Heat Pump Water Heater Impact Study Report

MA25R03-E-HPWHI

Prepared for:

The Electric and Gas Program Administrators of Massachusetts

Part of the Residential Evaluation Program Area

Submitted by:

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Executive Summary

Guidehouse evaluated the impacts of heat pump water heaters (HPWHs) in Massachusetts to update measure impacts, synthesize customer experience, and inform program and Technical Reference Manual (TRM) assumptions. The study integrates findings from a participant survey, analysis of previously collected metering data, and a review of stakeholder input to better reflect real-world HPWH operation and performance in Massachusetts homes.

The participant survey targeted customers who installed HPWHs through the 2024 and 2025 Mass Save® Retail and Residential Coordinated Delivery programs. A total of 191 HPWH rebate participants completed the survey, representing an 8% response rate, which is relatively low for participant-based evaluations but typical for midstream programs where customers may have limited direct interaction with program administrators or may not recall program participation. The survey captured information on installation context, operating modes, temperature set points, tank sizing, customer awareness, satisfaction, and perceived interactions with space conditioning and dehumidification.

To complement the survey, the study analyzed one-minute interval electric metering data from 65 HPWH installations, drawn from two prior Massachusetts evaluation efforts: the Residential Building Use and Equipment Characterization Study (RBUECS)[1] and the Heat Pump Metering Study (HPMS)[2]. These data span 2017 through 2024 and include units manufactured between 2012 and 2022. While the metered sample is not fully representative of the current Massachusetts HPWH market, it provides valuable insight into operating behavior, heating mode usage, and in-situ performance that cannot be observed through surveys alone.

[1] Residential Building Use and Equipment Characterization Study (RBUECS)
[2] Heat Pump Metering Study (HPMS)

Key findings from the integrated analysis include:

- Most HPWHs operate primarily in heat pump mode, but electric resistance heating is used frequently enough, largely through automatic hybrid operation, to reduce overall efficiency by approximately 20% on average relative to rated Uniform Energy Factor (UEF) values.
- Tank sizing, temperature set points, and operating mode selection are the primary drivers of HPWH performance and customer satisfaction. Homes with larger HPWHs (>55 gallons) have, on average, 56% higher hot water loads than homes with smaller units, reflecting higher demand rather than inherent efficiency differences.
- Installation location (conditioned versus unconditioned space) was not found to significantly affect mode-adjusted performance in this study.
- HPWH adoption is strongly correlated with broader household electrification: a substantial share of surveyed HPWH customers also use heat pumps for space heating, significantly higher than statewide averages.
- HPWHs reduce dehumidifier usage in homes where the two are co-located, yielding modest but measurable secondary energy savings.
- Customer satisfaction is high, with approximately 83% of respondents reporting no concerns, though opportunities remain to improve satisfaction. Among less satisfied customers, common concerns included hot water availability and installation costs, both of which are closely tied to sizing and operating practices.

Based on these findings, the study recommends updating HPWH savings assumptions in the Massachusetts TRM using a mode-adjusted UEF of approximately 0.81, refining guidance on tank sizing and temperature set points, and strengthening contractor and customer education related to operating modes. While some secondary impacts rely on older source studies, their contribution to total savings is small. Future updates could benefit from broader or regional research efforts if these effects become a higher policy priority.

1. Introduction

The Massachusetts Program Administrators (PAs) commissioned this study to update HPWH measure impacts and assess customer experience in the current market context. Recent program changes, evolving equipment options and stakeholder priorities necessitate updating baseline assumptions, savings factors, and customer education approaches.

The study aimed to answer the following questions:

- **Customer Satisfaction**
  - How satisfied are customers with their HPWHs compared to their previous water heating system?
  - What are the drivers of high or low customer satisfaction?
  - What is the impact of mixing valves on HPWH customer satisfaction?
  - What is the proportion of homes with a dehumidifier installed in the same space as the HPWH?
    - For homes that have a dehumidifier in the same space, do customers perceive that dehumidifier use is reduced compared to not having a HPWH?
- **Measure Impacts**
  - Are the HPWH Uniform Energy Factor (UEF) values in the measure impacts calculation in the TRM consistent with average UEF values from recent program installation data?
  - Does metered data from previous evaluation studies corroborate the annual usage used in the current measure impacts calculations?
  - To what extent is in situ HPWH performance impacted by operating in electric resistance heating mode?
  - How does installation location (space type, conditioned vs. unconditioned, space volume) impact the in-situ performance of the HPWH?
  - What are the updated measure impacts considering the changes to annual usage, average UEF, or other impact variables identified in this study?
- **Program Implementation**
  - What equipment would the customer have installed without program incentives?
  - What factors influenced the decision to purchase a HPWH?
  - What are program implementation recommendations based on the findings?

2. Methodology

This study integrates three complementary methodological components—a participant survey, a metering data analysis, and measure-impact updates—to develop a holistic understanding of HPWH performance, customer experience, and implications for the Massachusetts TRM. Together, these components enable the study team to combine customer-reported behavior and motivations with onsite metering data and updated engineering analysis. The following sections describe the approach taken for each component and how they collectively support the study's objectives.

2.1 Survey Methodology

The participant survey was designed to capture customer-reported information that cannot be observed through onsite metering alone. The survey collected data about installation context, equipment configuration, operating behavior, satisfaction, additional installation costs, and perceived performance. These findings help inform both customer-facing guidance and measure-impact assumptions.

2.1.1 Sampling and Recruitment

The survey targeted 2,349 HPWH rebate participants who installed HPWHs through the 2024 and 2025 Retail and Residential Coordinated Delivery programs. The Retail program was delivered through a midstream pathway so customer contact information was not available in PA tracking systems and had to be matched using vendor records. The survey was administered online between mid-August and late October 2025, offering a $25 incentive to encourage participation. A total of 191 respondents completed the survey (8% response rate). This response rate is relatively low for participant-based studies overall, but is more typical for midstream program evaluations where customers may not recall direct program participation.

2.1.2 Survey Structure and Topics

The survey instrument collected data across six key domains:

- Installation context (location, space conditioning, circuit configuration)
- Purchase motivations
- Operational behavior and mode usage
- Temperature settings
- Equipment characteristics
- Customer satisfaction and open-ended feedback

These domains directly correspond to the research questions of this study and provide essential context for interpreting metering data and refining TRM assumptions.

2.2 Metering Data Analysis Methodology

The analysis of metering data examined the performance of HPWHs using field data collected previously as part of the Residential Building Use and Equipment Characterization Study (RBUECS) and the Heat Pump Metering Study (HPMS). Between the two studies, metered average power data recorded at 1-minute intervals was available from 65 monitored sites (38 from RBUECS and 27 from HPMS). The metered data used in this study spanned from 2017 to 2024, and the metered units were manufactured between 2012 and 2022.

The objectives of the analysis were to:

- Estimate an mode-adjusted UEF by summarizing time spent in each operational mode (heat pump, electric resistance, combined)
- Explore the impact of installation conditions on in-situ performance, and
- Calculate average annual HPWH energy consumption, peak demand, and hot water load

2.2.1 Data Collection and Cleaning

First, the team gathered equipment characterization and installation data for each metered unit based on model number, including:

- Rated tank size, first hour rating and efficiency (UEF)
- Number of occupants in the home
- Installation location (conditioned vs unconditioned space)
- Rated power for each heating element (upper and lower electric resistance heating elements as well as max heat pump kW)
- HPWH type: standalone versus solar assisted

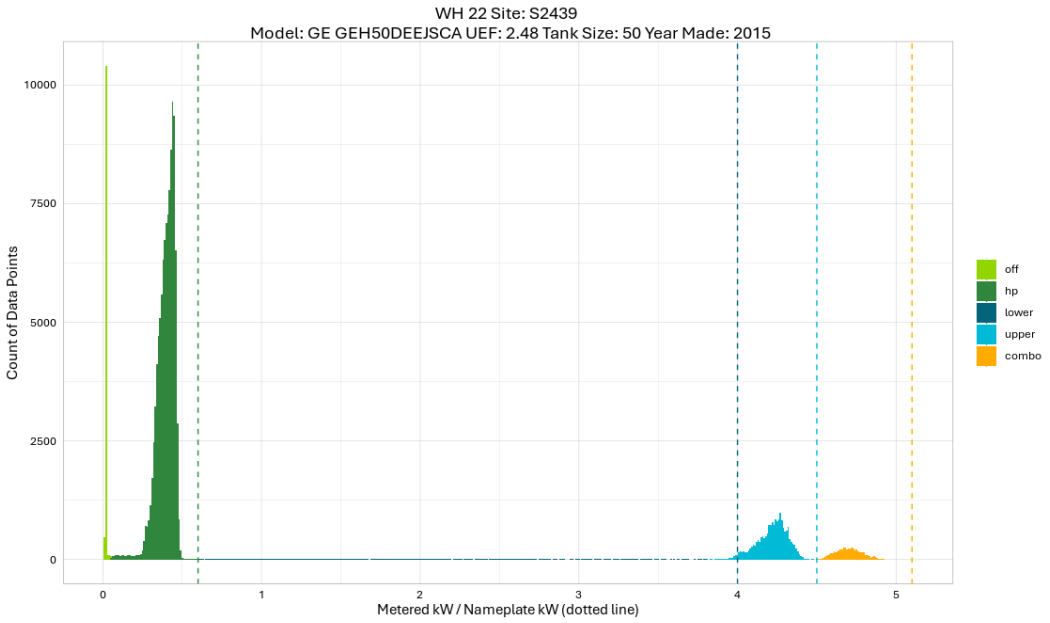
The team then checked the data availability and quality. Based on these checks, six of the 65 metered sites were removed from the analysis:

- One site had insufficient data (only 30 days total)
- One site had bad data (metered power draw never showed water heater in use)
- Four sites had solar-assisted heat pump water heaters, which were determined to be too distinct of a technology to include in the analysis

2.2.2 Heating Mode Assignment

To understand in-situ performance, the team identified the current heating mode (heat pump, lower/upper electric resistance heating element, or combined) for each data point. For each unit, power thresholds to determine heating modes were set by visual inspection, comparing clusters in the histogram of metered kW to the nameplate kW for each mode. Figure 2-1 shows an example of the plots used in the mode assignment process. The histogram shows the distribution of metered data points colored by the assigned heating mode, with the nameplate kW for each mode shown as a dotted vertical line.

Figure 2-1. Example Mode Assignment Plot



Source: Guidehouse analysis

2.2.3 Efficiency Adjustment Factor Calculation

Next, the team estimated a mode-adjusted UEF based on the share of operation occurring in each heating mode. An efficiency value was assigned to each heating mode as follows:

- Heat pump mode was assigned the unit's rated UEF[3]
- Electric resistance mode was assigned a UEF of 0.95, based on RBUECS benchmarks
- Combined mode UEF was calculated as the average of heat pump and electric resistance mode UEFs, weighted by the average power draw in each mode

A mode-adjusted UEF was then calculated for each unit by taking the average of the mode UEFs, weighted by the total energy consumed in each mode, and a UEF adjustment factor was calculated as the ratio of the mode-adjusted UEF to the rated UEF. Finally, the average UEF adjustment factor was calculated by taking the mean UEF adjustment across all sites, weighted by the site's annual hot water load.

