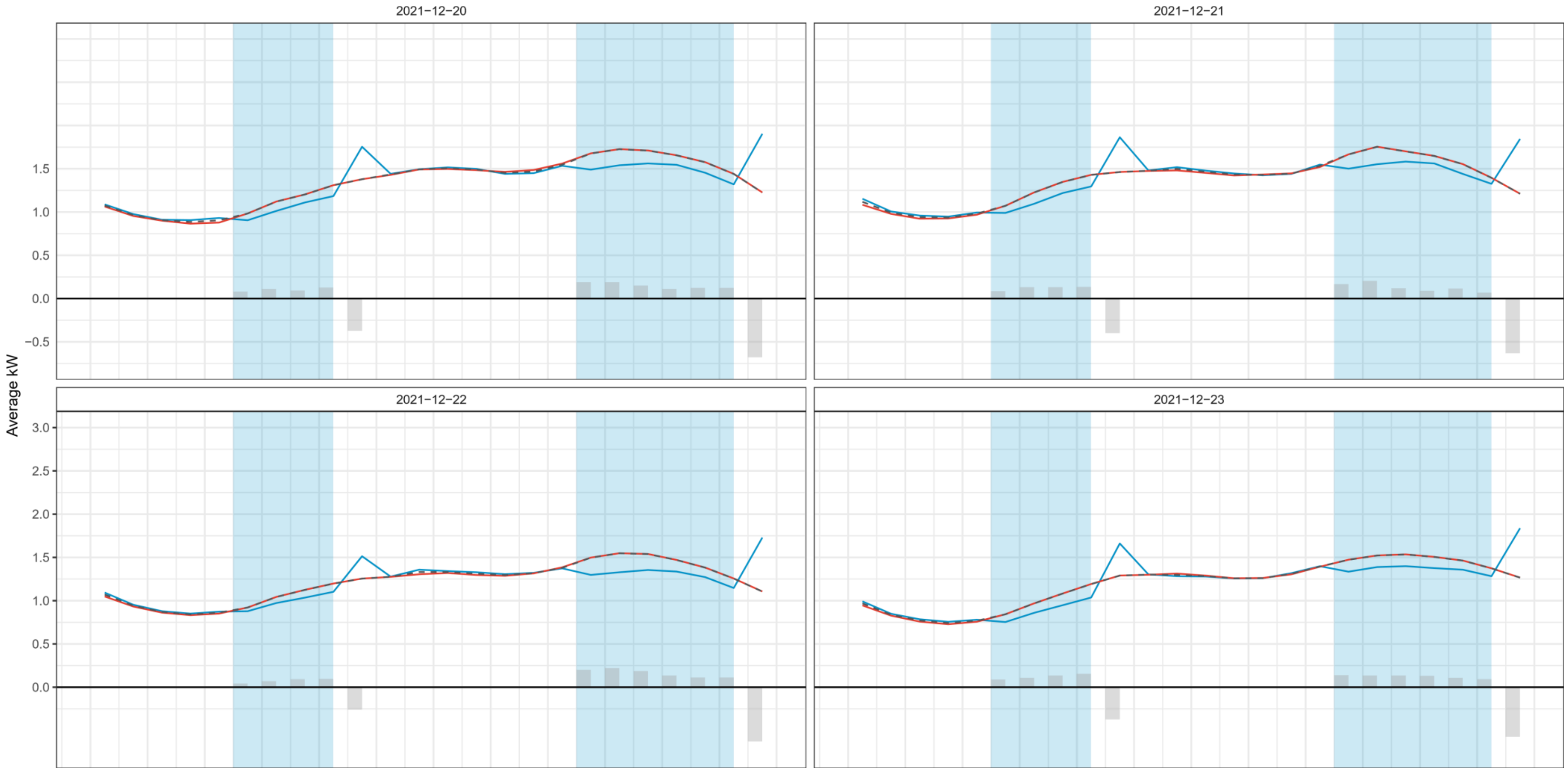

2021−08−16
2021−08−18
2021−08−19
2021−08−30
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5


2021−08−31
2021−09−02
2021−09−03
2021−09−14
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

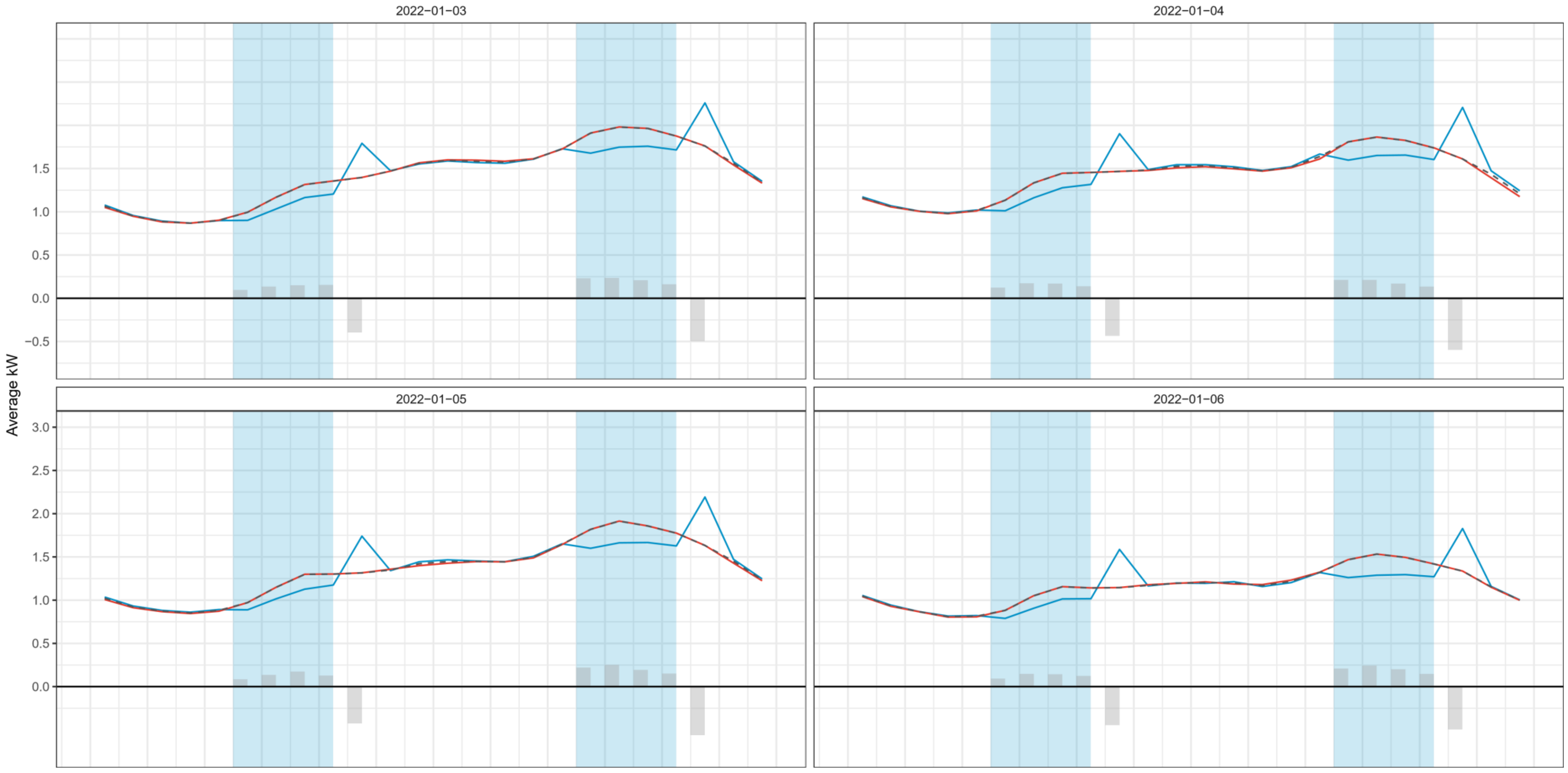

2021−09−15
2021−09−16
2021−09−27
2021−09−28
Average kW
1.5
1.0
0.5
0.0
−0.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

