

Should we take a step back from setbacks? Evidence from a mixed methods study of heat pump customer AMI and survey data

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ABSTRACT

As adoption of cold climate heat pumps continues, winter peaking is expected to become more common across the United States. The current study examines AMI (advanced metering infrastructure) and survey data of heat pump customers at Tacoma Power, a winter peaking municipal utility in the Pacific Northwest, to understand the prevalence and size of morning heat pump demand spikes coincident with Tacoma Power's winter system peak. Analysis of customer AMI data from Tacoma Power's January 12th, 2024, winter system peak day showed that 38% of heat pump customers experienced a demand spike greater than 1.5 kW between the hours of 7 and 10 am. A subset of customers included in this AMI analysis were surveyed regarding their heating equipment and their willingness to participate in programs that could help Tacoma Power to mitigate heat pump customers' coincident morning demand spikes. Survey data, AMI data, and heating equipment photos were used to group customers by their backup heating equipment type. Customers with central fossil fuel backup showed no evidence of coincident morning demand spikes. Amongst customers with central electric backup, coincident morning demand spike sizes were highly correlated with overnight setbacks. Central electric backup customers with a setback greater than five degrees experienced significantly higher average demand spike (5.5 kW) than both customers with a setback between one and five degrees (2.9 kW) and customers with no setback (.8 kW). Customers were most willing to participate in interventions that required small adjustments to their setback.

Introduction

Building electrification is a key pillar of many state climate plans. In the residential sector, this translates to a swift ramp up in residential heat pump installations. For electric utilities in cold climates, where policy encourages the full electrification of residential space heating, this will substantially increase winter heating load and create new demand management challenges. Some utilities, including Tacoma Power, are already experiencing winter peaks and their associated challenges. Heat pump adoption in Tacoma Power territory has increased significantly in recent years due to Washington State's Clean Building Performance Standards, Inflation Reduction Act tax credits, and Washington Climate Commitment Act investments in heat pump adoption. Between 2023 and 2042, residential heat pumps are expected to add between 50 and 100 MW of additional demand to Tacoma Power's winter morning peak (Cadmus 2024).

While many factors will play a role in determining how Tacoma Power's actual heat pump demand growth compares to this estimate, recent research suggests that heat pumps may cause greater demand increases on winter peak days than previously thought (Douglass and Rushton 2024). If this is the case, heat pumps may pose a larger challenge to winter demand management than anticipated. Higher than expected heat pump power usage on cold days can be caused by a range of factors, including poor system sizing, improperly setup backup heating "lockout" settings, poor ducting, inadequate weatherization, or customers behavior (Douglass and Rushton 2024). Research suggests that overnight setbacks are one of

the main behavioral reasons for heat pump demand spikes on the coldest winter mornings (Douglass and Rushton 2024). Given these findings, and Tacoma Power’s past efforts to promote overnight setbacks, this study focuses on the relationship between overnight setbacks and morning peak demand spikes during Tacoma Power’s 2024 winter peak to understand whether overnight setbacks are in fact associated with large heat pump demand spikes.

Centrally ducted heat pumps generally have two main heating sources: a high efficiency compressor and a low efficiency backup source. Backup sources are most commonly electric resistance strips or a fossil fuel system, such as a natural gas furnace boiler. When a customer uses an overnight setback, their resulting indoor air temperature before their thermostat switches to a higher temperature is lower than it would be otherwise, creating a greater differential between indoor and outdoor temperature. There are two main cases in which a large differential during a setback between the home’s air and the outdoor air temperature may lead to a spike in morning power usage.

First, if the heat pump is set up with lockout controls and the outdoor temperature does not cross the lockout threshold, which only allows the system to switch to its backup source when the outdoor temperature is below a certain point, the heat pump’s compressor may operate at or near its heating capacity to raise the indoor air temperature. Operating at or near capacity causes compressor efficiency to decrease substantially, which in turn can substantially increase the amount of power needed by the compressor to raise a home’s temperature up from its setback point. Secondly, if the backup system is electric resistance (also referred to as electric furnace), morning power usage will spike if the system crosses its lockout threshold or if the system does not have lockout controls setup, as is the case with many homes in the Pacific Northwest (SBW Consulting et al. 2019). In this case, a demand increase is caused by the low efficiency backup unit absorbing the heating load instead of the high efficiency compressor.

In an analysis that isolated the heating circuits of 36 homes in the Northwest, deep overnight setbacks (>4°F) were associated with 8 to 11 kW spikes during morning hours of the peak heating months (Douglas and Rushton, 2024). The authors noted that these findings may have significant grid implications due to the frequent coincidence of morning demand spikes with periods of higher net system demand and higher market prices in the Northwest. However, there are two primary conditions in which a heat pump system is unlikely to cause a morning demand spike. If the heat pump has a fossil fuel backup system that is activated, then the backup system will absorb the heating load and keep power usage low. Additionally, if the heat pump continues to run on its high efficiency compressor, then its power usage is unlikely to spike.