The resulting adjustment of approximately 0.81–0.83 reflects reduced performance relative to rated UEFs due to real-world operating conditions and mode-switching behaviors. Note that this mode-adjusted UEF accounts only for the performance degradation due to electric resistance heating operation and does not account for other factors that may cause in-situ efficiency to differ from rated efficiency. It was beyond the scope of this study to measure in-situ efficiency directly.

2.2.4 Annual Consumption, Peak Demand, and Load

To calculate normalized annual consumption, the team first summarized the metered 1-minute interval data to the hourly level. Unit-level linear models were then fit to predict energy consumption as a function of hour of day, day type (weekday vs weekend/holiday), average monthly temperature (as a proxy for mains water temperature) and normalized heat build-up (a composite temperature/humidity variable which accounts for thermal lag). The final models were then used to predict consumption in a typical year using TMYx weather data.

The team then calculated annual consumption by summing the typical year hourly consumption. Summer peak demand was calculated for each unit for the ISO-NE On Peak period by taking the average kW across non-holiday weekdays from 1 p.m.-5 p.m. in the months of June, July, and August. Lastly, the annual hot water load delivered was calculated for each unit by converting the annual energy consumption using the mode-adjusted UEF derived in the previous step.

The team then summarized the average weather-normalized annual consumption, peak demand, and water heating load across all units by tank size group (<= 55 gallons and >55 gallons).

[3] In theory, the rated UEF reflects a mix of heating modes. However, in practice, the test conditions are such that the rated UEF is essentially all heat pump mode operation. For a small sample of the included units, the manufacturer included rated UEF in both heat pump and hybrid modes, with the heat pump mode UEF being 3% higher on average. Based on this, the team decided to make the slightly conservative assumption that the rated UEF was equivalent to the heat pump mode UEF.

2.3 Measure Impacts Methodology

The study team updated HPWH measure impacts using inputs from both the participant survey and the metering data analysis, combined with current program data and external datasets such as RBUECS and the EIA Residential Energy Consumption Survey.[4] The goal was to improve alignment between assumed savings and real-world performance in Massachusetts homes.

2.3.1 Heat Pump Water Heater Energy and Demand Savings

The energy savings equations used in this analysis are as follows:

Electric Baseline Water Heater:

$$Electric\ Energy\ Savings\ (kWh) = Load\ (MMBtu) * \left(\frac{1}{UEF_{base}} - \frac{1}{UEF_{ee,adj}}\right) / 0.003412 (\frac{MMBtu}{kWh})$$

$$Fuel\ Energy\ Savings\ (MMBtu) = 0$$

Fuel Baseline Water Heater:

$$Electric\ Energy\ Savings\ (kWh) = Annual\ Energy_{base}\ (kWh) - \ Load\ (MMBtu) * \left(\frac{1}{UEF_{ee,adj}}\right) / 0.003412 (\frac{MMBtu}{kWh})$$

$$Fuel\ Energy\ Savings\ (MMBtu) = \ Load\ (MMBtu)\ /\ UEF_{base}$$

Where:

- $Load\ (MMBtu)$ is the annual water heating load,
- UEF_{base} is the baseline Uniform Energy Factor,
- $UEF_{ee,adj}$ is the HPWH Uniform Energy Factor, adjusted using the UEF adjustment from the metering analysis, and
- $Annual\ Energy_{base}\ (kWh)$ is the average annual electric energy consumption of the baseline fuel-fired water heater

[4] Energy Information Administration (EIA) 2020 Residential Energy Consumption Survey (RECS), Table CE4.7 (value for New England)

The team determined the annual water heating load using the average water heating consumption by fuel type from RECS. The annual consumption values were converted to loads by multiplying by the average installed water heater efficiency by fuel type, based on the RBUECS.[5] The loads by fuel type were then differentiated by water heater tank size using the ratio of loads by tank size from the metering analysis.[6]

The team derived baseline UEF values based on the average efficiency of newly installed DHW equipment from RBUECS. For each fuel type, a weighted average was taken across all equipment types, weighting by the proportion of the population which had that equipment type. UEFs for indirect DHW systems (which provide hot water from a boiler which is also used to heat the home) were estimated by taking the average efficiency of existing boilers by fuel type, and applying the adjustment by water heater tank size which is used in the Federal energy and water conservation standard.[7] The team used the code minimum UEF for equipment types (tankless water heaters) for which there was no efficiency data available from RBUECS. Code minimum was also used for the HPWH portion of the electric baseline, based on the assumption that if a customer had an existing HPWH, it would have been a lower efficiency unit to justify the new installation.

The efficient case HPWH UEF values were determined by taking the average rated UEF by tank size (<=55 gallons vs >55 gallons) from the Mass Save program data from 2024 and the beginning of 2025 (n = 5079). These average values were then adjusted using the UEF adjustment factor derived in the metering analysis.

The annual electric consumption of fuel-fired baseline water heaters was taken from RBUECS, using the value for annual energy consumption of natural gas and oil-fired water heaters.

Lastly, Summer peak demand values were calculated by using the peak demand factors (kW per annual kWh) derived in RBUECS for electric resistance, heat pump, and fuel-fired water heaters which correspond to the ISO-NE Summer "On Peak" period.[8]

[5] RBUECS (2023)

[6] Estimated annual load values were also calculated from the metered data for each unit. However, since the baseline water heating fuel type was not known for the metering sites, average load by fuel type couldn't be calculated. Based on the RECS data, fuel type is highly correlated with water heating load, so it was decided that it would be more accurate to use the RECS load data which captures differences by fuel type.

[7] Code of Federal Regulations 430.32

[8] The ISO-NE Summer On Peak period is non-holiday weekdays from 1 p.m.-5 p.m. in the months of June, July, and August.

2.3.2 Secondary Impacts to Heating and Dehumidification Energy Consumption

During standard operation, a HPWH removes heat from the space in which it is installed and dehumidifies the space to some degree. The team quantified the secondary impacts (interactive effects) of the HPWH on heating and dehumidification energy consumption.

The heating secondary impacts were determined based on a previous HPWH study.[9] The team took the electric and fuel penalty values from that study and scaled them by total HPWH consumption rather than energy savings, since the mechanism for the impact is based on the HPWH operation. The same study found that the secondary impacts on cooling energy were negligibly small, and thus assumed zero savings from reduced cooling load.

The team estimated dehumidification energy savings two different ways. The first was an engineering calculation based on the limited studies available on the dehumidification effects of HPWHs. First, HPWH dehumidification was estimated based on one study[10] which found the average HPWH condensate production in summer months in Kentucky was between 0.85 and 1.6 pints/day. Since Boston is somewhat cooler and less humid than Paducah, KY, the team assumed 1 pint/day.

Next, dehumidifier condensate production in MA was estimated based on a metering study[11] in MA, NY, MD, and VA, which found an average of 4.9 pints/day in October. The team then adjusted this to 6.7 pints/day based on the ratio of dehumidifier energy consumption in the summer to that in the month of October, based on RBUECS. Based on this, the HPWH reduction of 1 pint/day represented about 15% savings in dehumidification energy.

The other method which the team used was based on the online survey, in which customers that had a dehumidifier installed in the same space as their HPWH were asked the number of months/year that they used their dehumidifier before and after the HPWH was installed. The team calculated the percent reduction in months of use for each customer and then averaged across all customers, which came out to about 20% savings.

Neither of the two methods was high rigor, but both provided similar savings estimates. Based on this the team decided to take the average of the two numbers, recognizing that there is a fair amount of uncertainty in the estimate. However, given that the overall dehumidification energy savings is small relative to the HPWH savings, that uncertainty does not have a large impact on the total savings.

The average dehumidification energy savings percentage was then applied to the average annual dehumidifier energy consumption value from the RBUECS to determine the total dehumidification energy savings. That number was then multiplied by the percentage of survey respondents who indicated having a dehumidifier in the same space as their HPWH.

[9] Heat Pump Water Heater Impact Study Volume 1. Electric penalties were sourced from Table C-2 and fuel penalties were sourced from Table C-3.

[10] Fifteen Years of Dehumidification Results from Heat Pump Water Heaters

[11] Dehumidifiers: A Major Consumer of Residential Electricity

3. Participant Survey

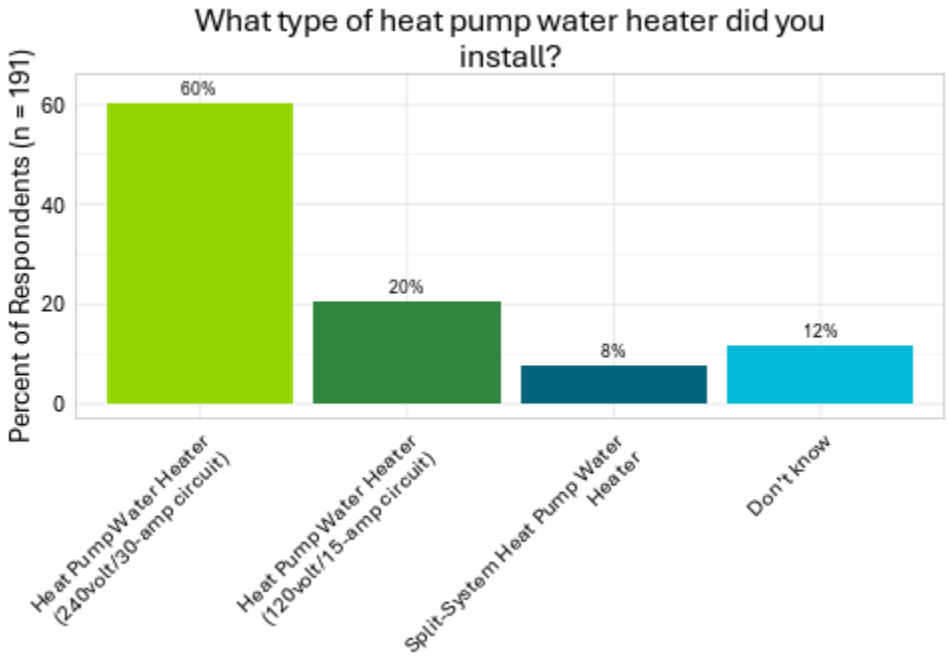
The participant survey results are discussed below. Additional figures can be found in Appendix A.