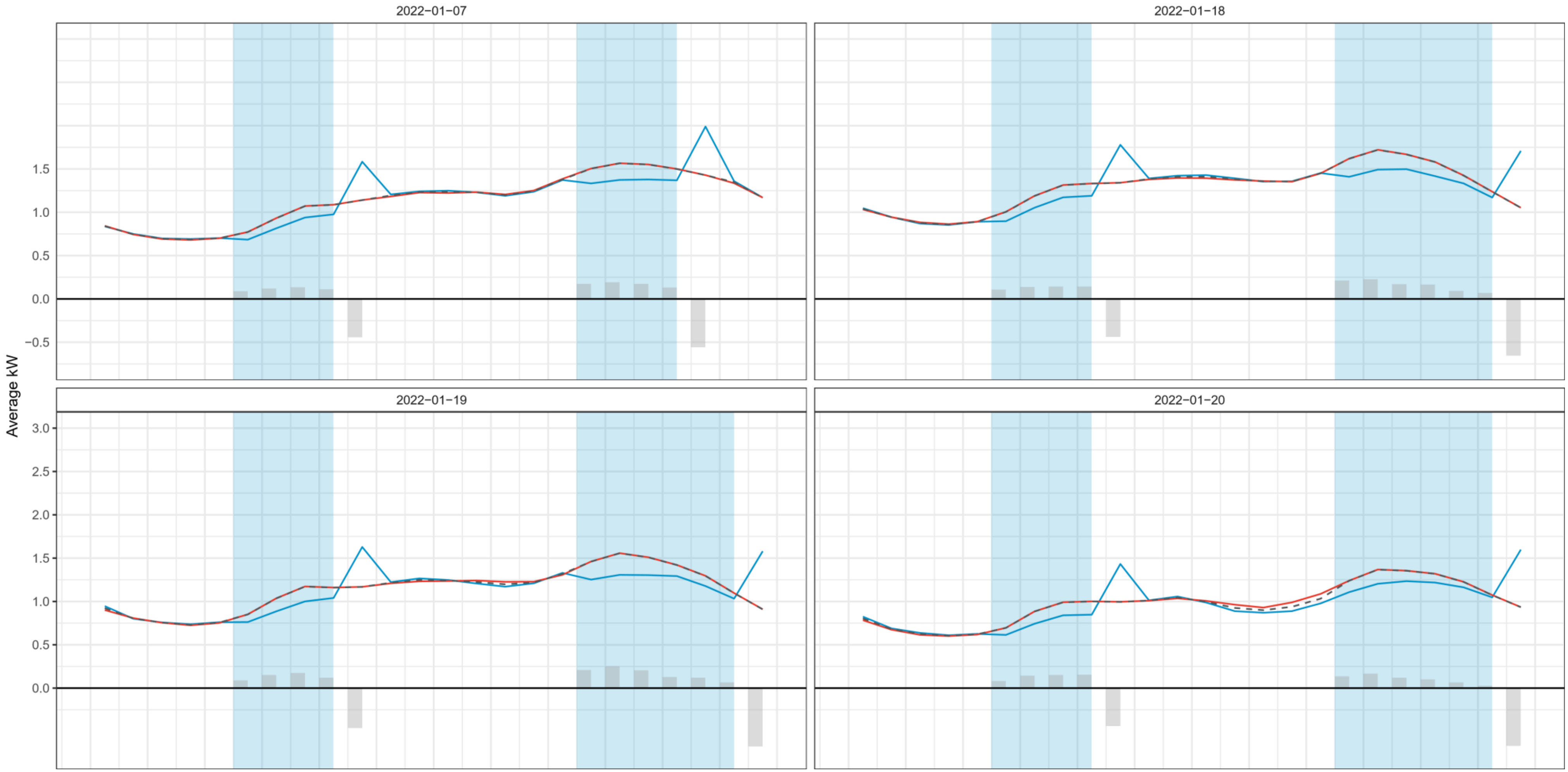
Appendix B. Winter 2021-22 Event Plots

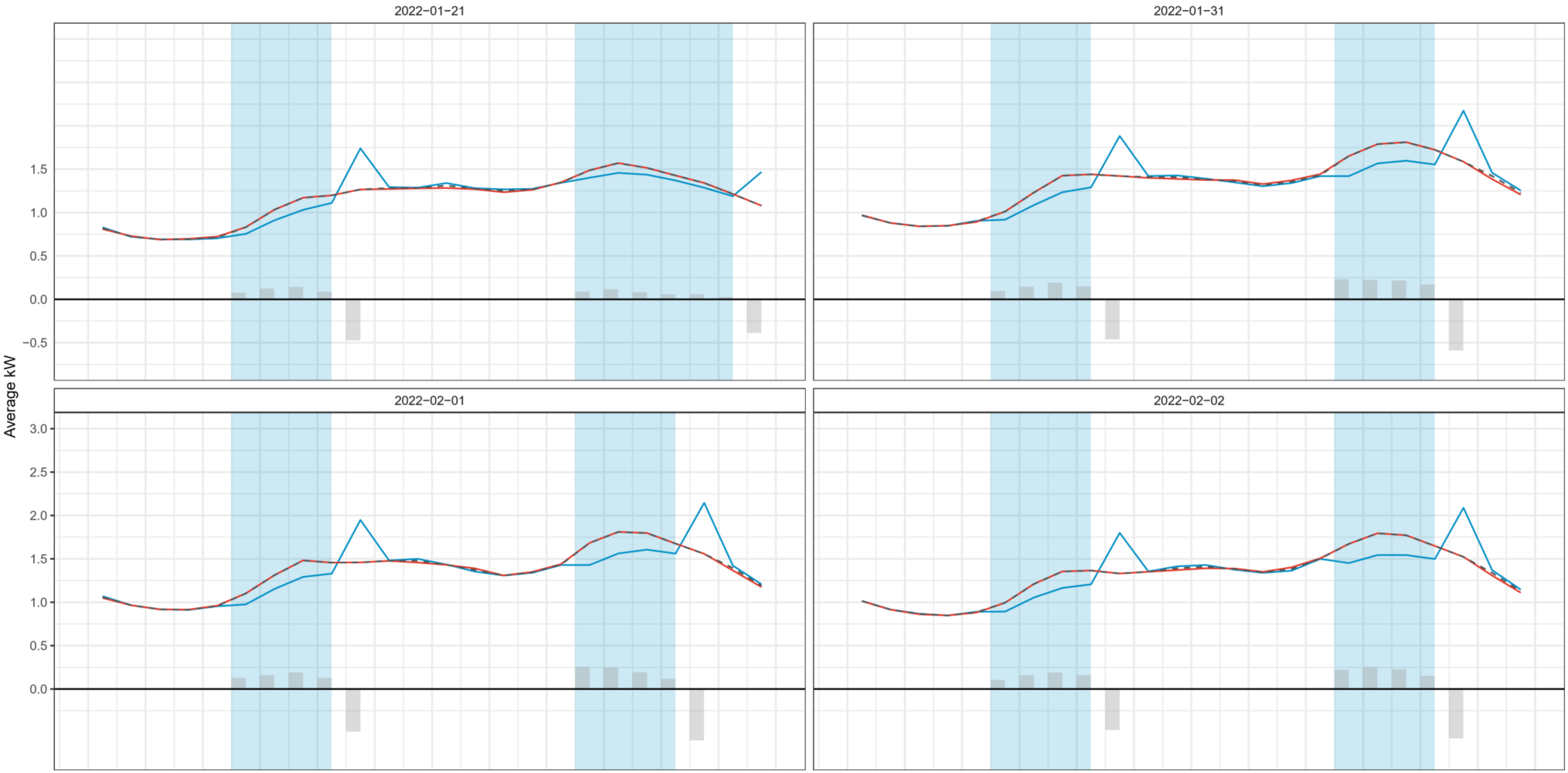

2021−12−07
2021−12−08
2021−12−09
2021−12−10
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