Scope

This paper draws on findings from a two-phase study of Tacoma Power’s heat pump customers. Both phases of this study focused only on customers with centrally ducted heat pumps, excluding customers with only ductless heat pump systems. Three main questions are addressed:

1. What is the observed prevalence and magnitude of morning demand spikes amongst Tacoma Power heat pump customers coincident with Tacoma Power’s January 12th, 2024, system peak?
2. To what degree is overnight setback size correlated with coincident demand spike magnitude?
 - a. Additionally, what other factors are associated with coincident demand spikes?
3. What interventions would customers be willing to participate in that could reduce the size of coincident demand spikes?

Methodology

Heat pump customers were identified via a mix of Tacoma Power High Performance Heat Pump program participation data (n=225) and county assessor household-level heating system data (n=2,748). In the first research phase, heat pump customer AMI data (n=2,973) was analyzed to identify the prevalence and magnitude of morning demand spikes coincident with Tacoma Power's January 12th, 2024, system peak (i.e. the day of the year that Tacoma Power experienced its highest peak demand). Larger than expected heat pump demand spikes have the greatest potential implications for utility capacity planning and system reliability when they are coincident with the system peak, due to the limited surplus system capacity during these times. Additionally, January 12th, 2024, was Tacoma's coldest weekday, on average, over the last two years (27°F). With lower temperatures expected to cause greater demand spikes, customers consistently using setbacks on winter nights should experience their greatest morning demand spike of recent years on January 12th, 2024. In the second research phase, a subset of customers included in phase one were recruited to participate in a survey regarding their heat pump usage and the actions that they might be willing to take to mitigate morning heat pump demand spikes.

AMI Data Processing

Only heat pump customers with AMI data starting the first week of September 2023 were selected for analysis. Having data that started in September 2023, instead of January 12th, 2024, allowed September data to be used for estimating each customer's non-heating baseload and their increase in heating-related usage coincident with system peak. Sites with solar or more than one AMI meter on site were excluded from this analysis to avoid the complications and ambiguities associated with processing data at these sites. Customer AMI data was averaged from 15-minute to hourly intervals for analysis.

Survey Methodology

Of the 2,973 heat pump customers whose AMI data was analyzed, 1,613 received outreach from Tacoma Power inviting them to participate in an online survey about their heat pump use. Outreach was stratified by relevant customer attributes such as past program participation and contact information (i.e. whether their account information included both physical and email addresses). Customers were offered a \$20 online gift card (redeemable at a vendor of their choice) for completing the core set of survey questions¹. Respondents could receive an additional \$20 for completing an optional section of the survey that required them to upload photos of their heating equipment. Survey recruitment was conducted between January and April 2025. All customers received an initial letter from Tacoma Power inviting them to participate in the survey. For non-respondents that did not opt out of receiving follow-up, the initial recruitment letter was followed up by an email, postcard, and up to two additional emails. Recruitment language and timing were varied across materials. The survey covered three main topics:

1. **Heating devices, comfort, and behaviors.** The first survey section collected information on customers' heating devices (both primary and secondary), comfort during the coldest parts of the year, and how they control their heating devices (both on a typical day and the five coldest days of the year).
2. **Willingness to change.** This section employed a between-subjects design to examine customers' willingness to participate in a range of potential interventions. Some interventions were presented without the mention of an incentive, while for other interventions customers were randomly assigned

¹ Customers answering only the core sections of the survey had a median response time of 11 minutes while customers that also included heating equipment photos had a median time to complete of 19 minutes.

to be presented with either a \$25 or \$50 incentive for their participation. Conversations with utility staff and a review of analogous program in the region lead to the choice of \$25 and \$50 incentive. The lower incentive of \$25 represents what might be considered a standard incentive level while \$50 is closer to the upper end of what utilities might be expected to provide for the interventions in question.

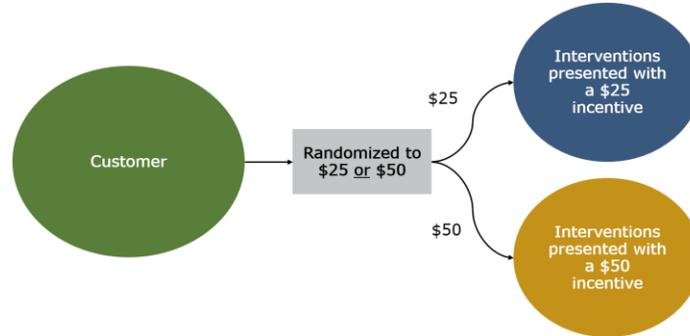


Figure 1. Design of willingness to change section.