3.1 Survey Results

3.1.1 Installation Context

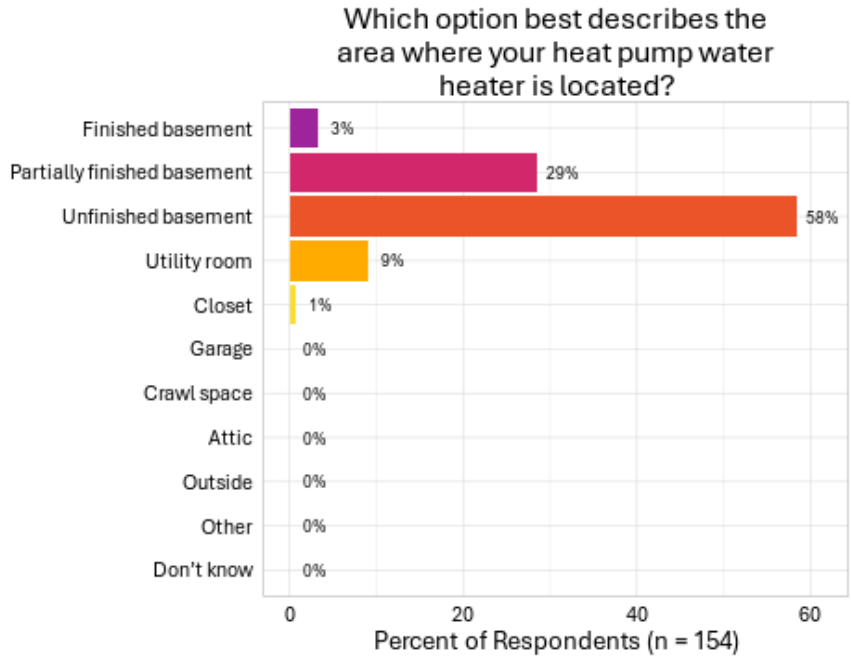
The majority of respondents reported installing 240V integrated HPWH units as shown in Figure 3-1, with most installations occurring in basements. Specifically, 58% of units were placed in unfinished basements, while 32% were installed in finished or partially finished basements (Figure 3-2). Notably, 64% of respondents indicated that their installation space was unheated (Figure 3-3). The survey also revealed that nearly half of the respondents used mini-split or ductless heat pumps for home heating, and over a quarter relied on central heat pumps (Figure 3-4).), both of which are significantly higher than the rates of those heating systems in MA as a whole. HPWH adoption appears to be strongly associated with prior adoption of heat pump space heating, indicating that HPWHs are most commonly adopted as part of broader household electrification.

Figure 3-1. Type of Installed HPWH



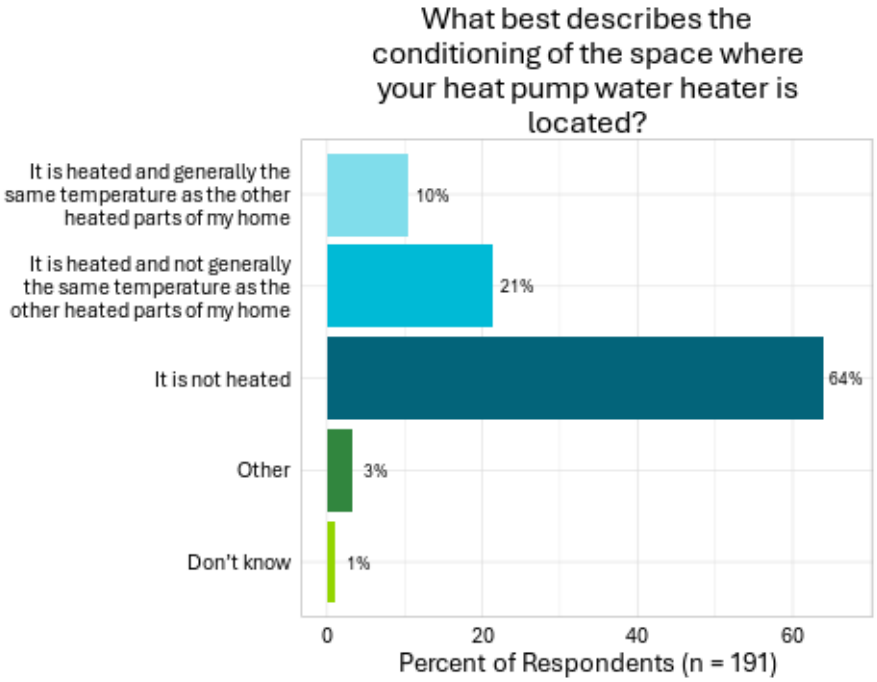
Source: Guidehouse analysis

Figure 3-2. Location of HPWH Installation



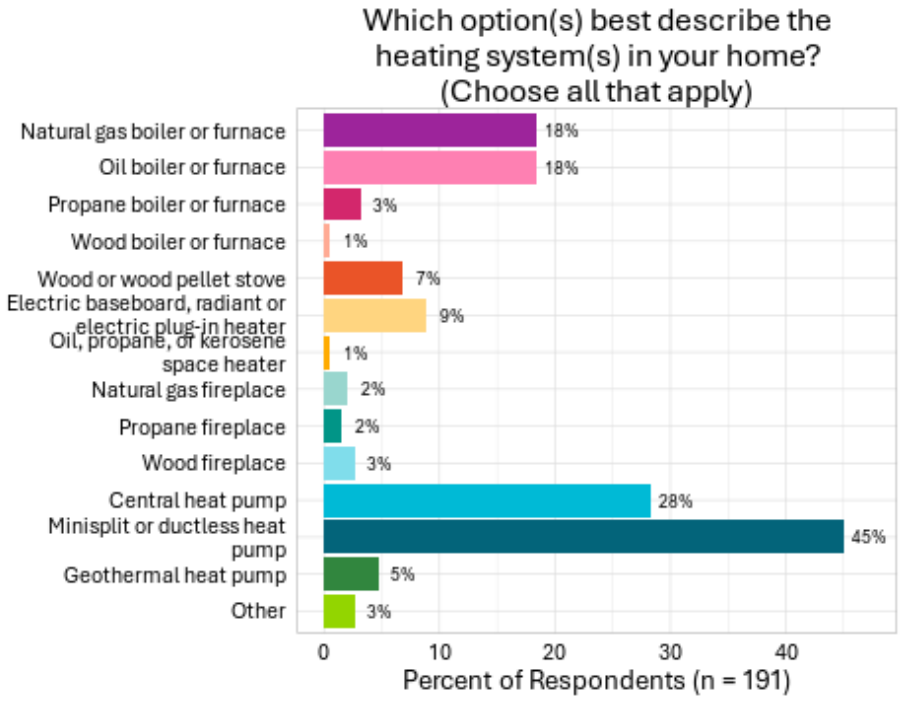
Source: Guidehouse analysis

Figure 3-3. Conditioning of HPWH Installation Space



Source: Guidehouse analysis

Figure 3-4. Primary Heating Systems in Respondent Home

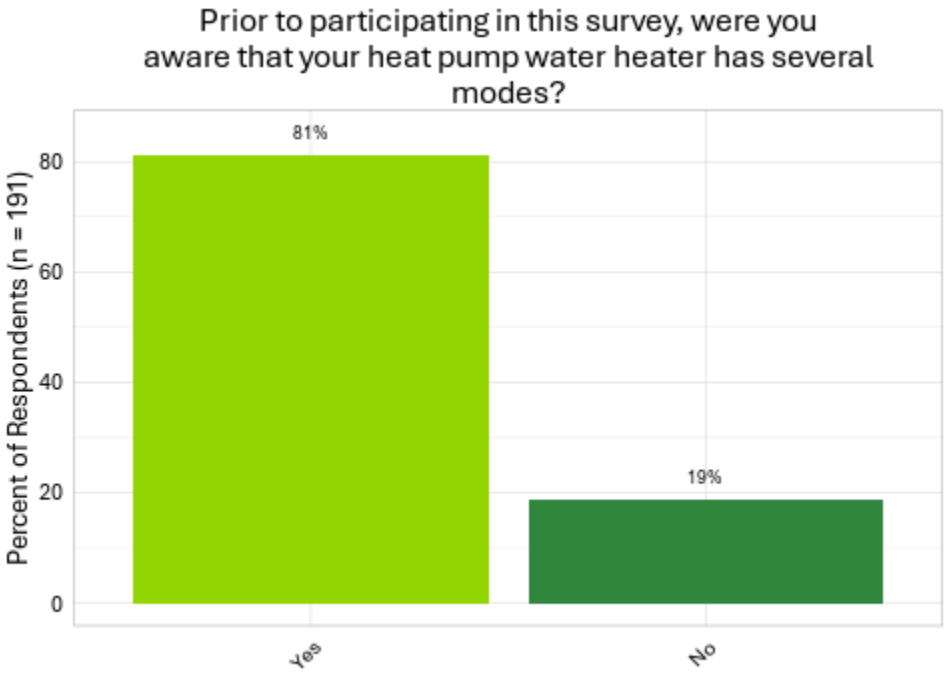


Source: Guidehouse analysis

3.1.2 Heat Pump Modes and Customer Knowledge

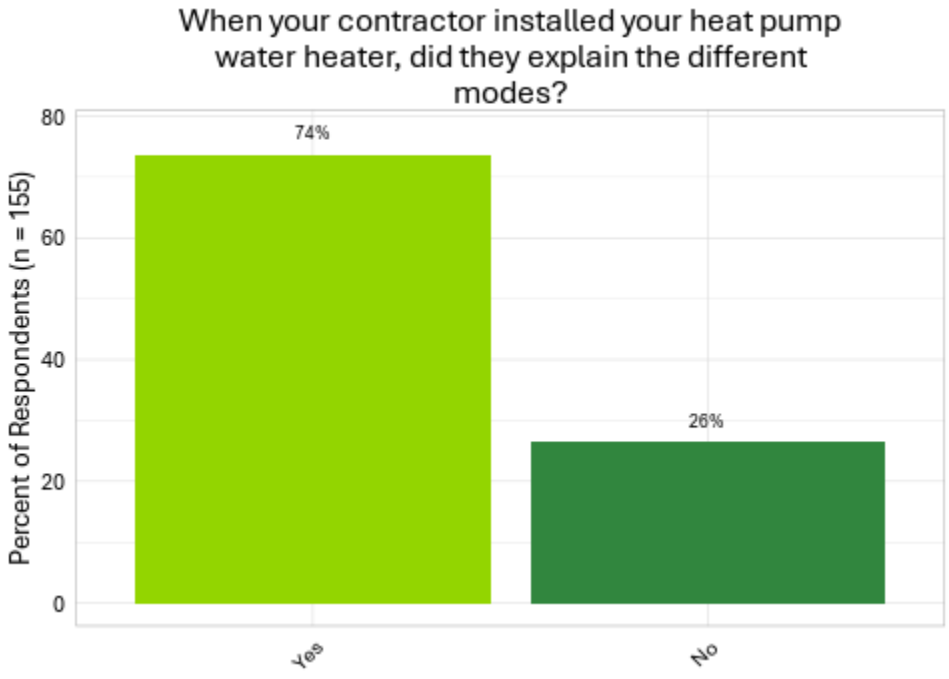
As shown in Figure 3-5, awareness of HPWH operating modes was moderately high among respondents, though the nearly 20% who were unaware point to the need for further customer education. Figure 3-6 shows that most customers (74%) received an explanation of these modes from their contractor, underscoring the importance of contractor education in shaping user behavior. Efficiency/economy mode was the most used setting (Figure 3-7), and many customers reported switching modes to save electricity or when using vacation settings (Figure 3-8).