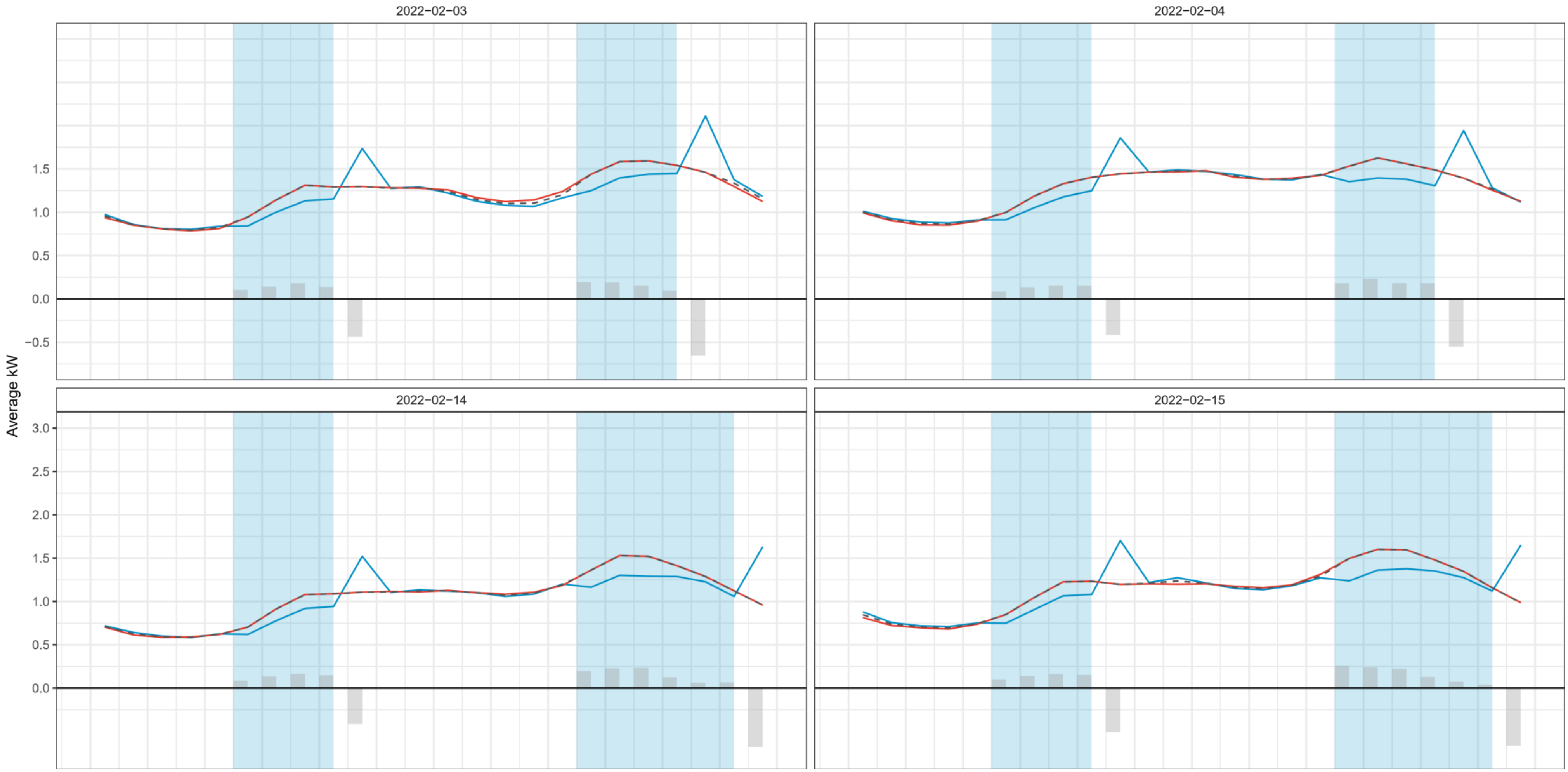


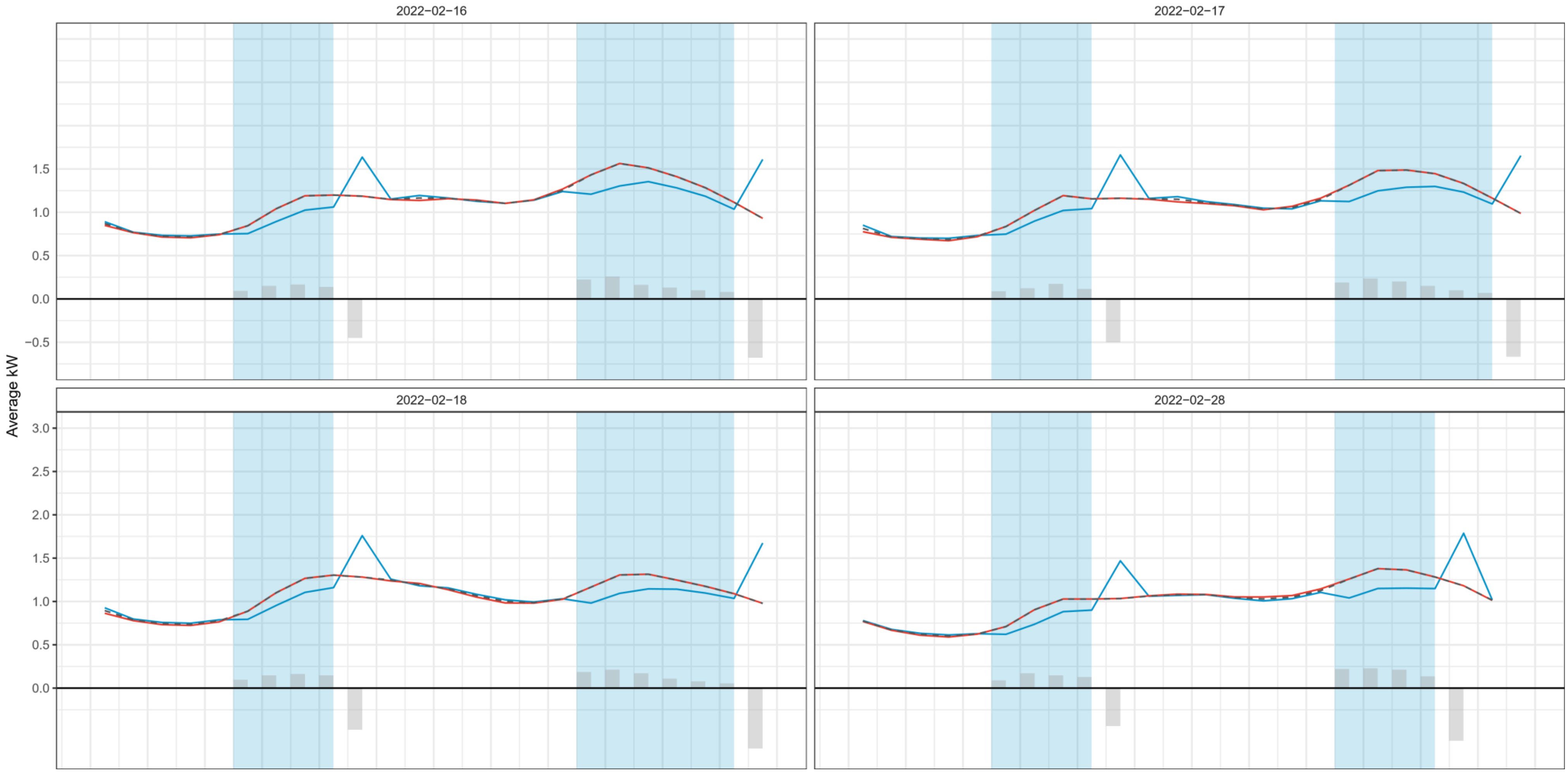
2021−12−20
2021−12−21
2021−12−22
2021−12−23
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

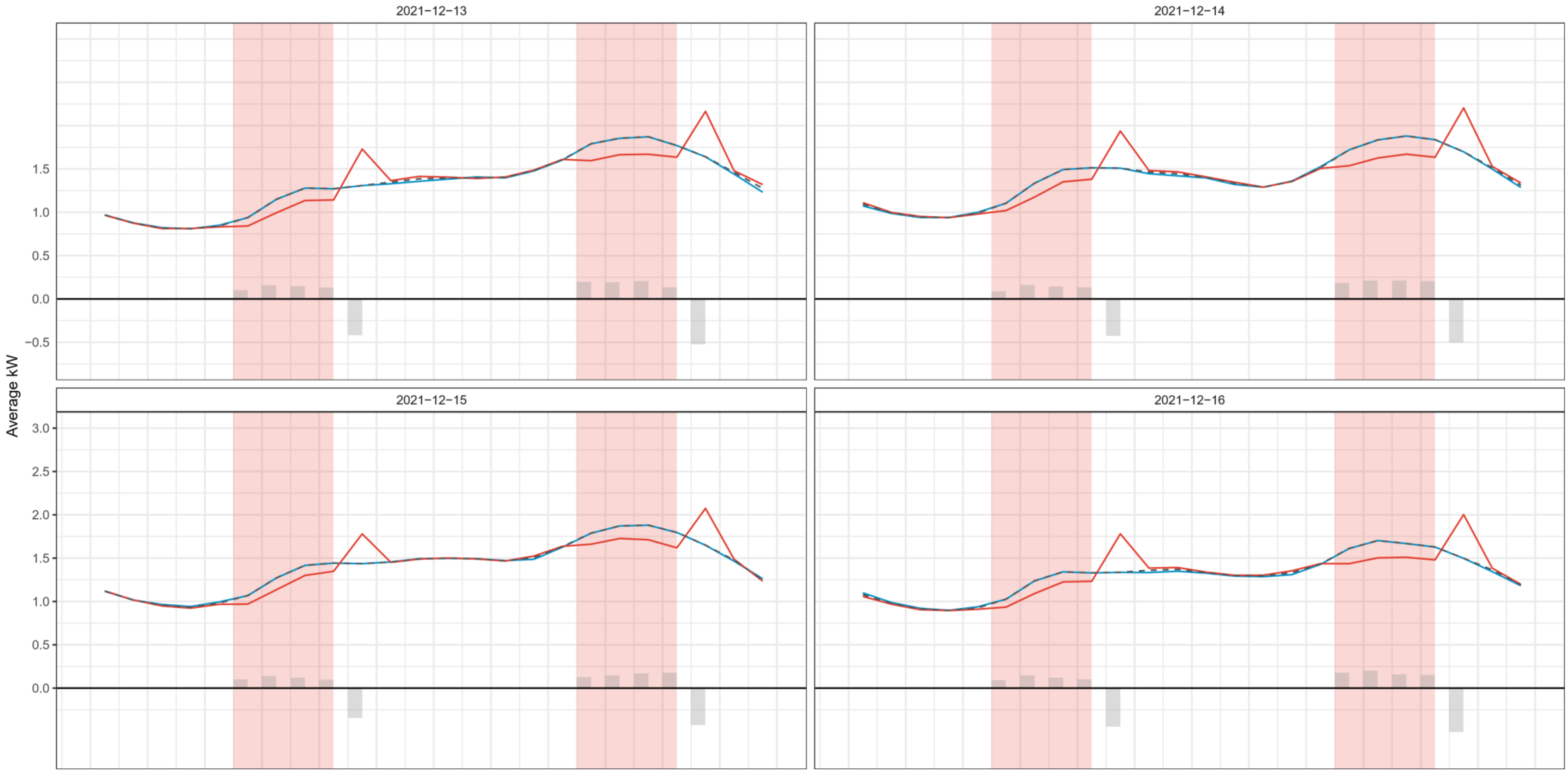

2022−01−03
2022−01−04
2022−01−05
2022−01−06
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

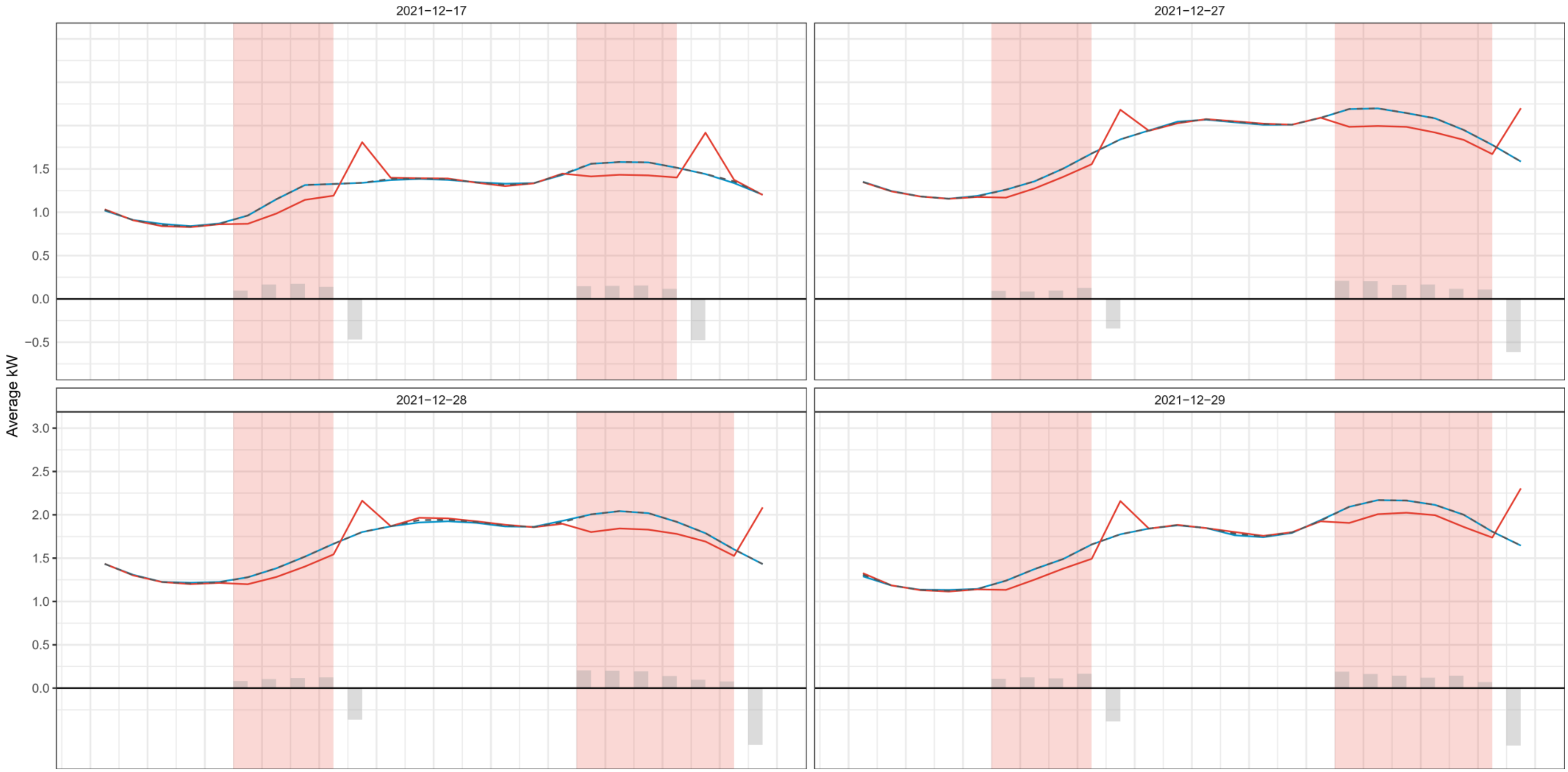

2022−01−07
2022−01−18
2022−01−19
2022−01−20
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