Customers were asked about their willingness to allow an HVAC contractor to adjust their heat pump settings, install a new thermostat, change their setback behavior every winter night, and change their setback behavior on the five coldest nights of the year. Customers were only presented with interventions fitting their current characteristics (e.g., a customer that does not use a setback would not be asked about their willingness to change their setback behavior).

3. **Heating Equipment photos.** In this optional section, customers were asked to upload photos of their heat pump indoor and outdoor units for an additional \$20. Customers were provided with sample pictures to help them identify what each piece of equipment might look like.

Results

Initial Demand Spike Analysis

Analysis of customers' January 12th, 2024, whole home hourly load shapes showed that customers most frequently experienced their highest average hourly demand between 7 and 10am. Each customer's coincident morning demand (kW) was then defined as the difference between their average morning usage (7-10am) and overnight (12-3am) usage. Figure 2 shows the actual load shape of a site that displayed a large coincident demand spike (average of the purple bars minus the average of the blue bars).

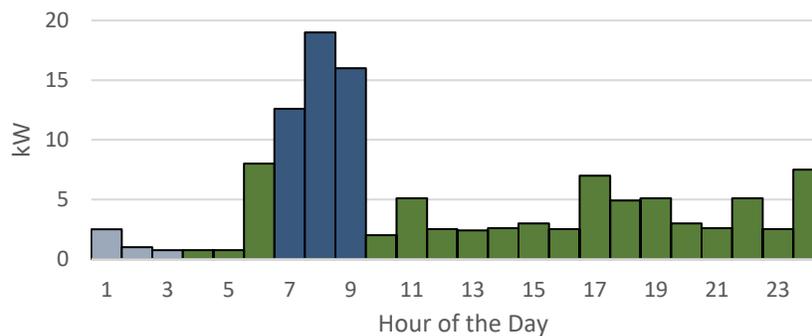


Figure 2. Heat pump customer whole-home load shape (1-12-2024).

Figure 3 shows the cumulative distribution of customers by the size of their coincident demand spike. The 10% of customers (green) with the largest demand spikes had spikes of 5.8 kW or greater, customers between the 30th and 10th percentile (blue) had spikes between 2.2 kw and 5.8 kW, and customers between the 50th and 30th percentiles (gold) had spikes between .85 kW and 2.2 kW.

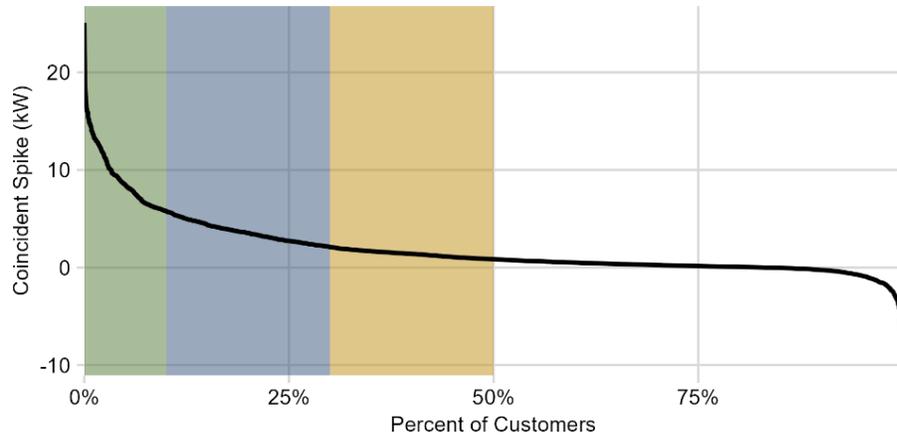


Figure 3. Duration curve of customers' coincident demand spikes

Reported setback behavior.

While initial AMI analysis showed that a significant proportion of heat pump customers have large coincident demand spikes, it did not provide enough information to determine whether these demand spikes were associated with overnight setbacks. To assess whether coincident demand spikes are associated by setback behavior, customers were asked to report how often they use an overnight setback during the winter. Most customers (67%) reported using a setback every day or most days².

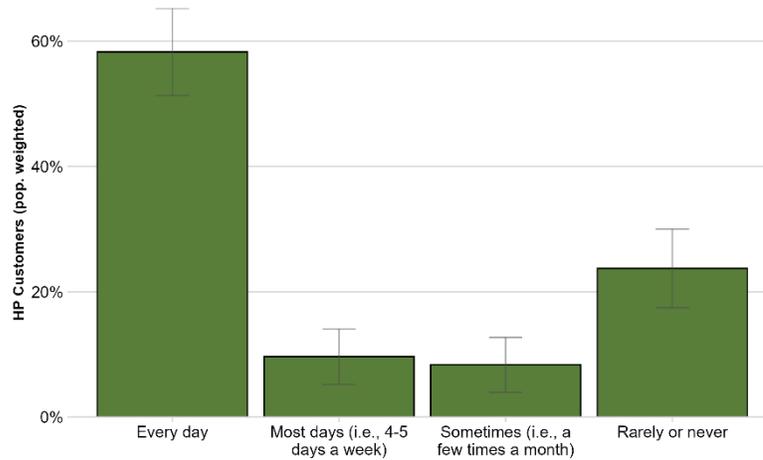


Figure 4. Overnight setback frequency.