Figure 3-5. Respondent Awareness of HPWH Modes



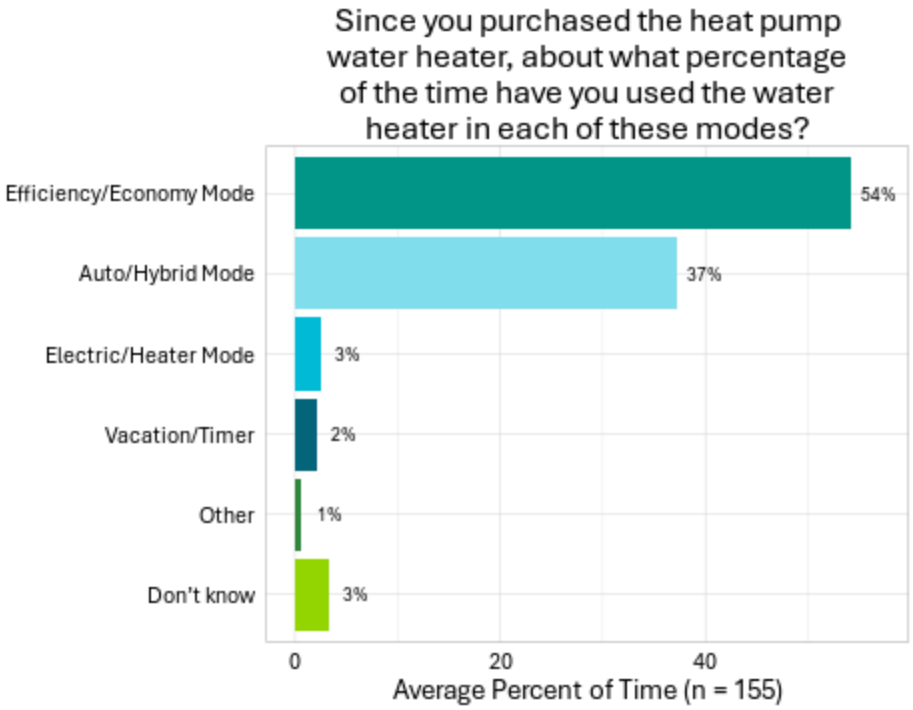
Source: Guidehouse analysis

Figure 3-6. Contractor Explanation of HPWH Modes



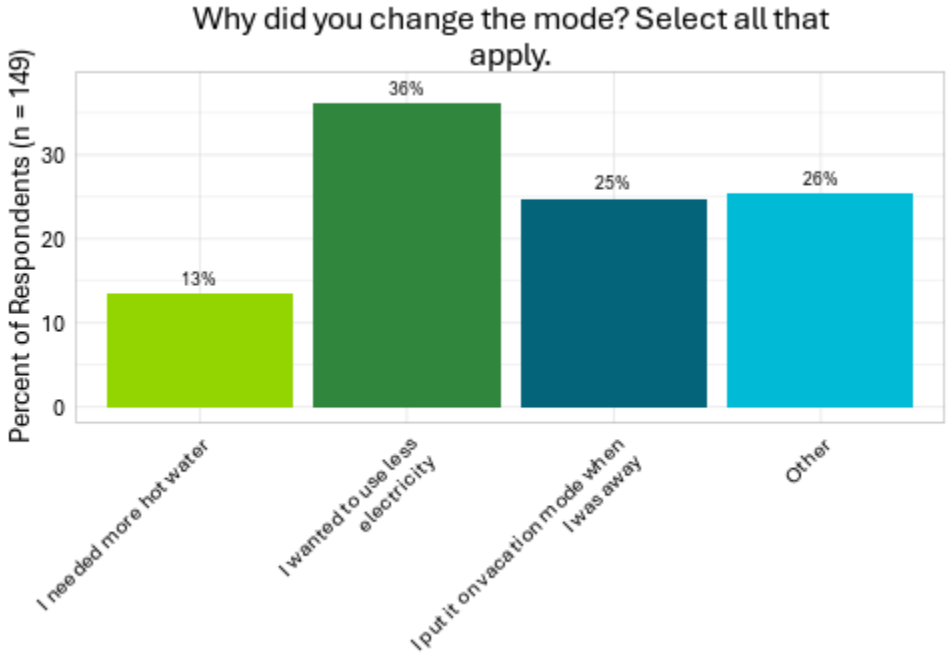
Source: Guidehouse analysis

Figure 3-7. HPWH Mode Usage among Respondents



Source: Guidehouse analysis

Figure 3-8. Reasons for Changing HPWH Operating Mode

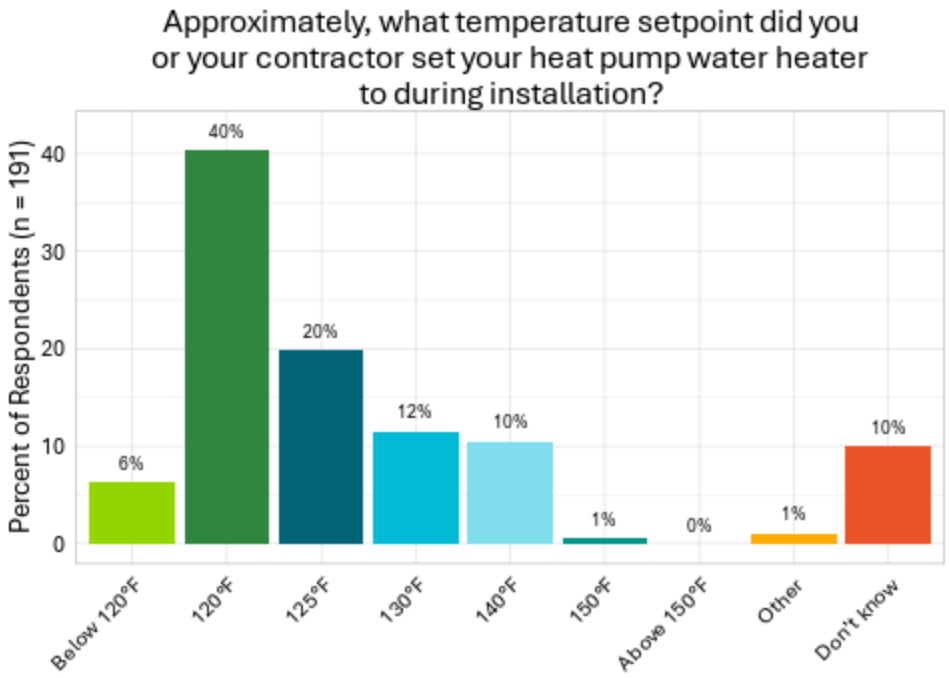


Source: Guidehouse analysis

3.1.3 Temperature Set Points

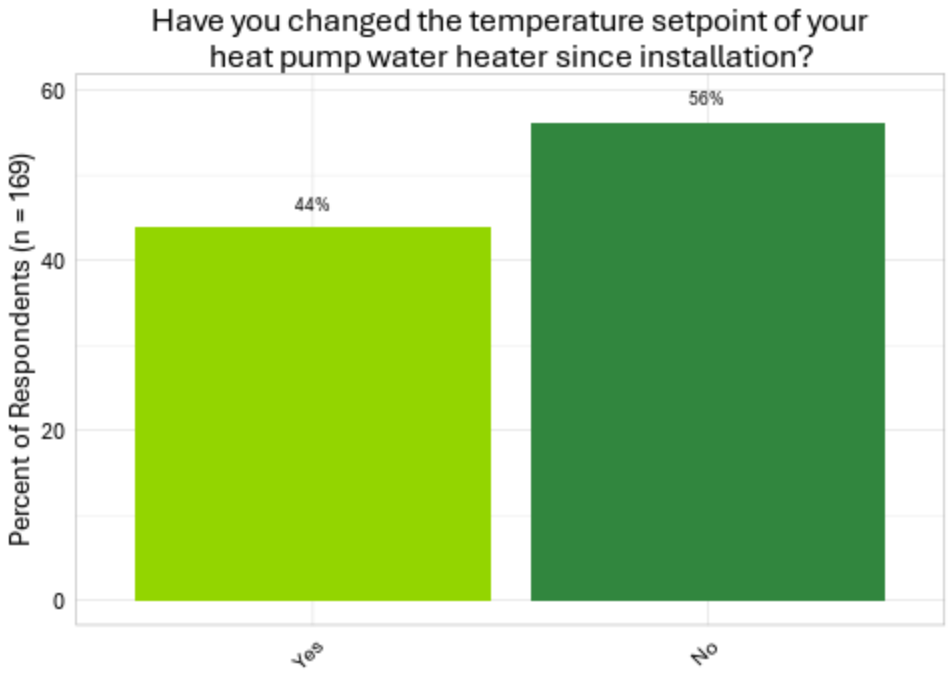
Figure 3-9 shows temperature setpoints set by the contractor during installation of the heat pump water heater. Adjusting these setpoints after installation was common, with 44% of respondents reporting that they made changes (Figure 3-10). The primary motivations for changing setpoints included improving hot water delivery, reducing energy consumption, and accommodating household preferences (Figure 3-11). Some respondents set temperatures below 120°F, which raises concerns regarding Legionella growth (CDC recommends ≥120°F) (Figure 3-12).