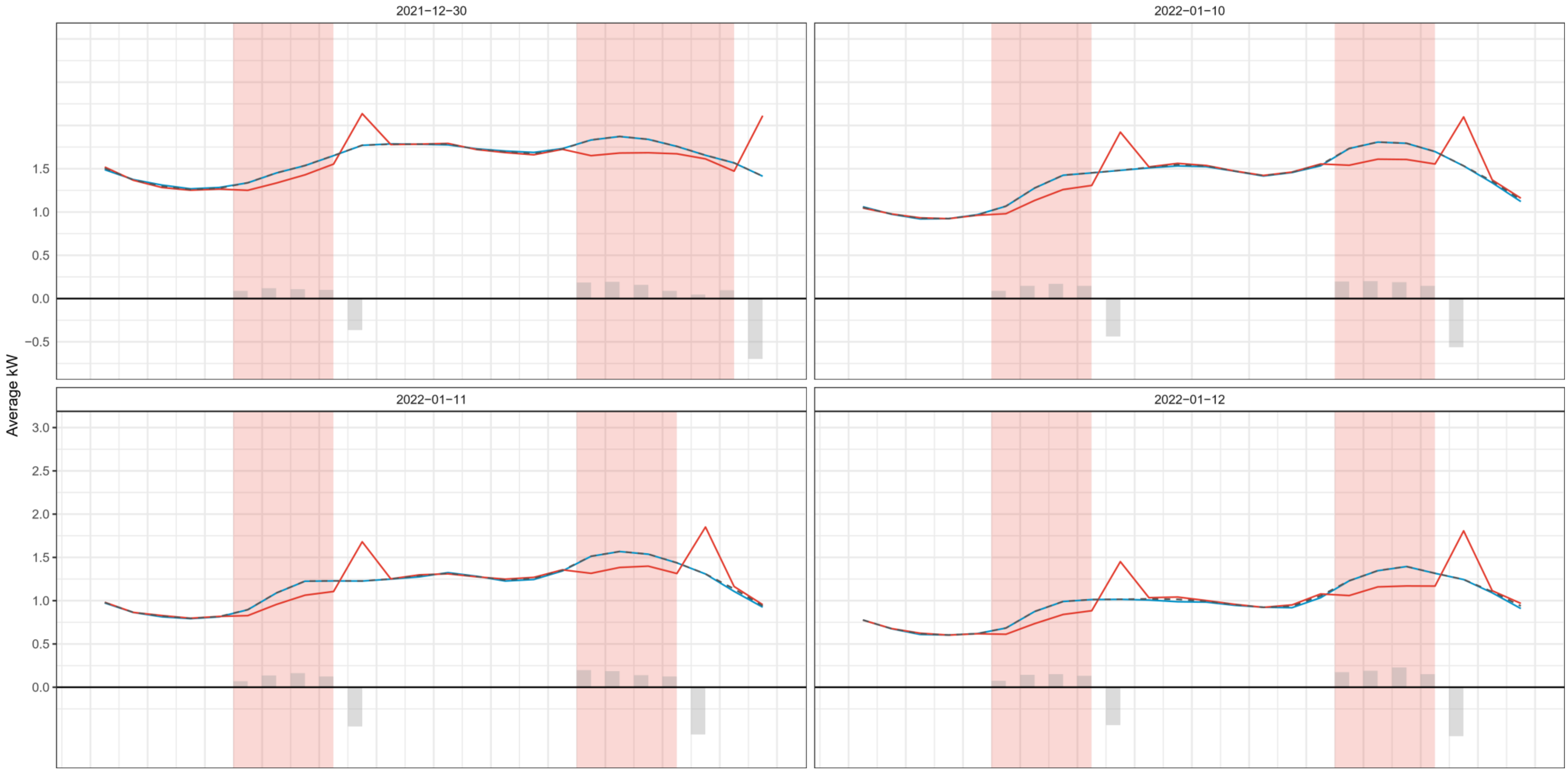

2022−01−21
2022−01−31
2022−02−01
2022−02−02
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

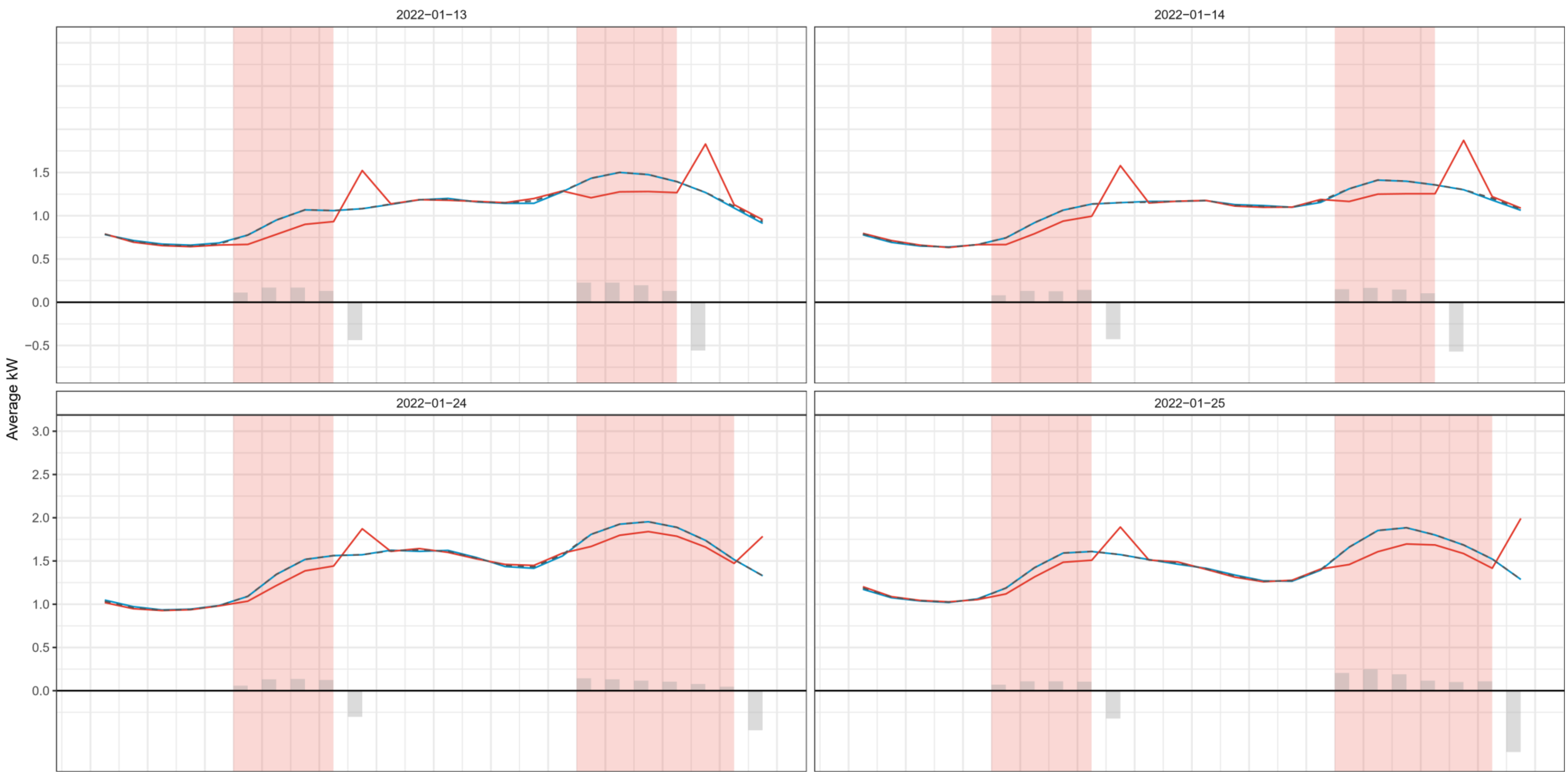

2022−02−03
2022−02−04
2022−02−14
2022−02−15
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

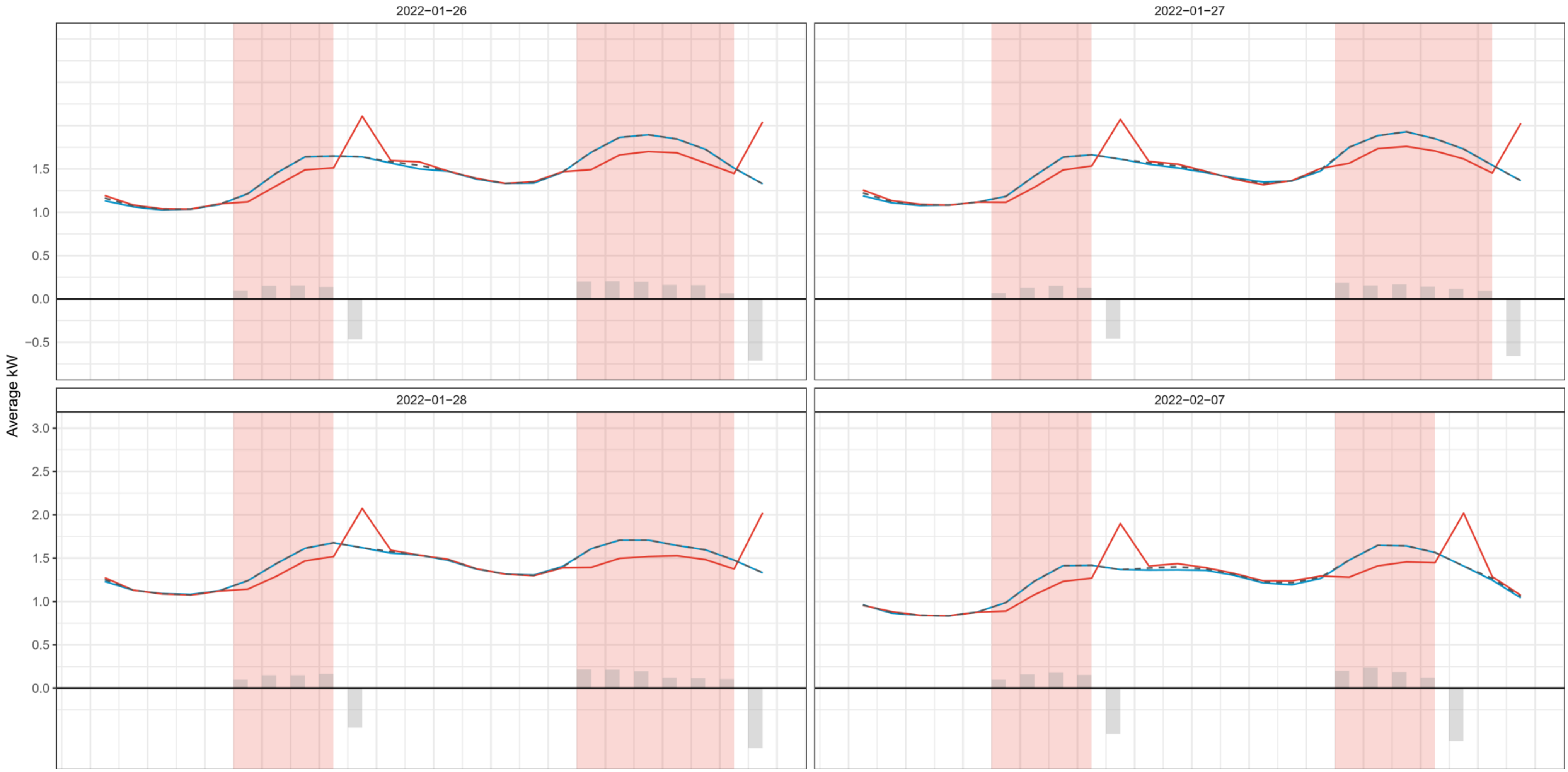

2022−02−16
2022−02−17
2022−02−18
2022−02−28
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