Customers were also asked about their reasons for using a setback (customers were allowed to report multiple reasons). The most commonly reported reasons were using a setback because someone in their home prefers to sleep at a cooler temperature overnight (71%) or because they want to save money on their bill (60%). Half of the customers who reported using a setback because they want to sleep

² All survey results are weighted to be representative of the broader population (n=2,973). Error bars represent two-tailed 90% confidence intervals.

at a cooler temperature reported that this was their only reason for using a setback (35% of total customers using a setback). The other half reported using a setback because they want to both sleep at a cooler temperature and save money (36%). A small proportion of customers reported using a setback because their thermostat automatically lowers the temperature at night and they haven't bothered to change the setting (23%). Customers also reported their thermostat setpoint for when they are home and asleep (average = 66°F) and when they are home and awake (average = 69°F). Reported setpoints were used to calculate each customer's overnight setback, and to compare the average peak-day load shape of each setback group.

AMI analysis with backup heating equipment and setback behavior

Before examining the relationship between thermostat setback level and morning spikes, customers' backup heating systems were categorized. Customers with central fossil fuel backup were not expected to show morning demand spikes, regardless of their setback level, due to their anticipated switch from electric to fossil fuel heating on the coldest days of the year. Therefore, accurately assessing the relationship between setback levels and morning spikes at sites with electric backup heating required first separating sites with central fossil fuel backup from sites with central electric backup. Customers' central backup equipment was identified using survey responses, heating equipment photos³, and load shapes. Survey data and heating photos indicated that 39% of customers had central electric backup and 32% of customers had fossil fuel furnace or boiler backup. The other group of customers (29%) either did not report having a central backup system or did not provide photos of their heating equipment.

Analyzing the average load shape of this group, labeled inferred electric backup in Figure 5, showed an almost identical peak day load shape to the group with confirmed central electric backup. Shading alongside each load shape represents the 95% confidence interval of each group's average hourly usage. Both electric backup groups showed sharp increases in morning load, peaking between seven and ten, while central fossil fuel sites, on average, had no evidence of a morning spike. Combined with the results above, a revised categorization of customers' central backup heating was created, with 68% of customers categorized as having electric backup and 32% of customers categorized as having central fossil fuel backup.

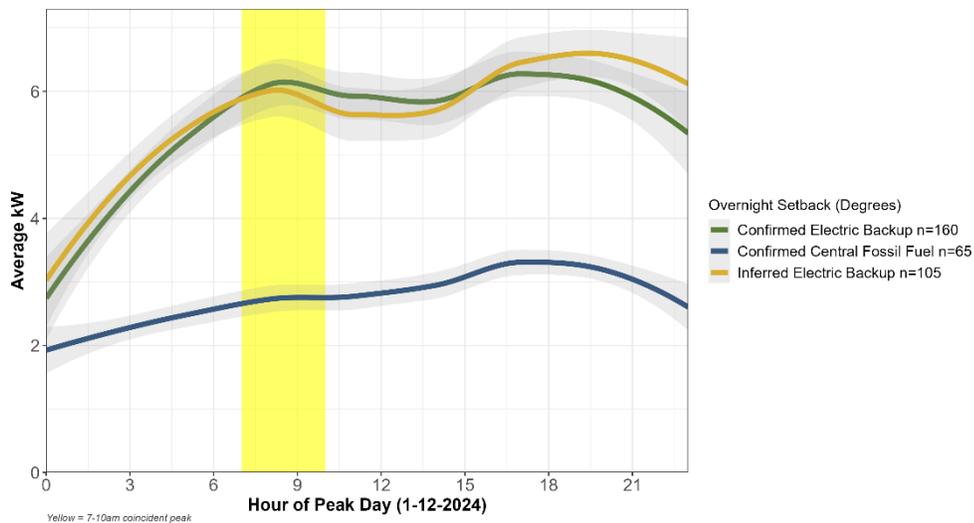


Figure 5. Peak day load shapes by central backup heating group⁴

³ Most customers (88%) provided heating equipment photos.

⁴ Load shapes in this figure, as well as all load shapes that follow, are weighted to be representative of the population.

The lack of morning demand spikes amongst customers with central fossil fuel likely indicates that outside temperatures crossed the lockout temperature for most of these systems, causing their backup fossil heating to kick in and cover most of their heating load. Consequently, for systems where this was true, even a customer with a large overnight setback would not have experienced a coincident demand spike. Given that customers with central fossil backup did not display evidence of peak-day morning spikes, these customers are excluded from subsequent analyses that examine the relationship between overnight setbacks and morning spikes. Figure 6. shows average load shapes of central electric customers, grouped by reported overnight setback size. Amongst central electric backup customers, morning coincident spike is highly correlated with setback size. Customers with a setback greater than five degrees experienced an average coincident demand spike (5.5 kW) that was significantly higher than both the average of customers with a one to five degree setback (2.9 kW) and the average of customers with no setback (.8 kW).