Figure 3-9. Temperature Setpoints Recommended by Contractor



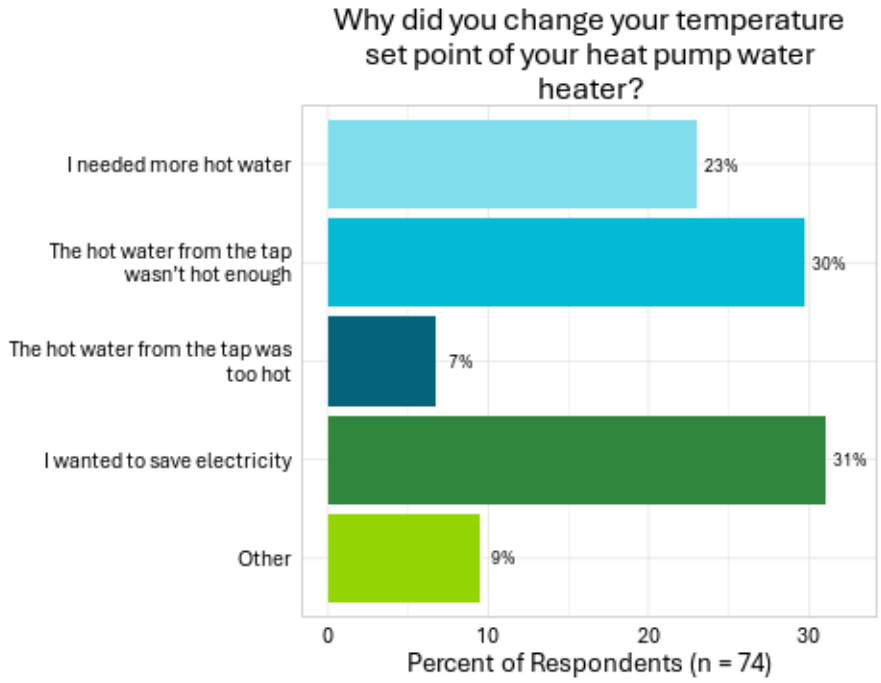
Source: Guidehouse analysis

Figure 3-10. Respondents who Changed HPWH Temperature Set Point



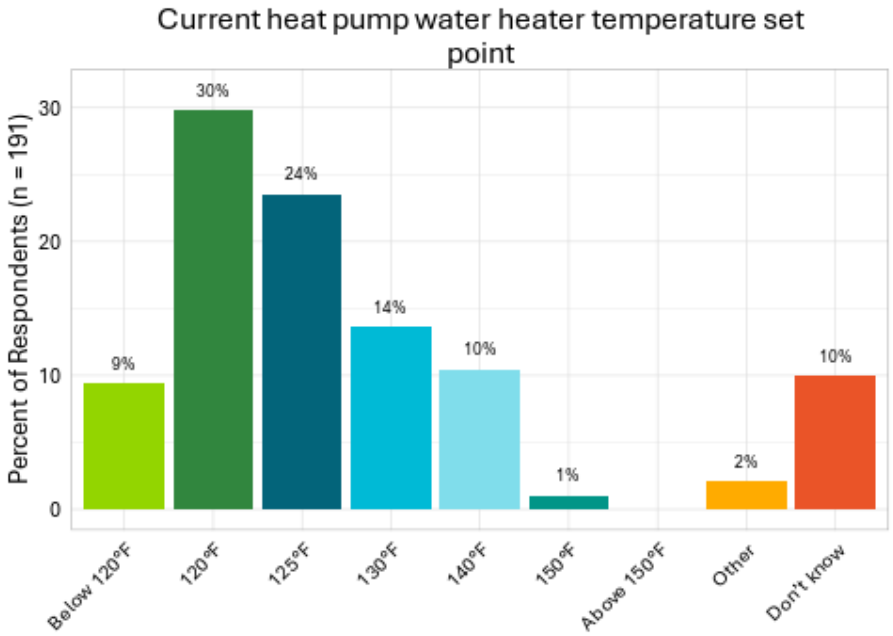
Source: Guidehouse analysis

Figure 3-11. Reason for Changing HPWH Temperature Set Point



Source: Guidehouse analysis

Figure 3-12. Current HPWH Temperature Set Points

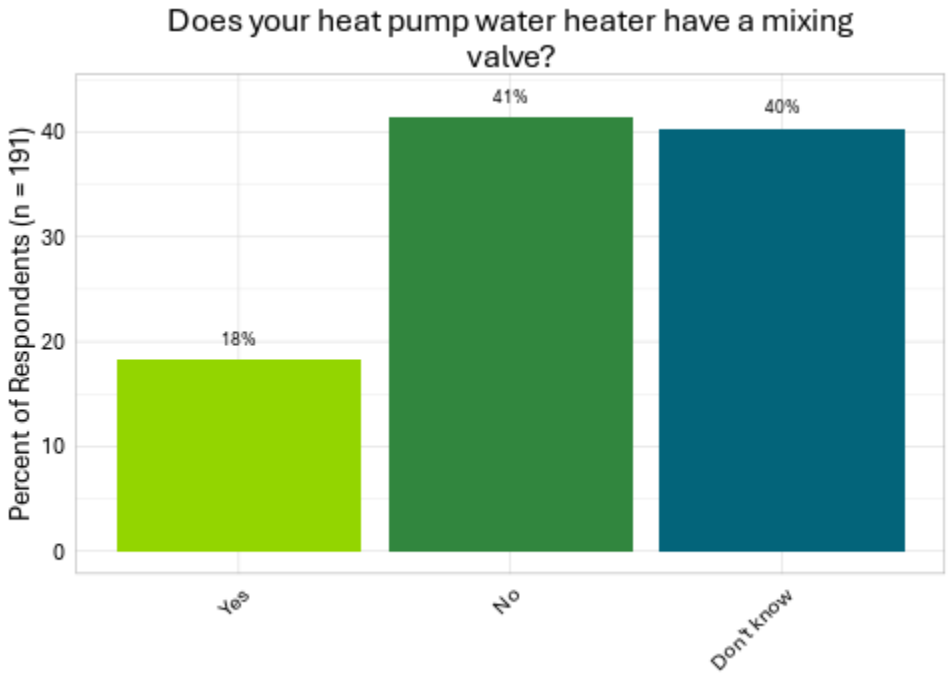


Source: Guidehouse analysis

3.1.4 Mixing Valves

A significant proportion of customers either did not have or were unsure if they had a mixing valve installed, as Figure 3-13 shows. This low penetration of mixing valves suggests opportunities to enhance hot water availability and reduce the risk of scalding when higher temperature setpoints are used.

Figure 3-13. Respondents with a Mixing Valve Installed

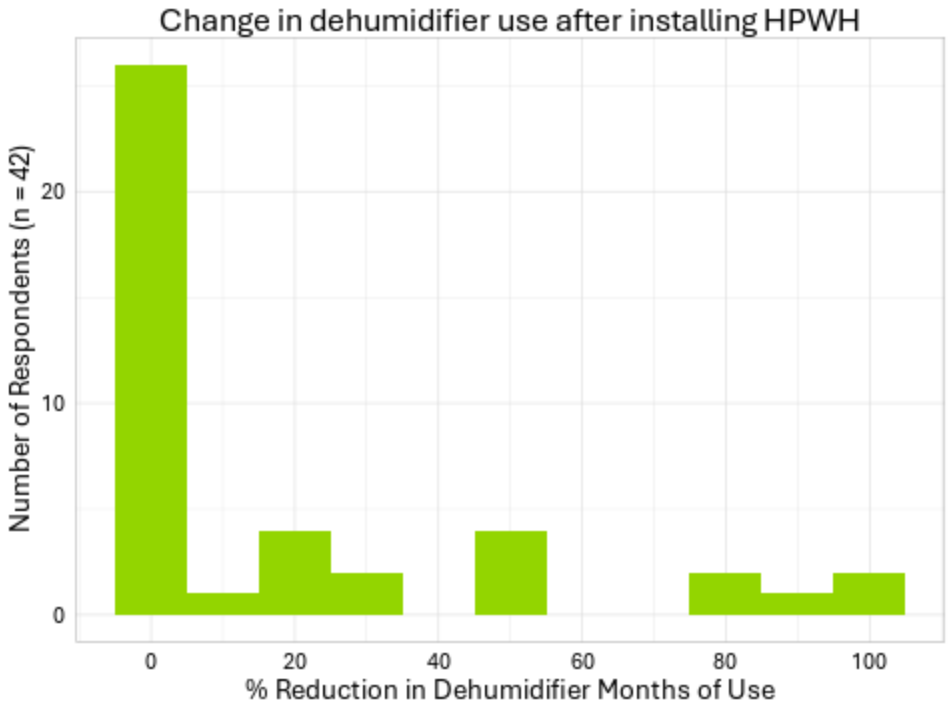


Source: Guidehouse analysis

3.1.5 Dehumidifier Interaction

The survey found that 39% of respondents had a dehumidifier in the same space as their HPWH. Of those, nearly half reported that their dehumidifier ran less often after installing the HPWH. Analysis of self-reported data indicated an average reduction of about 20% in dehumidifier operation across all customers when located in the same space as their HPWH (not just the ones who reported a reduction), supporting the inclusion of dehumidification savings in program impact calculations. Figure 3-14 shows the distribution of the change in dehumidifier use, indicating a large range in the impact across households.

Figure 3-14. Dehumidifier Use with HPWH

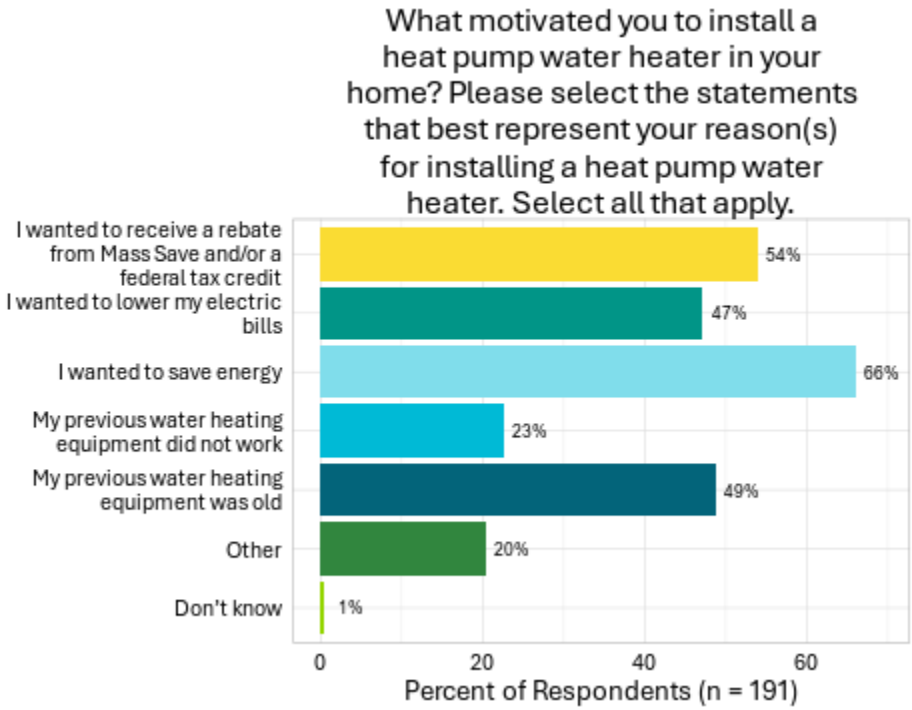


Source: Guidehouse analysis

3.1.6 Purchase Motivations

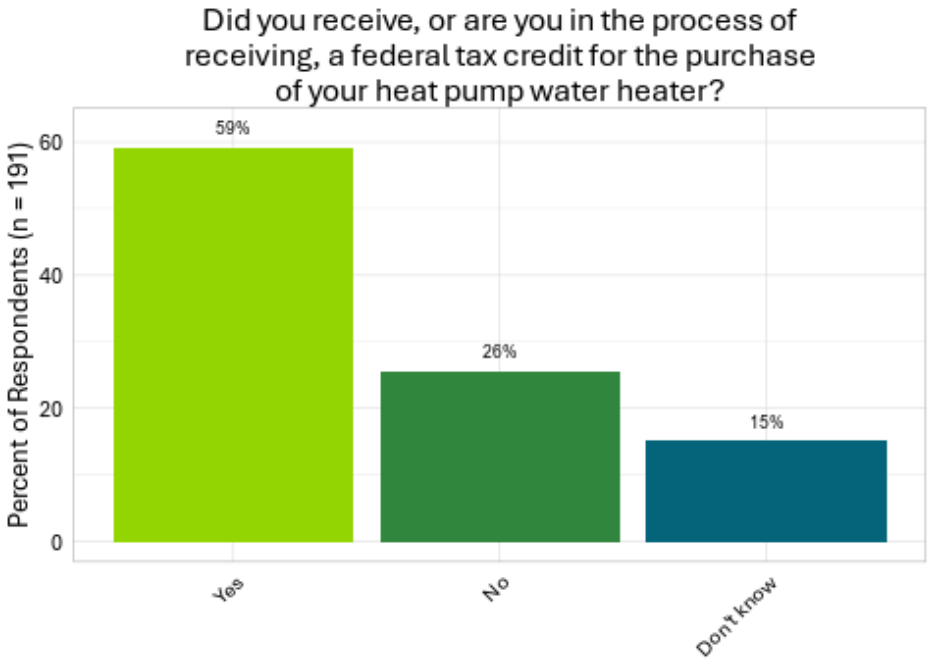
Figure 3-15 shows that financial incentives/rebates were the most frequently cited reasons for installing a HPWH, followed by the need to replace old or non-functional equipment and the desire to save energy. Additionally, 59% of respondents reported receiving or expecting a federal tax credit, highlighting the influence of stacked incentives on customer decision-making, see Figure 3-16.