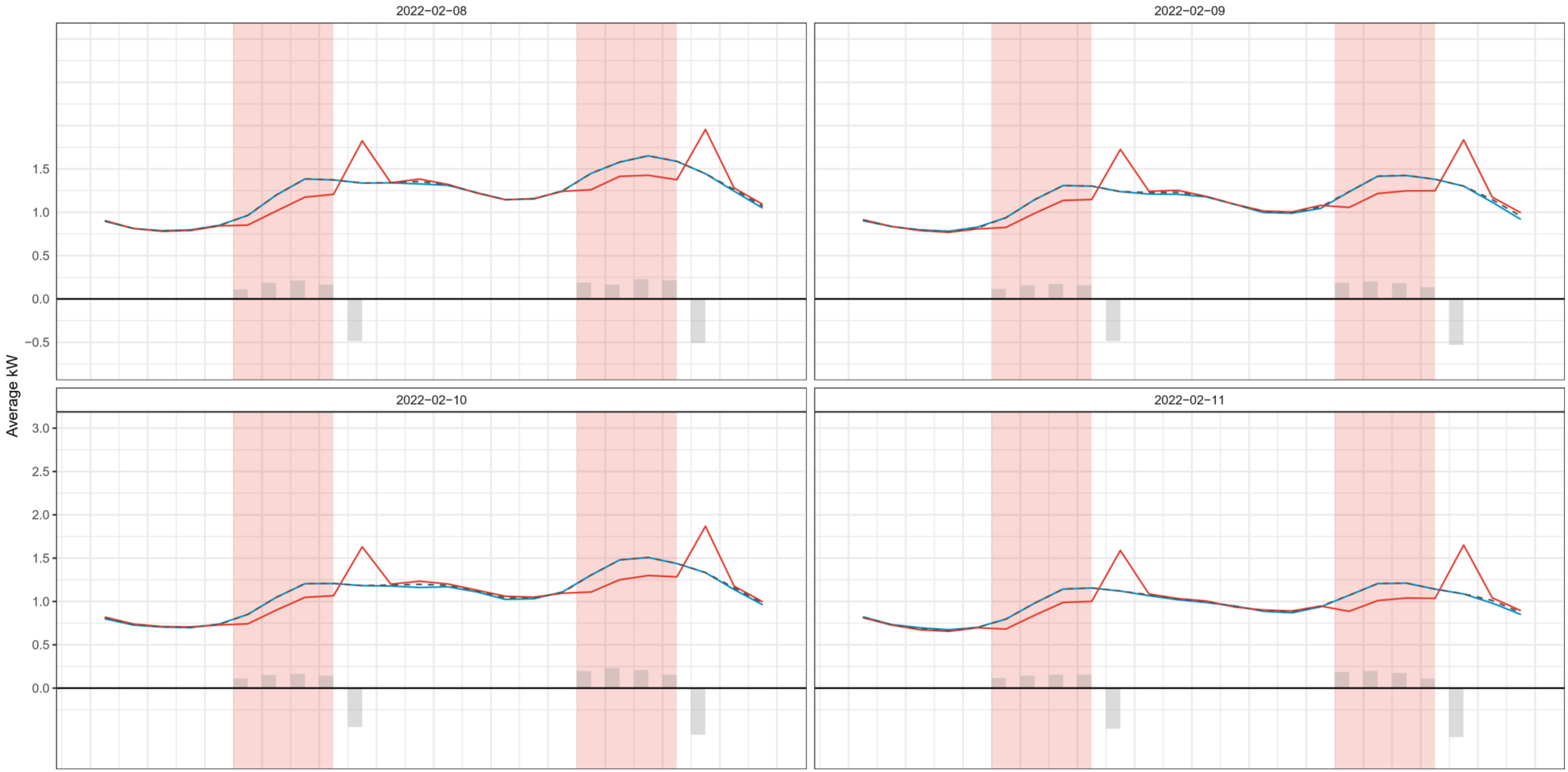

2021−12−13
2021−12−14
2021−12−15
2021−12−16
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

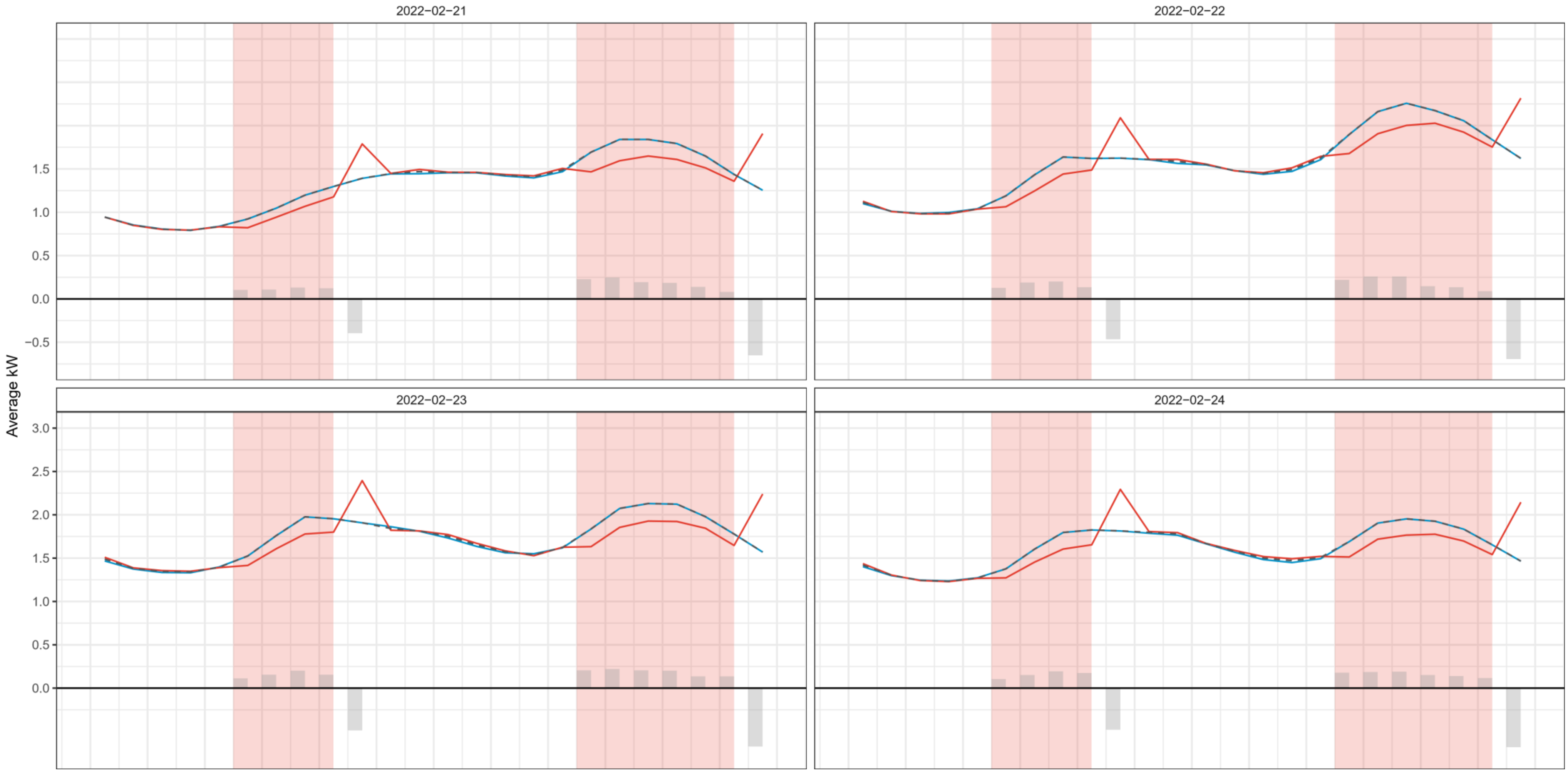

2021−12−17
2021−12−27
2021−12−28
2021−12−29
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

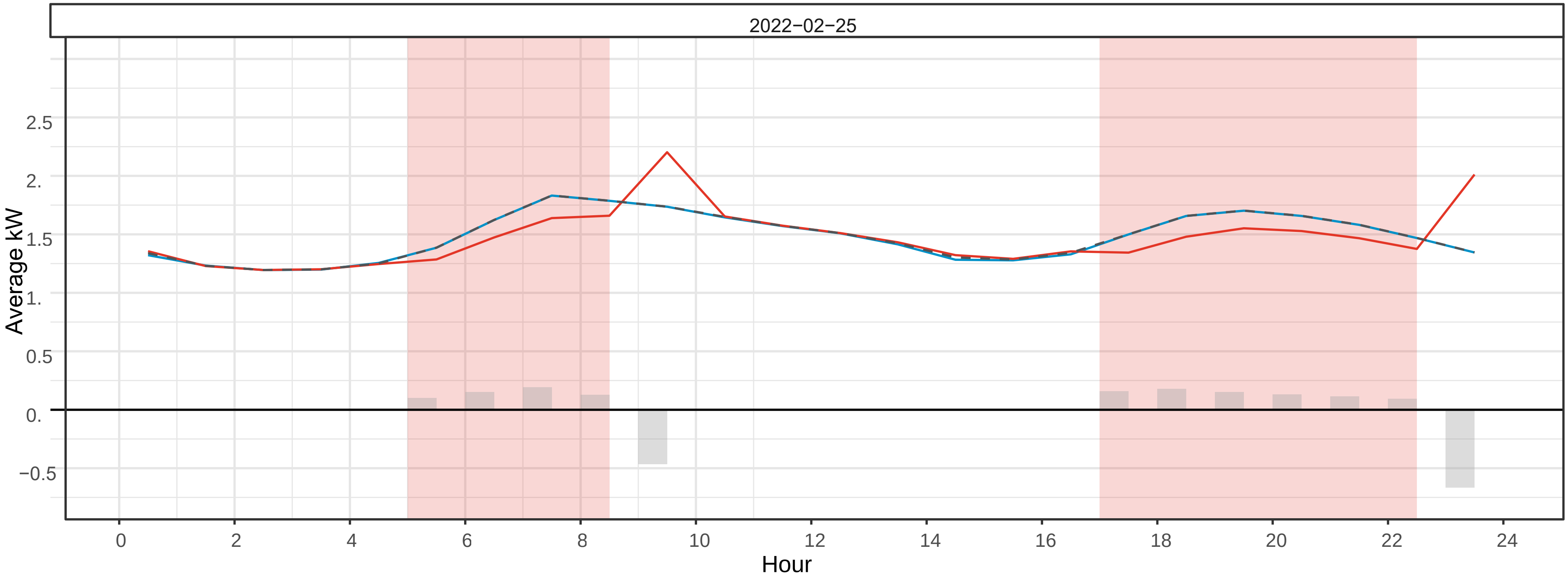

2021−12−30
2022−01−10
2022−01−11
2022−01−12
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5