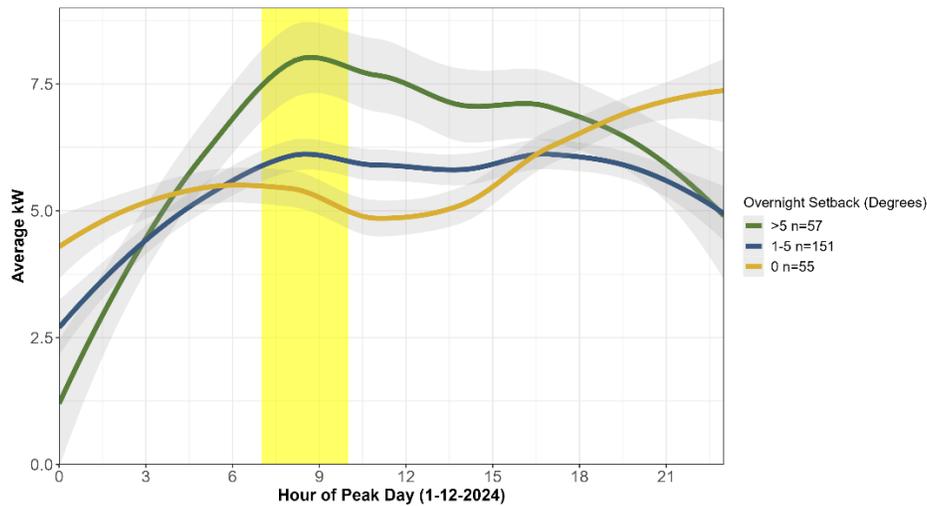


Figure 6. Peak day load shapes by central backup heating group

The load shapes above illustrate important differences in the average load shape of each group, but they do not speak to the spread of morning spike values within each group. Figure 7 shows a density plot of morning spikes within each setback group. The lines within each shape illustrate the 25th, 50th, and 75th percentiles of each group. The density plot of customers with a setback greater than five degrees shows that 30% of customers in this group have a coincident demand spike of 10 kW or greater, much higher than the group average of 5.5 kW.

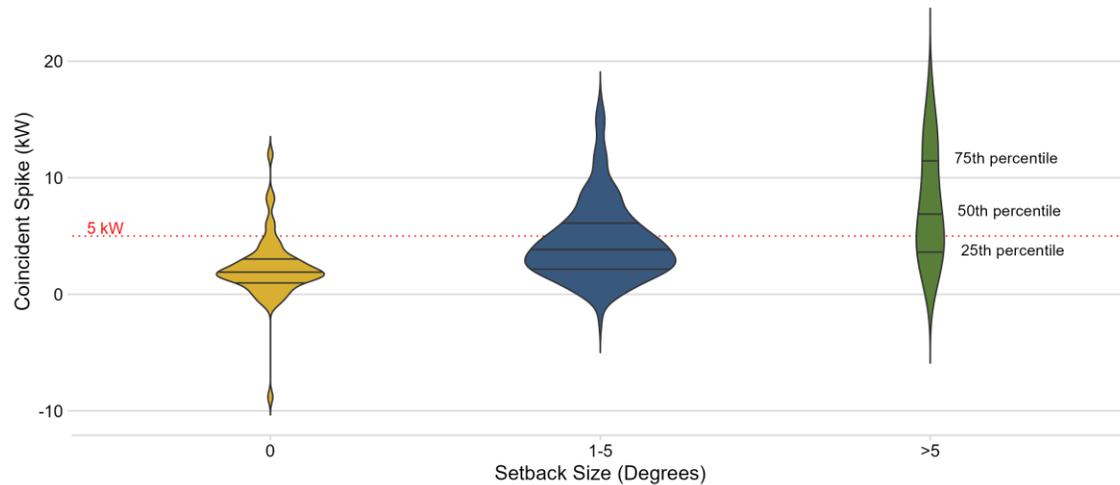


Figure 7. Weighted distribution of coincident demand spikes amongst central electric backup customers by size of reported setback.

The results above support the hypothesis that using an overnight setback, especially one greater than five degrees, can cause morning demand spikes on the coldest days of the year. However, these results only support this hypothesis insofar as it applies to customers with central electric backup. Central fossil fuel backup customers do not appear to experience large coincident demand spikes.