Figure 3-15. Motivations for Installing a HPWH



Source: Guidehouse analysis

Figure 3-16. Respondents Receiving a Federal Tax Credit

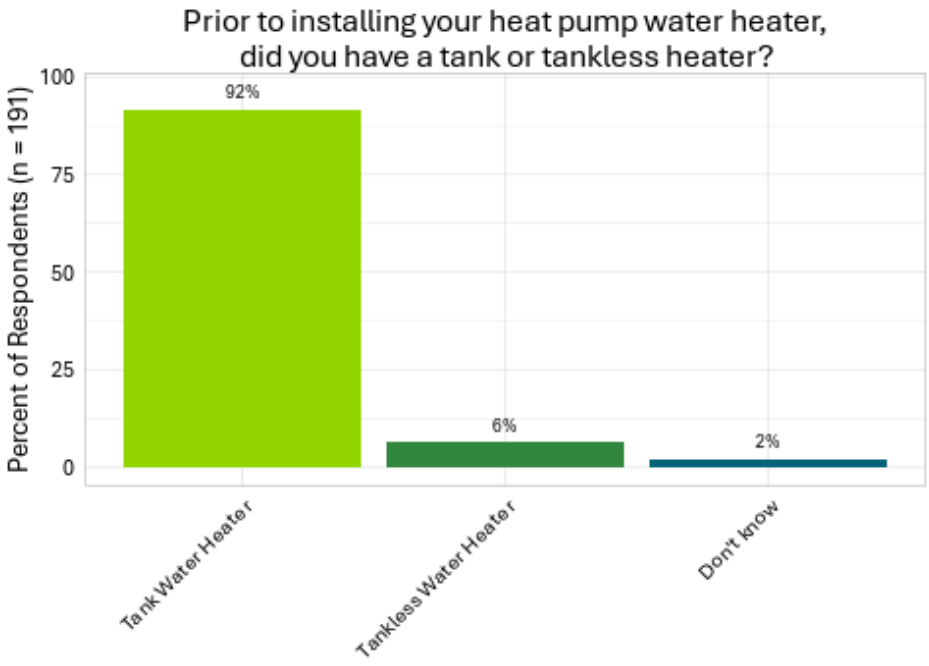


Source: Guidehouse analysis

3.1.7 Pre-Existing System

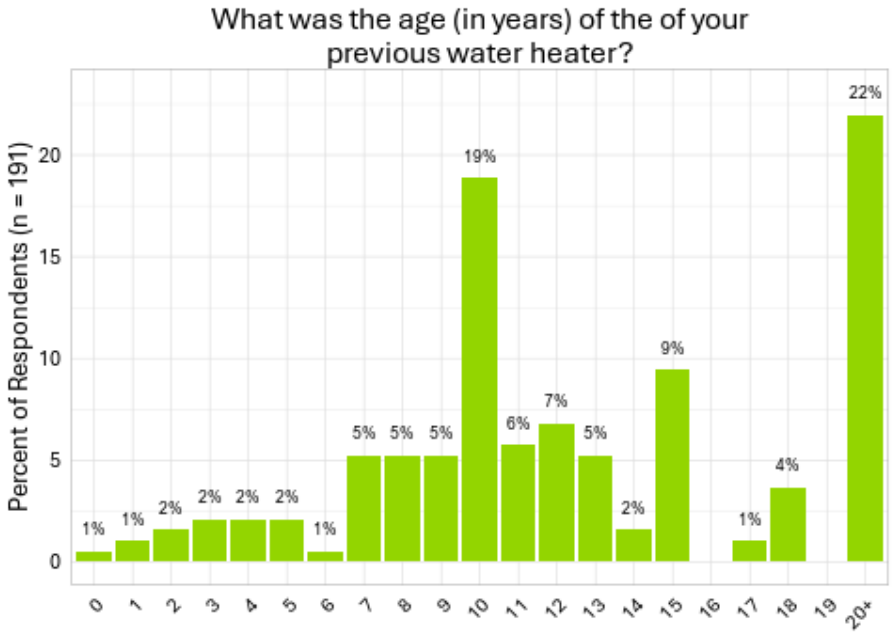
Understanding the type of water heating equipment installed prior to the HPWH upgrade provides important context for energy savings calculations. Figure 3-17 shows that most respondents replaced a traditional storage tank water heater, with a smaller share transitioning from tankless units. Figure 3-18 indicates that many of the replaced units were older, with the largest share reporting units that were either around 10 years old (19%) or more than 20 years old (22%).

Figure 3-17. Type of Previous Water Heater (Tank vs. Tankless)



Source: Guidehouse analysis

Figure 3-18. Age of Previous Water Heater

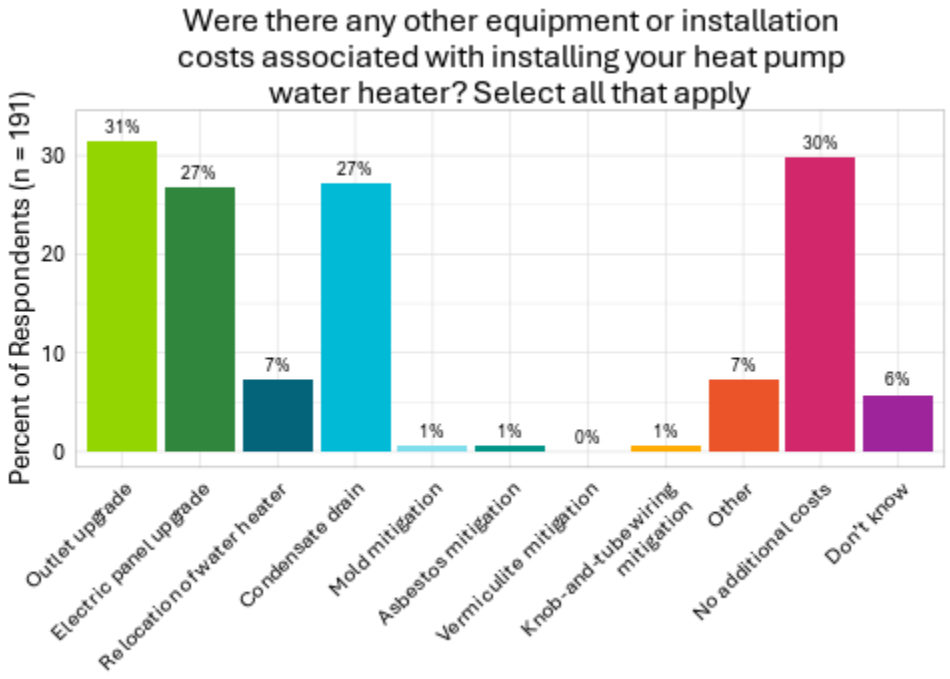


Source: Guidehouse analysis

3.1.8 Additional Installation Costs

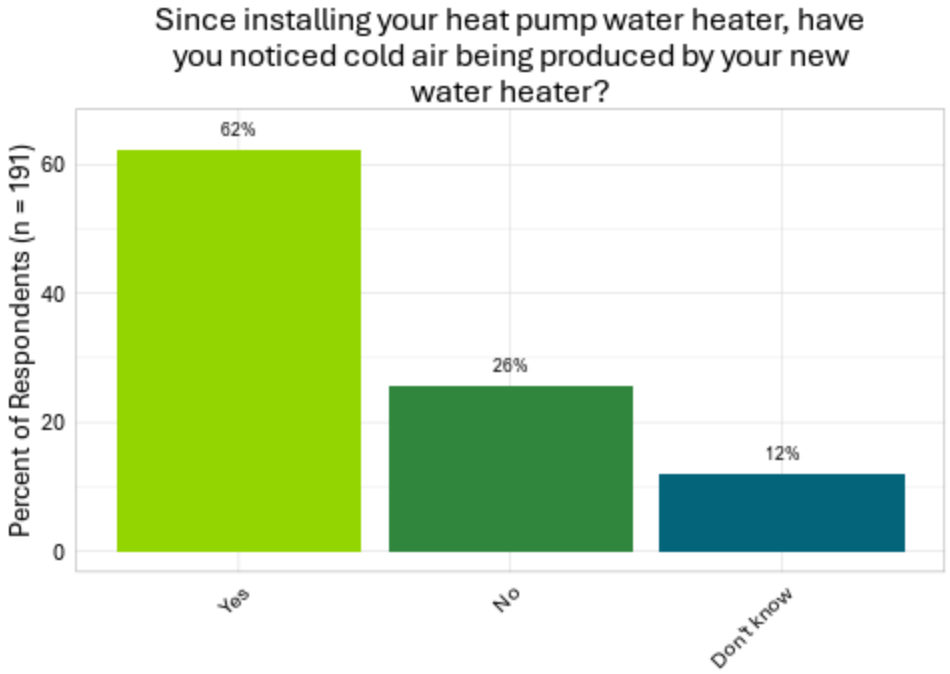
Figure 3-19 indicates that many customers incurred extra costs during installation, such as outlet upgrades (31%), electrical panel upgrades (27%), and condensate drain installation (27%). While 62% of respondents noticed cold air discharge from their HPWH, only a small fraction (3%) installed additional heating equipment to compensate, as shown in Figure 3-20 and Figure 3-21.