2022−01−13
2022−01−14
2022−01−24
2022−01−25
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

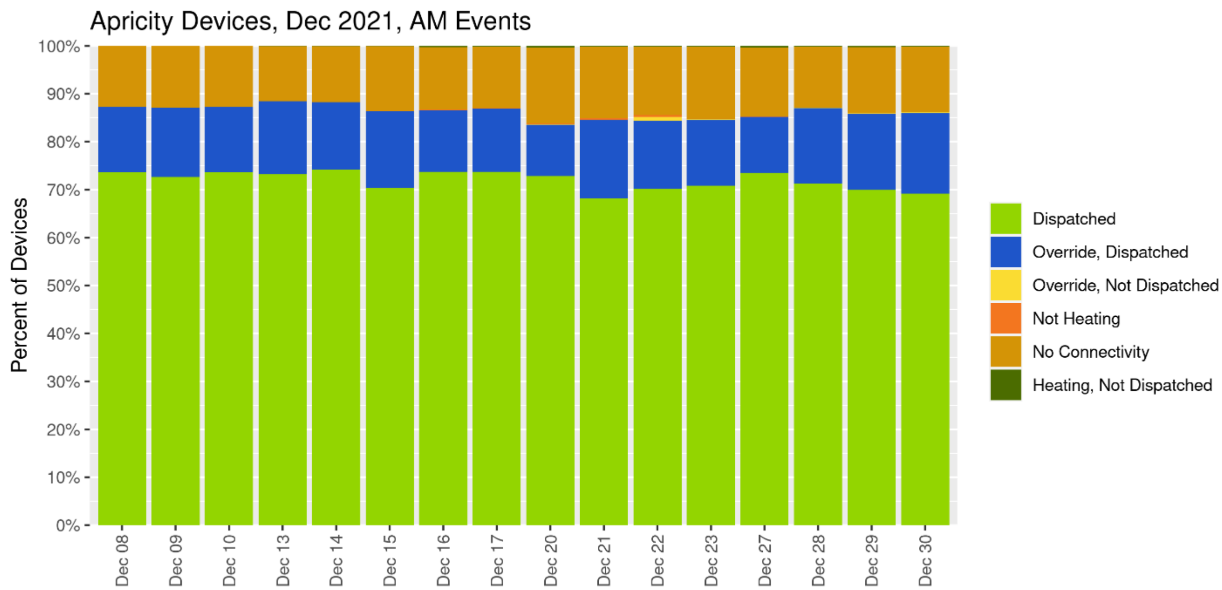

2022−01−26
2022−01−27
2022−01−28
2022−02−07
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

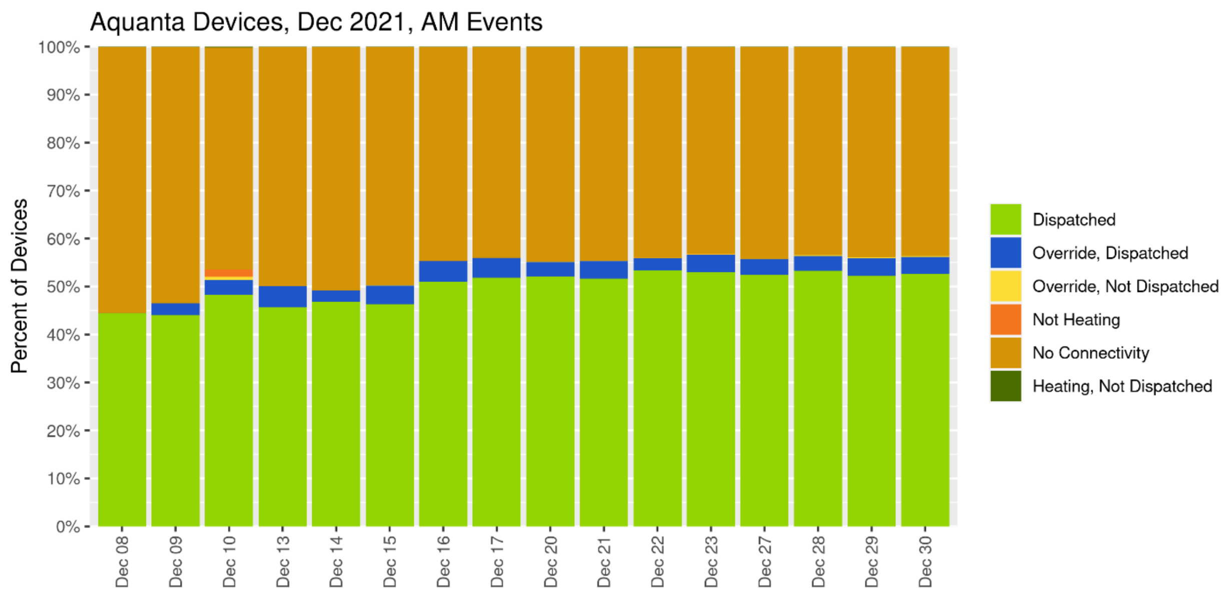

2022−02−08
2022−02−09
2022−02−10
2022−02−11
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

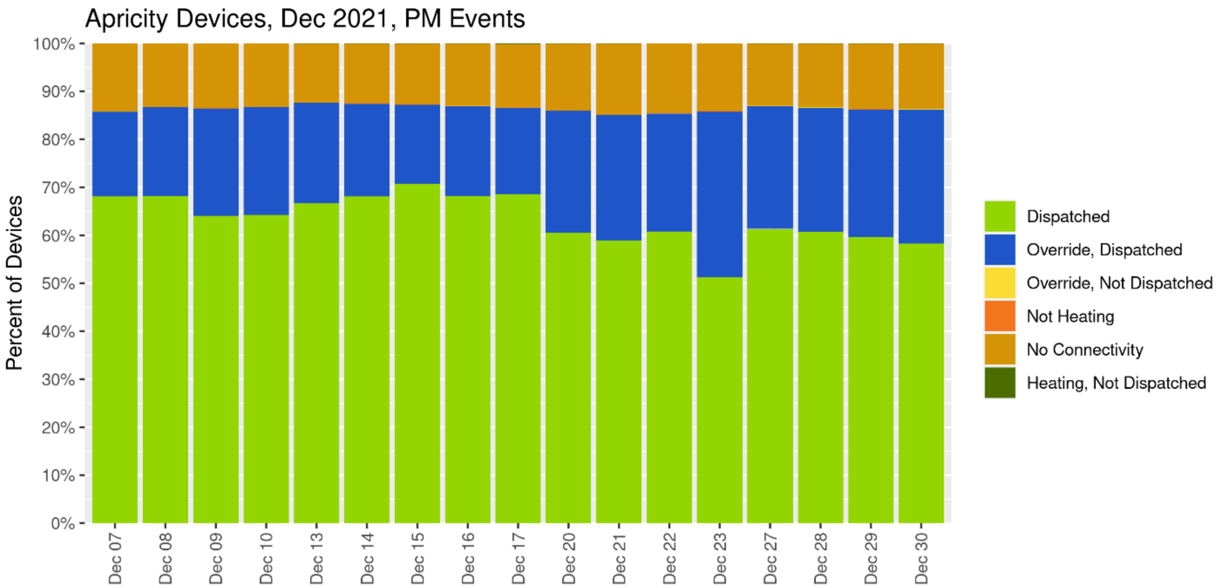

2022−02−21
2022−02−22
2022−02−23
2022−02−24
Average kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

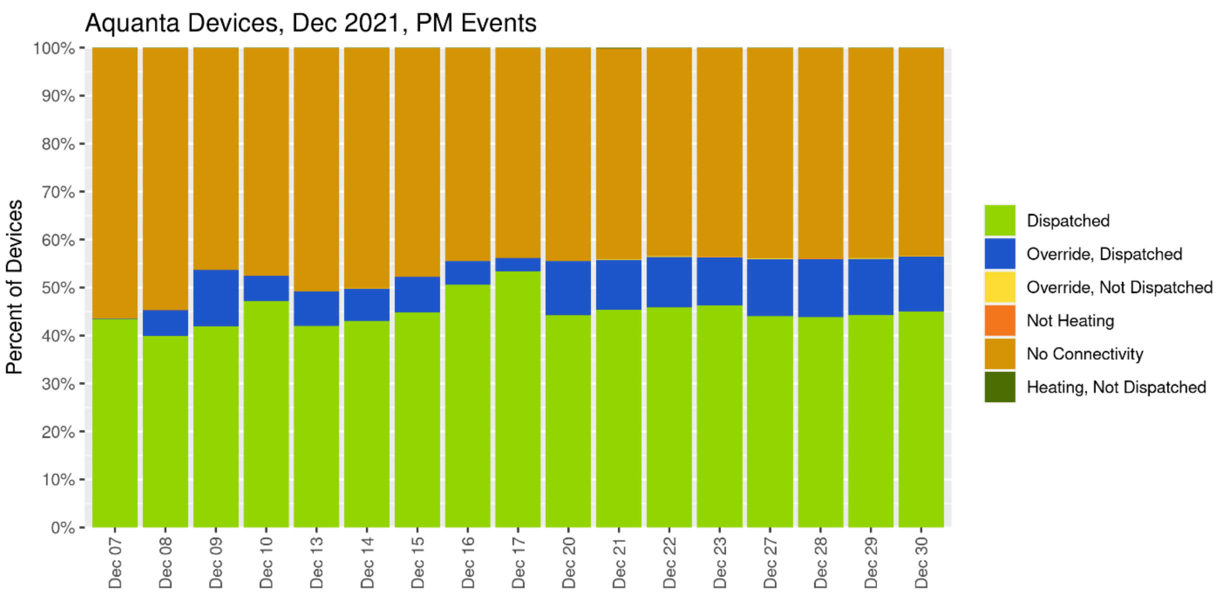

2022−02−25
Average kW
2.5
2.
1.5
1.
0.5
0.
−0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour

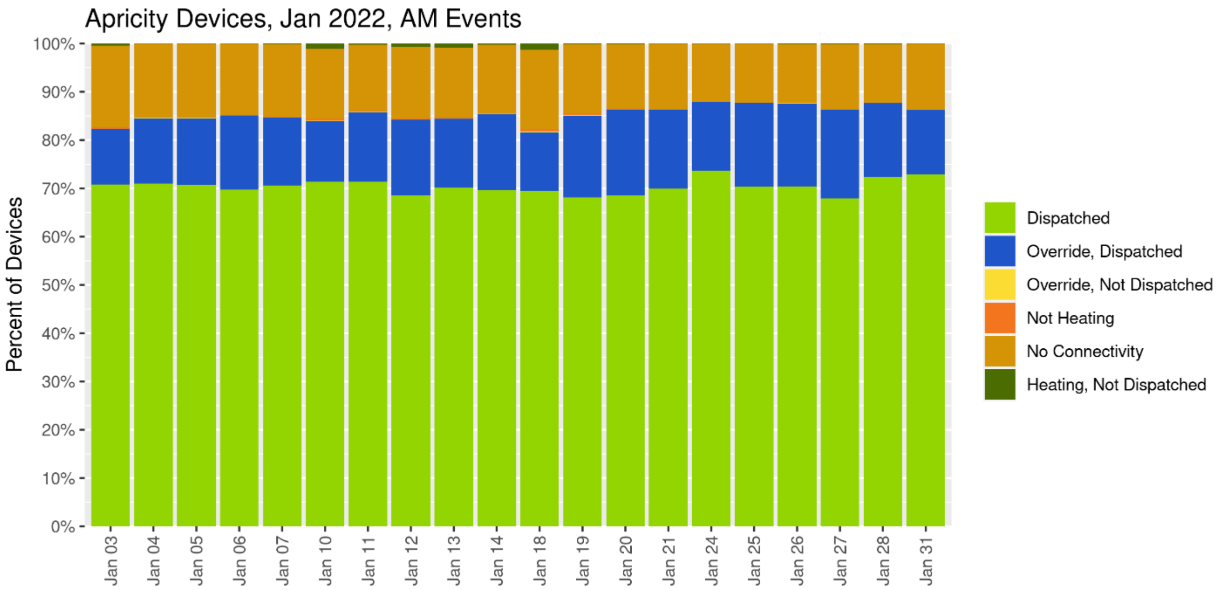
Appendix C. Event Device Status Plots by Time of Event (Winter 2021-22)

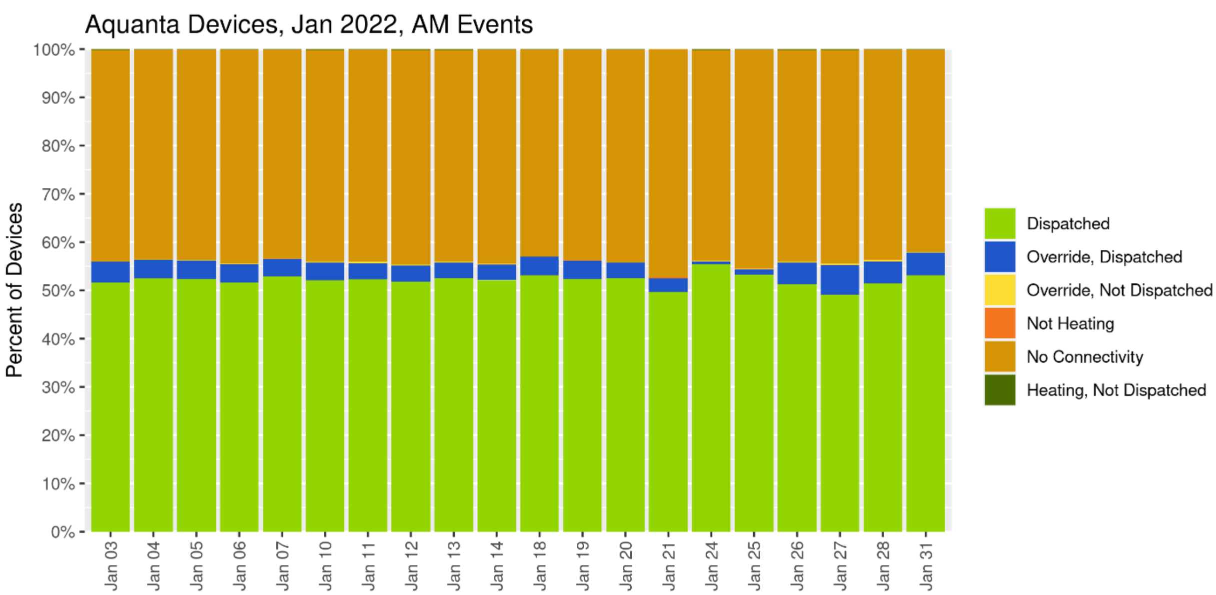


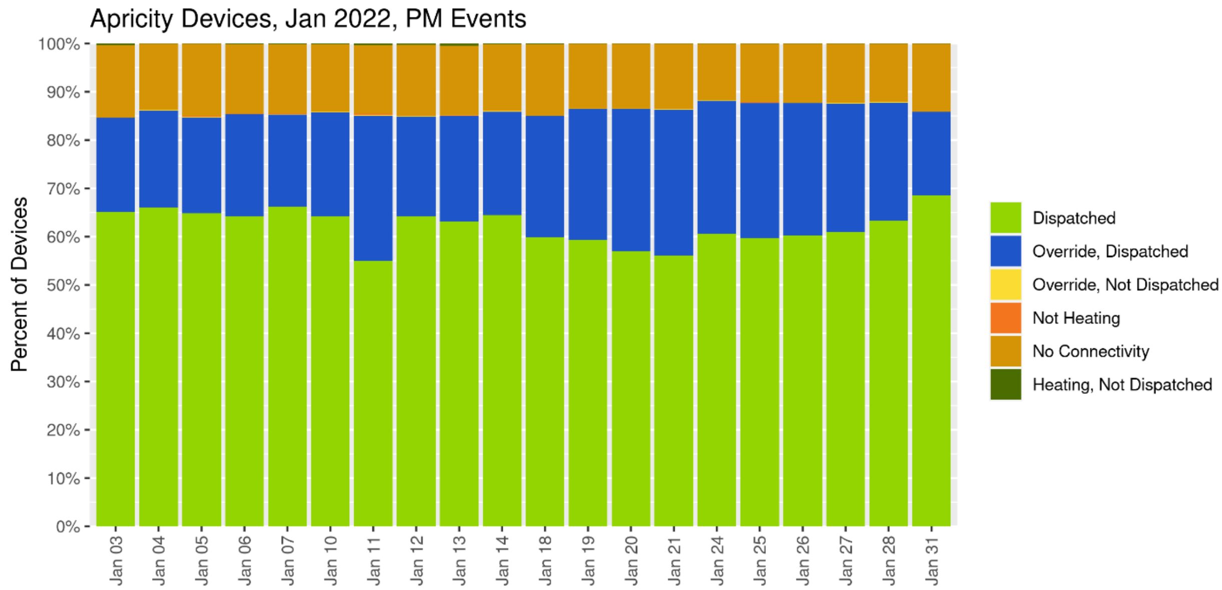


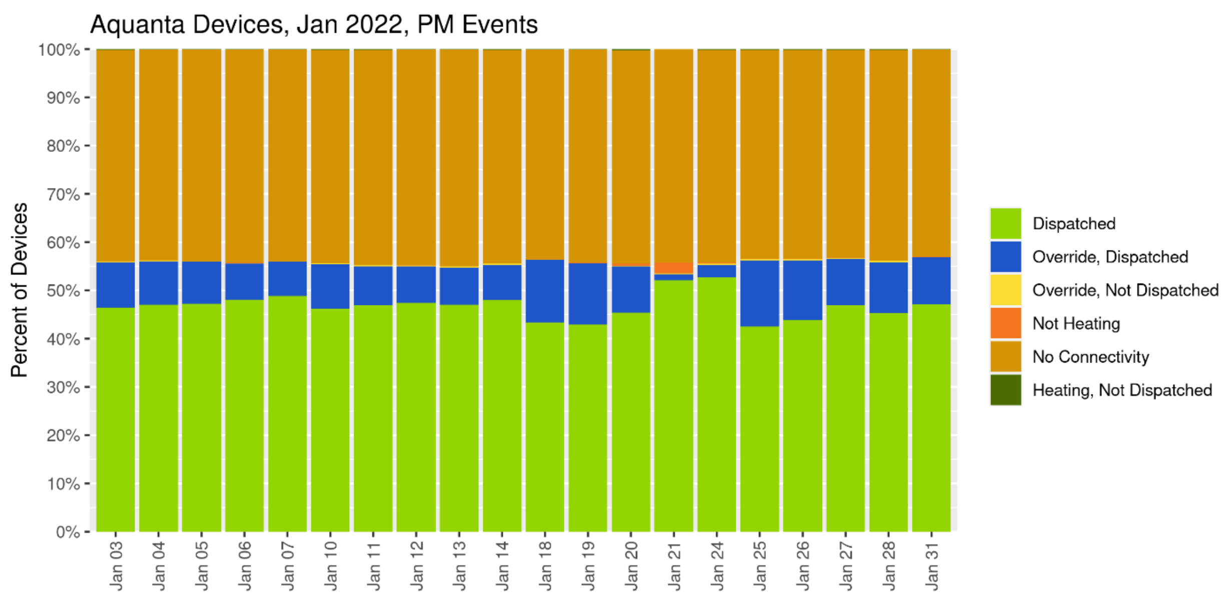

Apricity Devices, Dec 2021, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Dec 07
Dec 08
Dec 09
Dec 10
Dec 13
Dec 14
Dec 15
Dec 16
Dec 17
Dec 20
Dec 21
Dec 22
Dec 23
Dec 27
Dec 28
Dec 29
Dec 30
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched

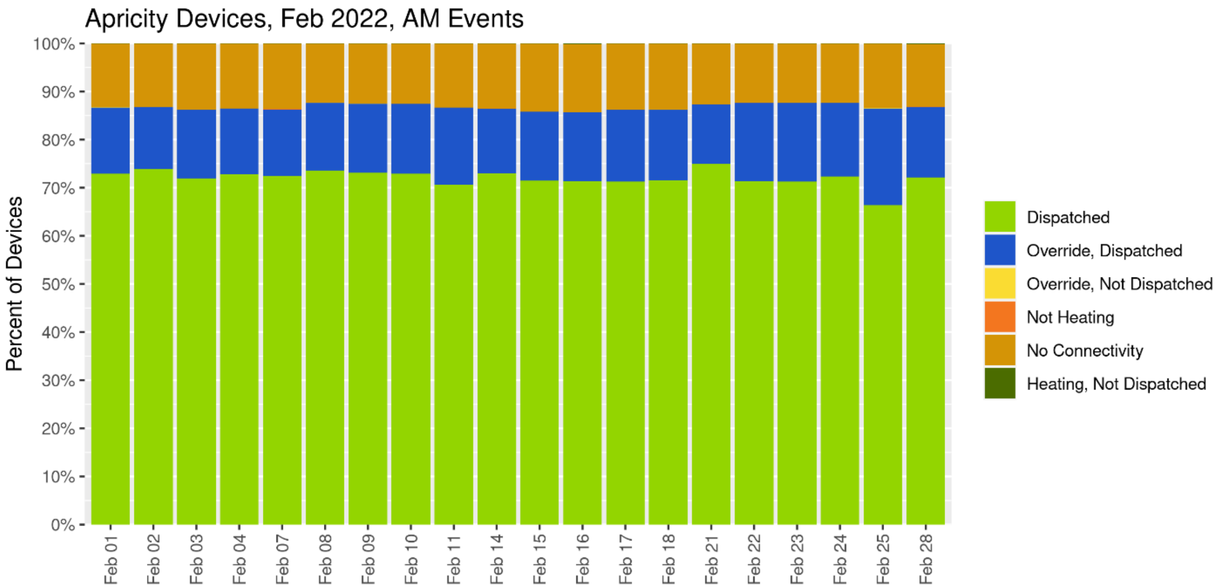

Aquanta Devices, Dec 2021, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Dec 07
Dec 08
Dec 09
Dec 10
Dec 13
Dec 14
Dec 15
Dec 16
Dec 17
Dec 20
Dec 21
Dec 22
Dec 23
Dec 27
Dec 28
Dec 29
Dec 30
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched

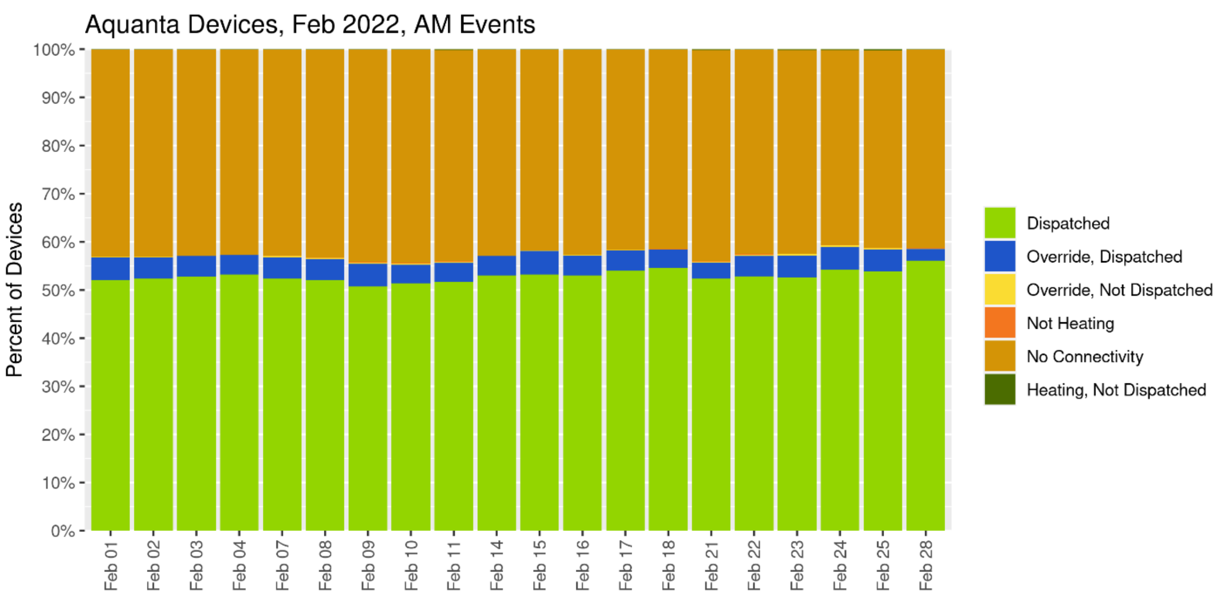

Apricity Devices, Jan 2022, AM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan 03
Jan 04
Jan 05
Jan 06
Jan 07
Jan 10
Jan 11
Jan 12
Jan 13
Jan 14
Jan 18
Jan 19
Jan 20
Jan 21
Jan 24
Jan 25
Jan 26
Jan 27
Jan 28
Jan 31
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched

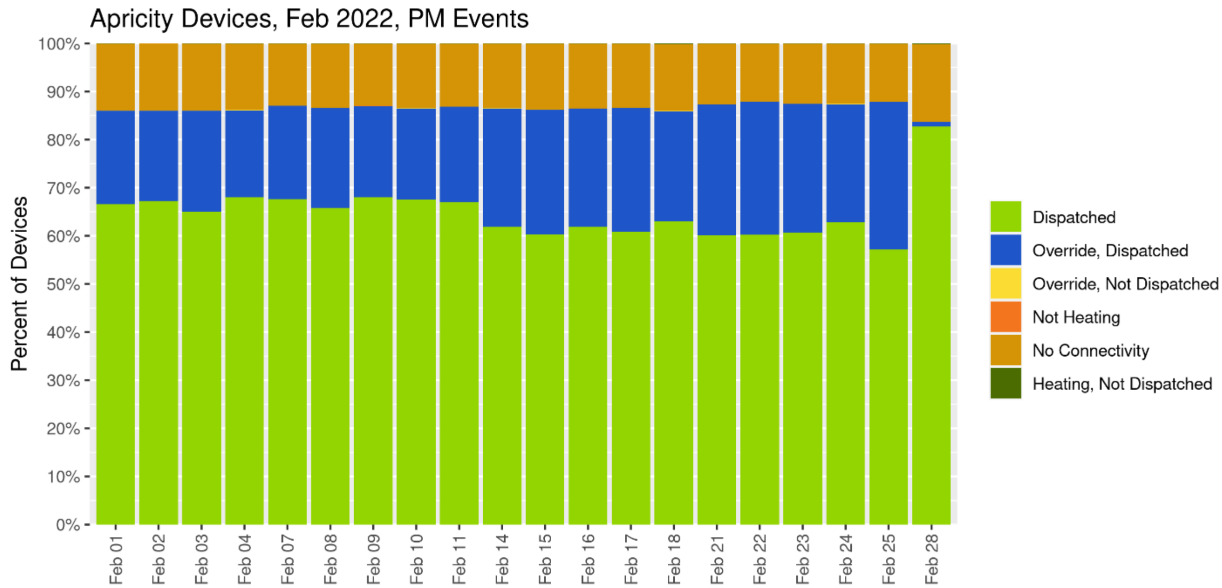

Aquanta Devices, Jan 2022, AM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan 03
Jan 04
Jan 05
Jan 06
Jan 07
Jan 10
Jan 11
Jan 12
Jan 13
Jan 14
Jan 18
Jan 19
Jan 20
Jan 21
Jan 24
Jan 25
Jan 26
Jan 27
Jan 28
Jan 31
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched

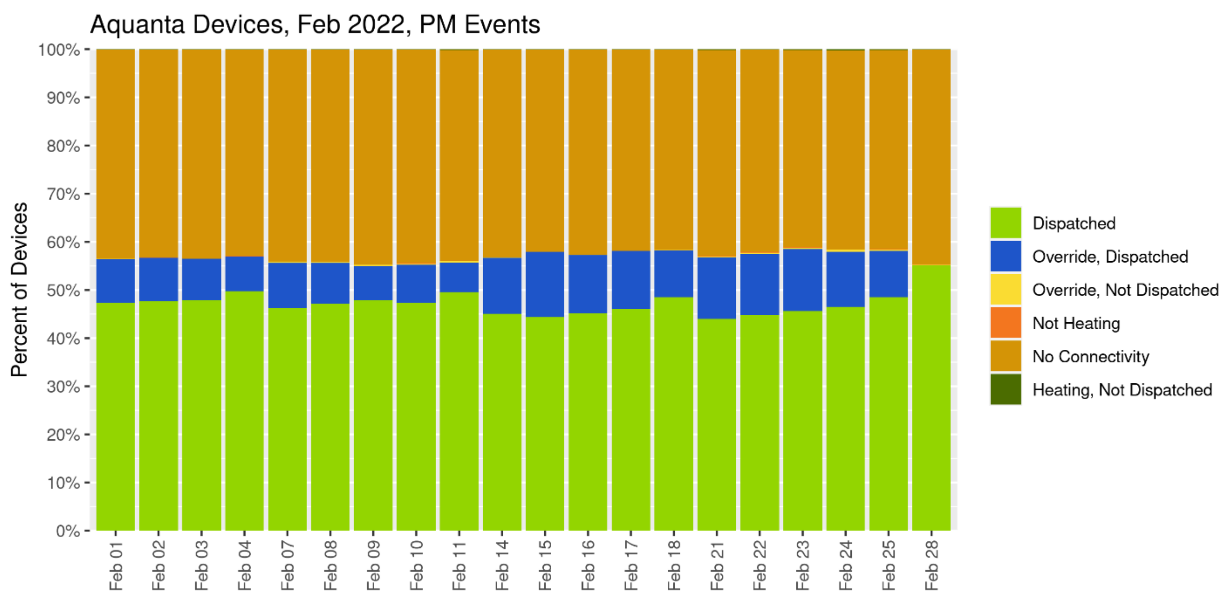

Apricity Devices, Jan 2022, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan 03
Jan 04
Jan 05
Jan 06
Jan 07
Jan 10
Jan 11
Jan 12
Jan 13
Jan 14
Jan 18
Jan 19
Jan 20
Jan 21
Jan 24
Jan 25
Jan 26
Jan 27
Jan 28
Jan 31
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched


Aquanta Devices, Jan 2022, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan 03
Jan 04
Jan 05
Jan 06
Jan 07
Jan 10
Jan 11
Jan 12
Jan 13
Jan 14
Jan 18
Jan 19
Jan 20
Jan 21
Jan 24
Jan 25
Jan 26
Jan 27
Jan 28
Jan 31
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched


Apricity Devices, Feb 2022, AM Events
Percent of Devices
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Feb 01
Feb 02
Feb 03
Feb 04
Feb 07
Feb 08
Feb 09
Feb 10
Feb 11
Feb 14
Feb 15
Feb 16
Feb 17
Feb 18
Feb 21
Feb 22
Feb 23
Feb 24
Feb 25
Feb 28
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched


Aquanta Devices, Feb 2022, AM Events
Percent of Devices
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Feb 01
Feb 02
Feb 03
Feb 04
Feb 07
Feb 08
Feb 09
Feb 10
Feb 11
Feb 14
Feb 15
Feb 16
Feb 17
Feb 18
Feb 21
Feb 22
Feb 23
Feb 24
Feb 25
Feb 28
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched


Apricity Devices, Feb 2022, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Feb 01
Feb 02
Feb 03
Feb 04
Feb 07
Feb 08
Feb 09
Feb 10
Feb 11
Feb 14
Feb 15
Feb 16
Feb 17
Feb 18
Feb 21
Feb 22
Feb 23
Feb 24
Feb 25
Feb 28
Dispatched
Override, Dispatched
Override, Not Dispatched
Not Heating
No Connectivity
Heating, Not Dispatched


Aquanta Devices, Feb 2022, PM Events
Percent of Devices
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Feb 01
Feb 02
Feb 03
Feb 04
Feb 07
Feb 08
Feb 09
Feb 10
Feb 11
Feb 14
Feb 15
Feb 16
Feb 17
Feb 18
Feb 21
Feb 22
Feb 23
Feb 24
Feb 25
Feb 28
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.