Customer heat pump satisfaction and comfort

Most customers (79%) reported being very satisfied or satisfied with their heat pump. Coincident demand spike size was not correlated with customers' heat pump satisfaction. Additionally, most heat pump customers (67%) reported being comfortable or very comfortable on the coldest days of the year. Customer comfort was not correlated with demand spike size⁵. The lack of correlation between coincident demand spike size and both heat pump satisfaction and customer comfort suggests that demand spikes may not be creating noticeable issues for customers. Consequently, if a utility asks customers to change how their heat pump operates on the coldest days, customers will likely need a reason to change. Most customers who use a large setback both have a reason for using this setback, primarily comfort or savings, and are not experiencing any issues that would make them want to change. The following section explores customer willingness to take action through the frames of taking action to help the utility and taking action to receive an incentive.

Willingness to take action – no mention of an incentive

After providing information about their heating system use, customers were asked a set of questions about which actions they would be willing to take to help Tacoma Power reduce strain on the grid during the coldest winter mornings, without any mention of an incentive. When asked about an initial set of actions, 45% of customers reported that they would be willing to allow a contractor to adjust their heat pump settings, 30% reported that they would be willing to keep their heat constant on all winter nights (e.g., not use a setback), and 20% of customers who did not already own a smart thermostat reported that they would be willing to install a new thermostat. Overall, 69% of customers were willing to take at least one action.

⁵ Figures of both customer comfort and heat pump satisfaction are included in the appendix.

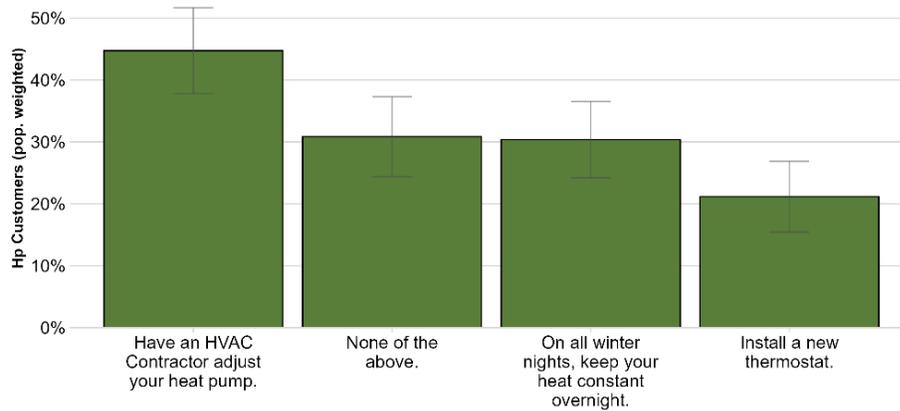


Figure 10. Willingness to take action with no mention of an incentive.

Customers were then asked, without mention of incentive, about their willingness to take certain actions on the five coldest nights of the year. Thirty-nine percent of customers who had reported using a setback were willing to use a smaller setback and 35% were willing to keep their heat constant. Very few customers who reported switching their heat pump to emergency heat mode on the coldest nights of the year were willing to not use emergency heat mode on the five coldest nights of the year (8%)⁶. Most customers (79%) were willing to take at least one action.

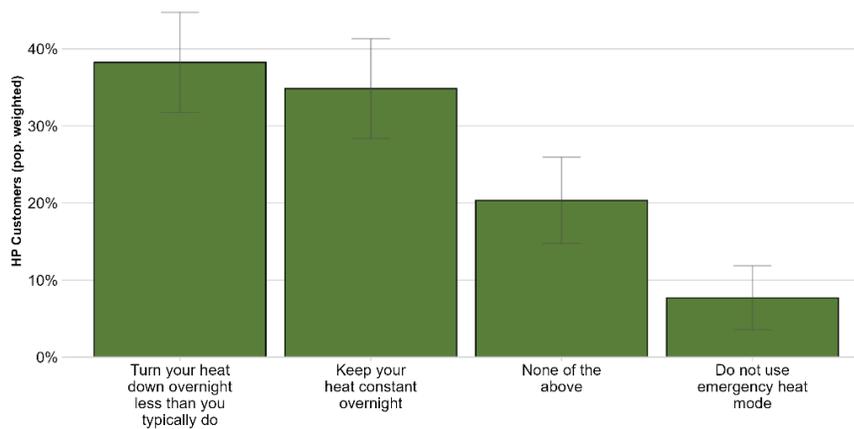


Figure 11. Willingness to take action on the five coldest days of the year with no mention of an incentive.

Willingness to change – with incentives

Customers were then randomly assigned to either a \$25 or \$50 incentive level and asked a similar set of questions. There were no statistically significant differences in willingness between the two incentive levels (Figure 12). Across both groups, customers were more willing to keep their heat constant on the five coldest nights of the year than on every night of the year. However, this result was only statistically significant ($p < .10$) for customers in the \$50 group. Slightly less than half of customers in the

⁶ Emergency heat mode is likely not widely understood by customers, and customers were likely to have underreported whether their heat pump switches into emergency heat mode on especially cold days. This study did not collect data on customers' understanding of emergency heat mode so additional research is needed to support this.