Figure 3-19. Additional Installation Costs Incurred by Respondents



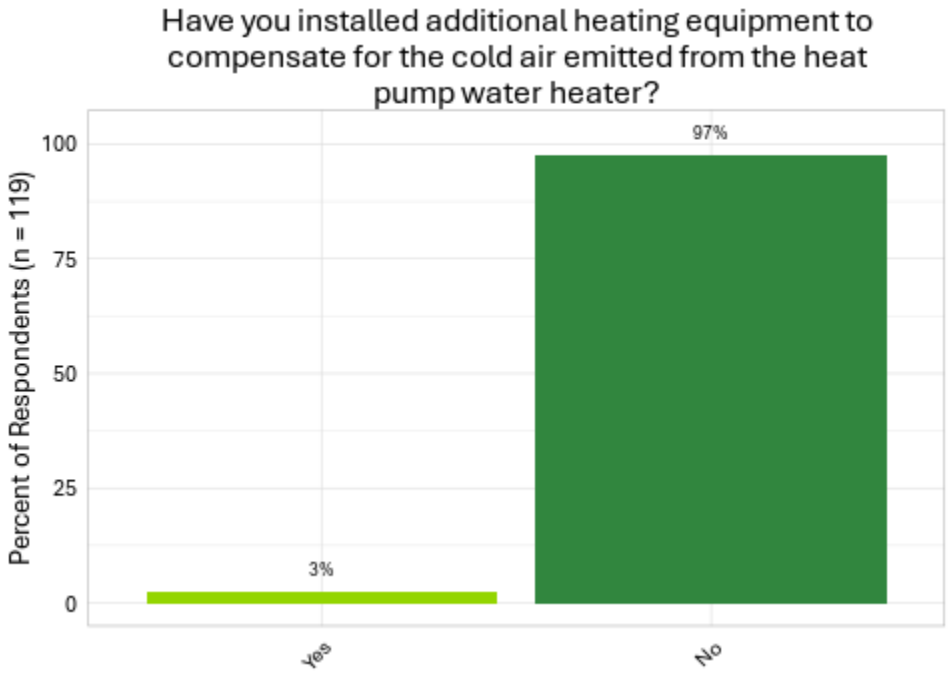
Source: Guidehouse analysis

Figure 3-20. Supplemental Heating Installed to Offset Cold Air Discharge



Source: Guidehouse analysis

Figure 3-21. Awareness of a Cold Air Discharge from HPWH

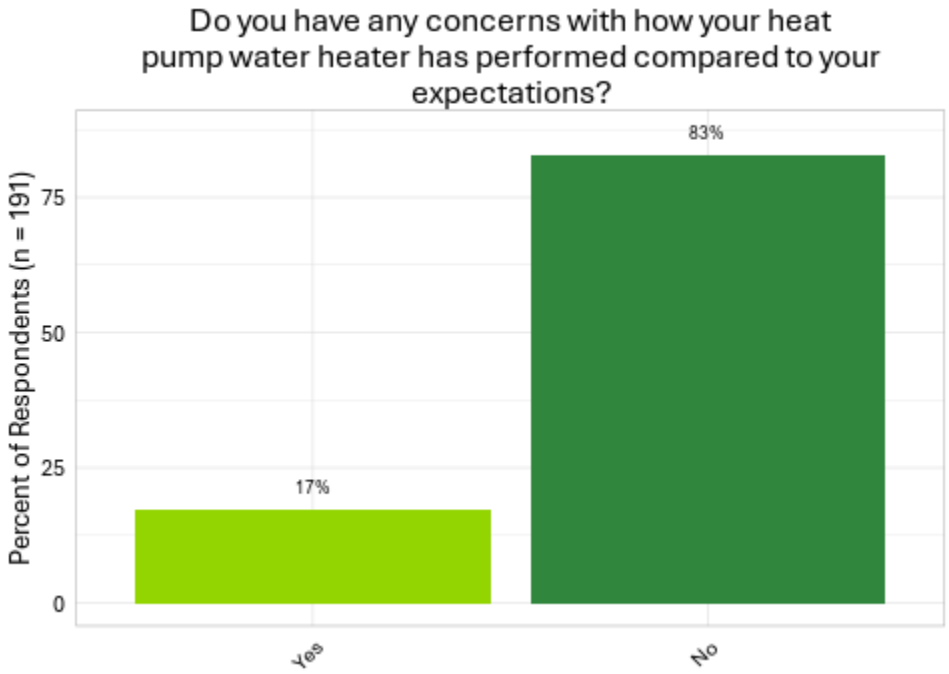


Source: Guidehouse analysis

3.1.9 Customer Satisfaction

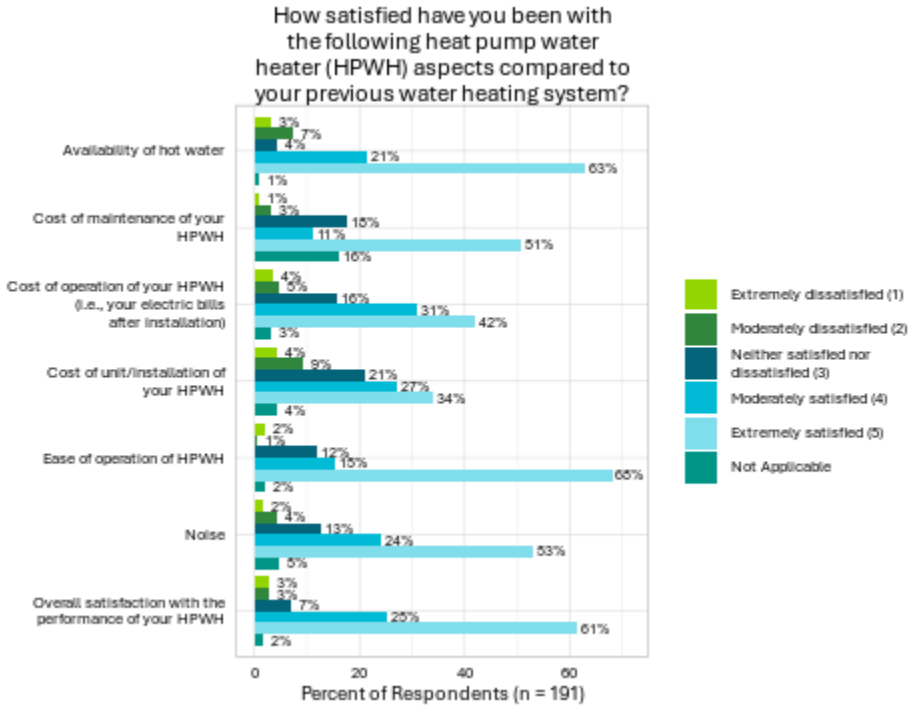
Overall, satisfaction with HPWH performance was high, with 83% of respondents reporting no concerns, see Figure 3-22. When dissatisfaction was expressed, it was most often related to installation cost, the cost of operation, or the availability of hot water as shown in Figure 3-23. While most respondents reported being satisfied with their HPWH compared to their previous system across all evaluated aspects, the small proportion of dissatisfied customers indicate that there is still an opportunity to improve program delivery in order to raise overall satisfaction.

Figure 3-22. Respondents Reporting Concerns with HPWH Performance



Source: Guidehouse analysis

Figure 3-23. Satisfaction with HPWH Compared with Previous System



Source: Guidehouse analysis

4. Metering Data Analysis

In the metering analysis, the team analyzed metered HPWH energy consumption data to estimate in-situ HPWH performance as well as average annual HPWH energy consumption, peak demand, and hot water load.

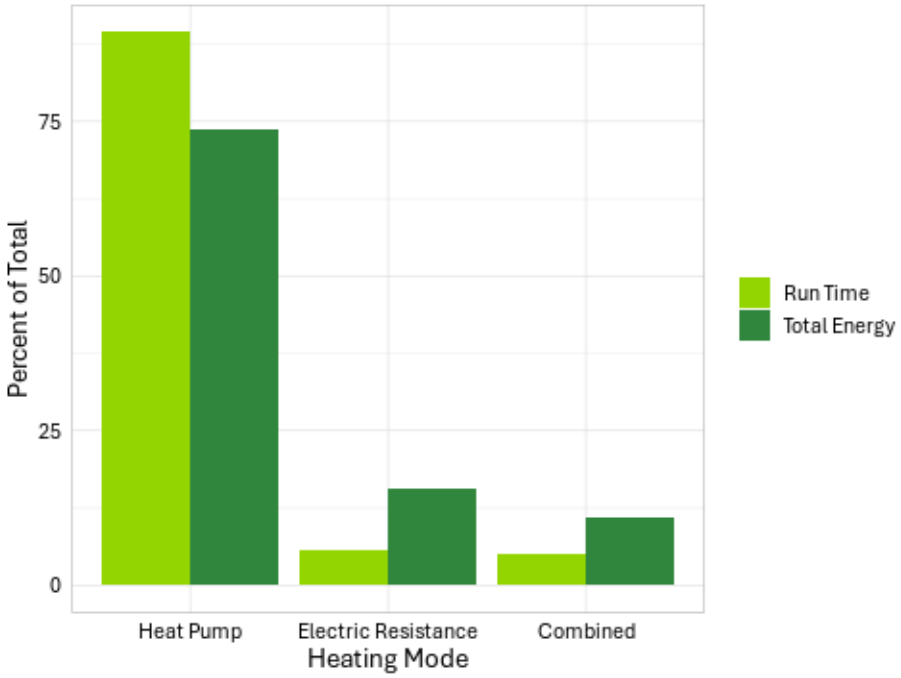
4.1 Adjusted Performance

HPWHs have several operational modes which determine how the unit uses the heat pump and electric resistance heating elements to meet the hot water load. Available modes typically include one which uses all heat pump operation, a hybrid mode which selects heat pump or electric resistance based on demand, and one which uses all electric resistance.

At any given moment, based on the operational mode the HPWH selects the appropriate heating mode: heat pump, electric resistance, or combined (both running simultaneously). In this study, the team estimated performance of HPWHs based on the proportion of operation in each heating mode. Note that this efficiency adjustment accounts only for the performance degradation due to electric resistance heating operation, and does not account for other factors that may cause in-situ efficiency to differ from rated efficiency.

Figure 4-1 shows the average percentage of total run time and energy consumed in each heating mode. Across all metered units, 89% of run time was spent in heat pump mode, accounting for 74% of total energy consumed. This finding indicates moderate usage of the lower efficiency electric resistance heat.

Figure 4-1. Metered Run Time and Total Energy by Heating Mode

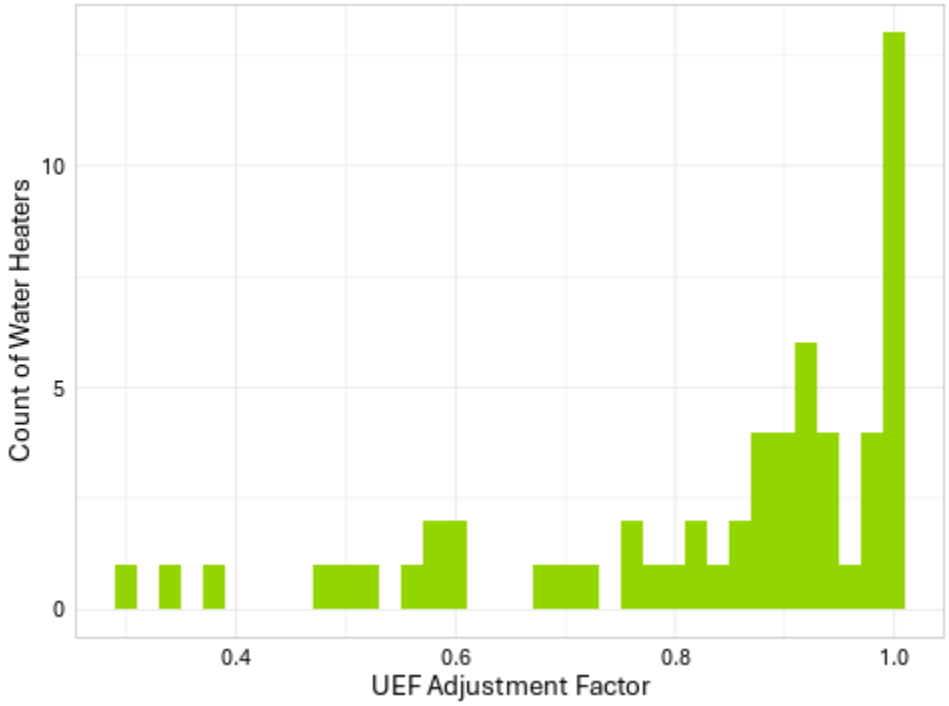


Source: Guidehouse analysis

The team calculated performance adjustments to the rated UEF for each unit based on the proportion of energy used in each heating mode and the corresponding efficiency (Uniform Energy Factor, UEF) of each mode. The average UEF adjustment across all units was 81%, indicating moderate usage of electric resistance heating and a meaningful reduction from rated efficiency.

Figure 4-2 shows the distribution of UEF adjustment factors across all metered units. Most units are clustered near 1.0, but there is a wide range, with some values as low as 0.3-0.4 indicating frequent electric resistance operation for those units.