\$50 group (46%) were willing to keep their heat constant on the coldest nights of the year and 25% were willing to keep their heat constant on all nights. The subset of customers who reported using backup heating mode were willing to not use it at a similar rate with incentives (12%) as without incentives (8%).

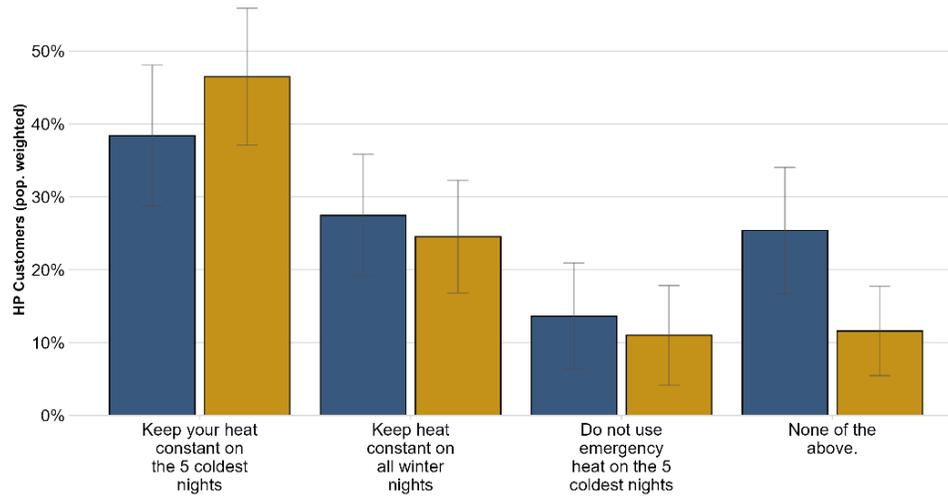


Figure 12. Willingness to take action with incentives.

Willingness to switch setback – respondents with a 3 or 4° setback

Customers with a setback of three or four degrees who had indicated that they would be willing to use a smaller setback were asked about their willingness to switch to a setback of one or two degrees on the five coldest nights of the year. Customers in the \$50 group were significantly more willing ($p < .10$) to switch to a lower setback on the five coldest days of the year (95%) than customers in the \$25 group (67%).

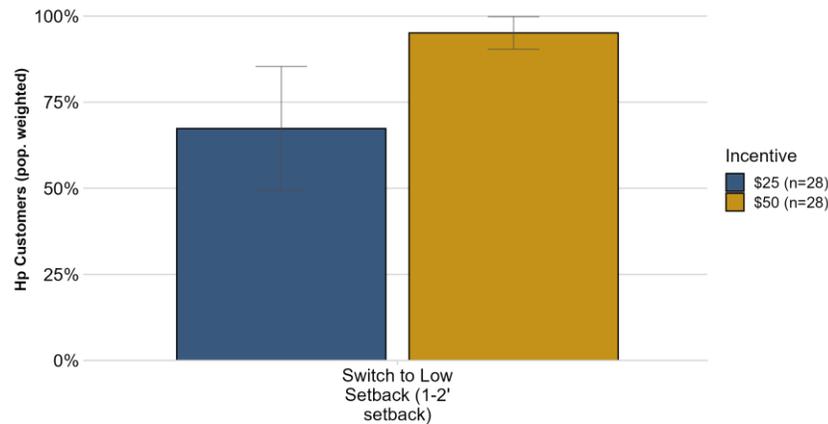


Figure 13. Willingness to switch to a lower setback on the five coldest nights of the year amongst customers with a three or four degree setback.

Willingness to switch setback – respondents with a > 5° setback

Customers with a deep setback (greater than five degrees) were asked a similar question, with the additional option of switching to a three to four degree setback. Most customers in both the \$25 group (78%) and the \$50 group (84%) were willing to make a small adjustment and switch to a medium

setback of three to four degrees. Customers in both the \$25 group and the \$50 group were significantly less willing ($p < .10$) to switch to a one to two degree setback than a three to four degree setback.

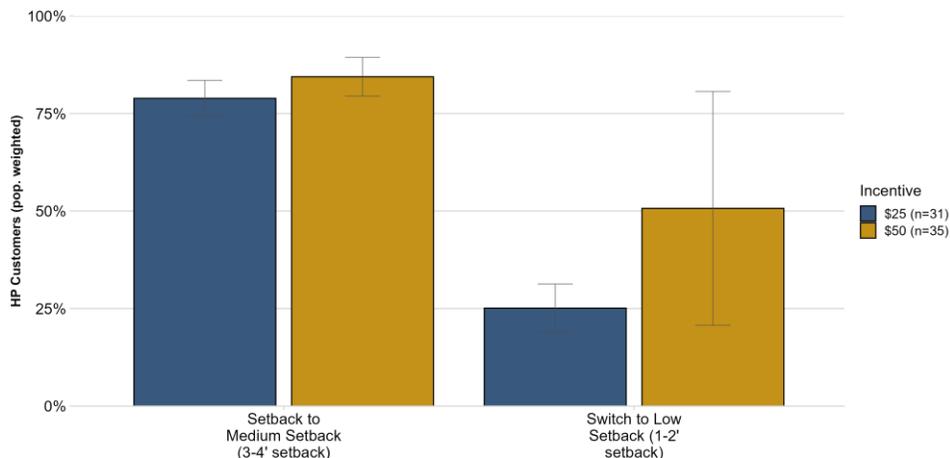


Figure 14. Willingness to switch to a lower setback on the five coldest nights of the year amongst customers with a setback greater than five degrees.⁷

Conclusions

Analysis of heat pump customer AMI data showed that 38% of customers had a significant spike (defined as 1.5 kW) in morning usage coincident with Tacoma Power’s January 12th, 2024, system peak. Survey data revealed that customers with central fossil backup heating largely did not experience large coincident demand spikes. Amongst customers with central electric backup heating, overnight setback size was highly correlated with coincident demand spike size. Amongst customers with central electric backup, customers who reported a setback greater than five degrees, on average, experienced a significantly higher coincident demand spike (5.5 kW) than both customers who reported a one to five degree setback (2.9 kW) and customers who reported no setback (.8 kW).

Given that comfort is a primary motivator for why many customers use a setback and that customers experiencing large coincident spikes are, on average, satisfied with their heat pump, there is a degree of misalignment between how customers want to use setbacks and how utilities aiming to reduce morning peak demand likely will want setbacks to be used. Additionally, while reducing or eliminating customers’ heat pump setbacks could reduce morning demand, it would likely increase customers’ total heating usage. Further research is needed to understand how setback adjustments impact overall energy use. The reasons above, as well as the data collected in this study, indicate that at present, the most successful interventions for addressing heat pump coincident demand spikes will likely be those that only ask customers to change their setback on the coldest days of the year. While some customers may be willing to make larger changes to their setback, on average, customers are more willing to make small adjustments. Consequently, interventions should also be flexible to allow customers to participate at a level that is comfortable for them. In cases where customers are being asked to make larger changes to their setback level, modest incentives may be effective at increasing customer participation.

⁷ The large confidence interval of the \$50 one to two degree setback group reflects low confidence of the population weighted result that was introduced by low representation of customers in certain stratum for this subgroup.

Acknowledgements

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Appendix

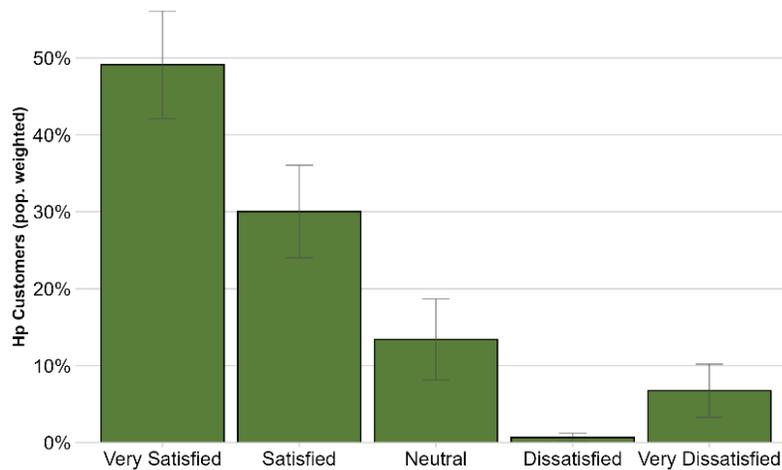


Figure A1. Heat pump satisfaction.

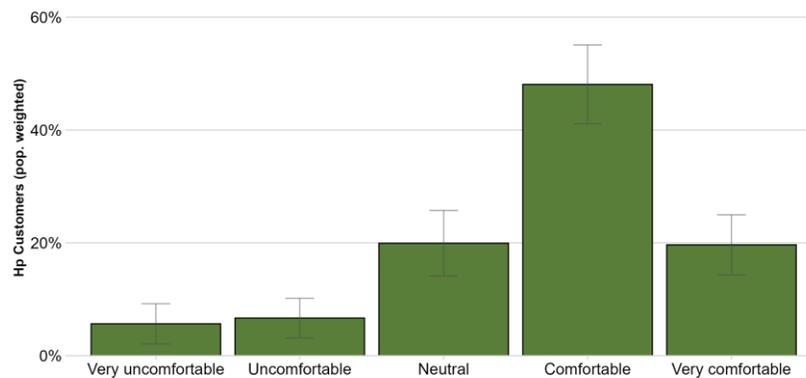


Figure A2. Comfort on the coldest days of the year.