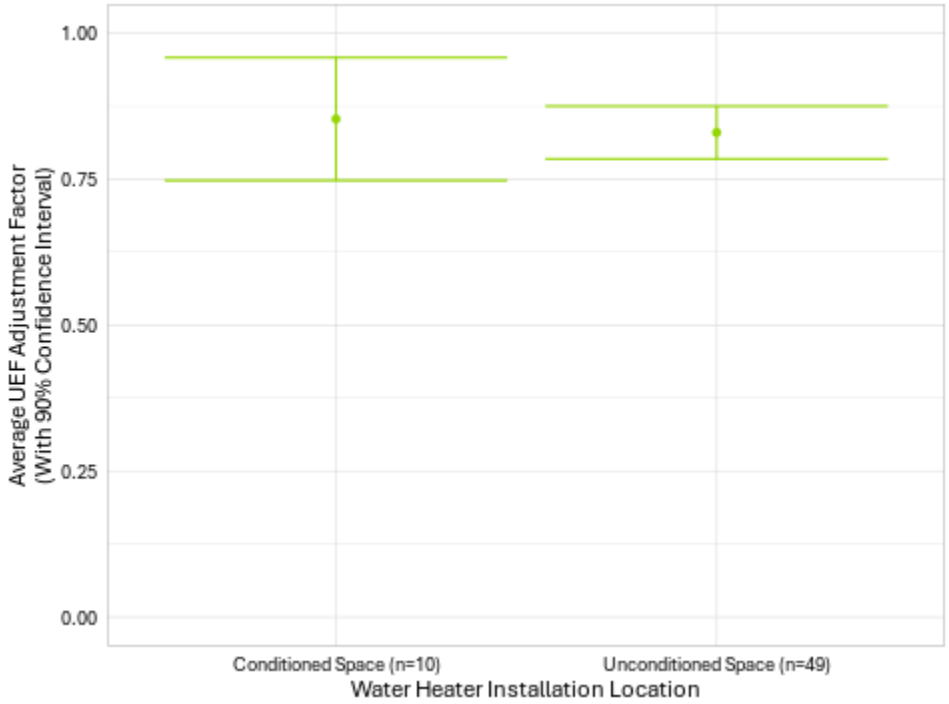
Figure 4-2. Distribution of UEF Adjustment Factors



Source: Guidehouse analysis

The team analyzed the available data on installation conditions to try to identify the factors that may be driving the lower UEF values for some units, but did not find anything conclusive. Figure 4-3 shows the average UEF adjustment factor by installation location (conditioned vs unconditioned space) along with 90% confidence intervals. The average UEF adjustment is similar and the confidence intervals are fully overlapping, indicating that the difference is not statistically significant.

Figure 4-3. Average UEF Adjustment Factor by Installation Location



Source: Guidehouse analysis

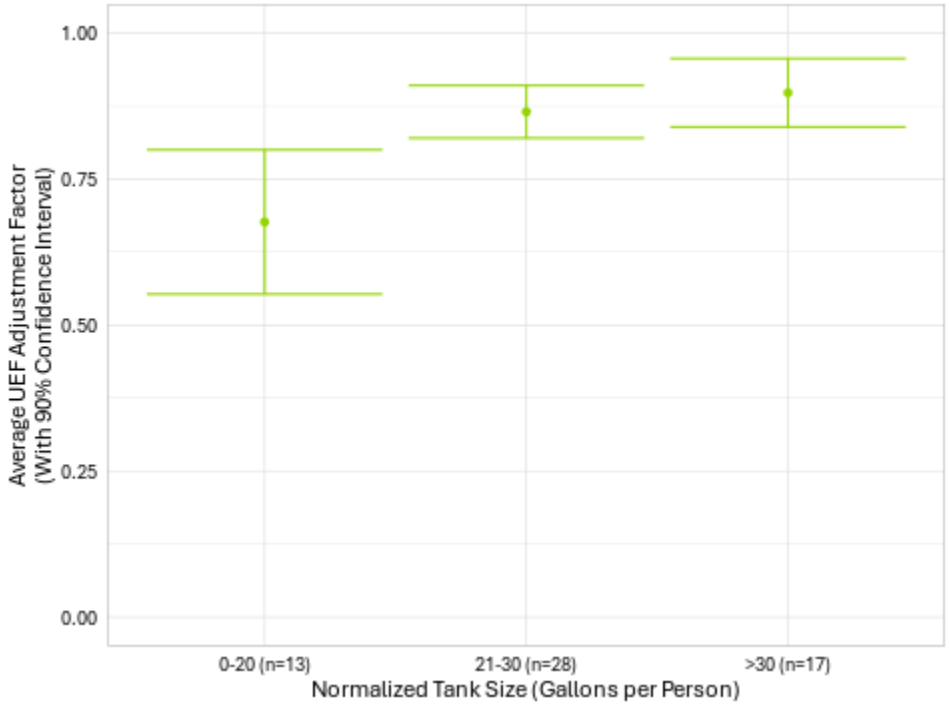
The team also explored whether installation in small spaces or the presence of nearby obstructions might be a driver. Based on installation photos, only one unit met these criteria, which was an insufficient sample size to assess their impact.

It is likely that the primary driver of mode-adjusted UEF was the operating mode selected by the customer rather than installation environment, since that directly determines which heating modes will be used. Based on the survey results, there are several likely reasons for customers choosing a less efficient mode:

- Lack of awareness of modes: 19% of customers surveyed said they were not aware that the HPWH had modes, and thus they were likely operating in the default mode or the one selected by the contractor.
- Insufficient hot water: the most likely reason for using a less efficient mode is the unit not meeting the hot water demand in heat pump mode. This could potentially be addressed by installing a larger unit, raising the water temperature setting, or both.

This study did not include a direct measurement of hot water usage, so the team used normalized tank size (gallons per occupant) as a proxy for exploring the impact of insufficient hot water on mode-adjusted UEF, since hot water usage is highly correlated with occupancy. Figure 4-4 below shows the average UEF adjustment by normalized tank size along with 90% confidence intervals. Homes with <= 20 gallons per person showed significantly lower adjusted UEF values on average, though there was a large spread in the individual values (which is reflected in the large confidence interval). This is consistent with the conclusion that insufficient hot water (and a resulting switch to a mode that allowed for electric resistance heating) was likely a driver of the mode-adjusted UEF.

Figure 4-4. Average UEF Adjustment Factor by Normalized Tank Size

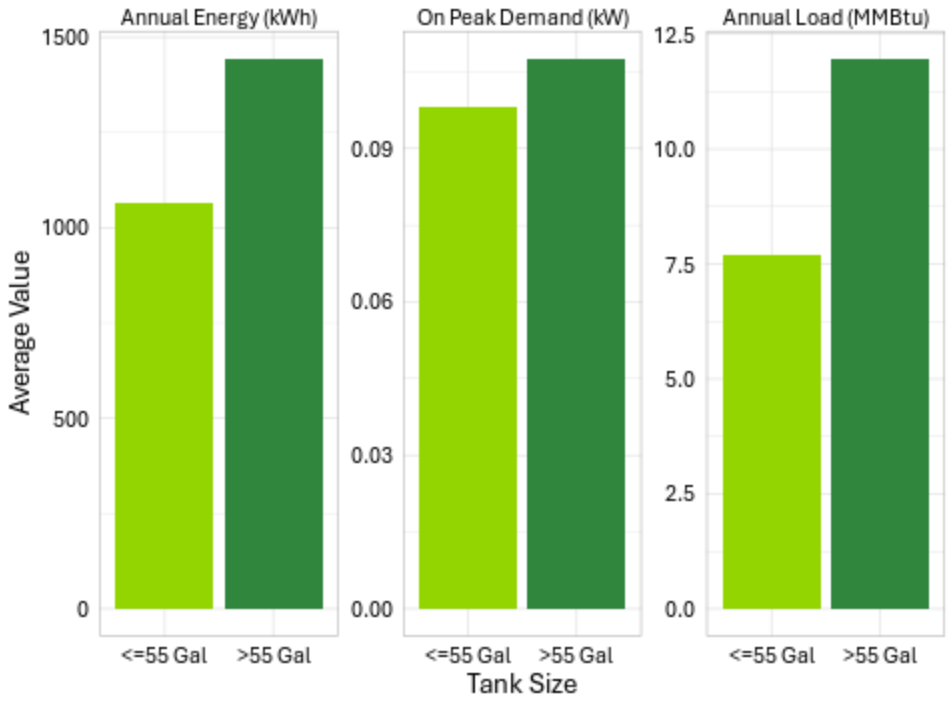


Source: Guidehouse analysis

4.2 Metered Energy, Peak Demand and Load

The team used the metered data to estimate typical year annual energy consumption, peak demand, and water heating load associated with HPWHs. Energy and peak demand were metered directly, while water heating load was estimated from annual energy by converting using the mode-adjusted UEF values. Figure 4-5 shows average energy, peak demand and load by water heater tank size. >55 gallon units had 36% higher energy consumption, 10% higher peak demand, and 56% higher load on average than ≤55 gallon units.

Figure 4-5. Metered HPWH Energy, Peak Demand and Load



Source: Guidehouse analysis

5. Measure Impacts

The team used the results of the survey and metering analyses to develop updated measure impacts for residential HPWHs, with the goal of ensuring savings estimates reflect real-world HPWH operation in Massachusetts homes. The first section presents baseline and energy efficient water heater consumption, with following sections showing the measure impacts results, which are presented separately for water heating savings, secondary impacts on heating and dehumidification, and total savings.

5.1 Baseline and Efficient Water Heating Energy Usage

Table 5-1 below shows the water heating load and efficiency values used in the analysis alongside the calculated electric and fuel usage values for the baseline and energy efficient (EE) cases.

Table 5-1. Water Heating Loads, Efficiencies, and Usage

Measure Name	Water Heating Load (MMBtu)	Baseline Efficiency (UEF)	EE Efficiency (UEF)[12]	Baseline Electricity Usage (kWh)	EE Electricity Usage (kWh)	Electricity Savings (kWh)	Baseline Fuel Usage (MMBtu)	EE Fuel Usage (MMBtu)	Fuel Savings (MMBtu)
≤55 Gal HPWH Replacing Electric Water Heater	8.1	1.02	2.95	2309	801	1508	0	0	0
>55 Gal HPWH Replacing Electric Water Heater	12.6	1.02	3.01	4446	1223	3223	0	0	0
≤55 Gal HPWH Replacing Gas Water Heater	12.6	0.67	2.95	41	1256	-1214	19.0	0	19.0
>55 Gal HPWH Replacing Gas Water Heater	19.7	0.67	3.01	64	1917	-1852	29.6	0	29.6
≤55 Gal HPWH Replacing Propane Water Heater	12.5	0.74	2.95	41	1239	-1198	16.9	0	16.9
>55 Gal HPWH Replacing Propane Water Heater	19.4	0.74	3.01	64	1891	-1827	26.3	0	26.3
≤55 Gal HPWH Replacing Oil Water Heater	14.3	0.71	2.95	41	1420	-1379	20.1	0	20.1
>55 Gal HPWH Replacing Oil Water Heater	22.3	0.71	3.01	64	2167	-2103	31.3	0	31.3

[12] Includes HP UEF adjustment factor of 0.81

5.2 Water Heating Savings

Table 5-2 shows the water heating savings from HPWHs. Electricity savings are negative for measures with a fuel-fired baseline water heater, since in those cases the baseline water heater used very little electricity. The savings values are significantly higher for the measures with the larger tank size, due mostly to the underlying hot water load being higher for those homes on average.

Table 5-2. Water Heating Savings[13]

Measure Name	Electricity Savings (kWh)	Peak Demand Savings (kW)	Natural Gas Savings (MMBtu)	Propane Savings (MMBtu)	Fuel Oil Savings (MMBtu)
≤55 Gal HPWH Replacing Electric Water Heater	1508	0.12	0	0	0
>55 Gal HPWH Replacing Electric Water Heater	3223	0.25	0	0	0
≤55 Gal HPWH Replacing Gas Water Heater	-1214	-0.08	19.0	0	0
>55 Gal HPWH Replacing Gas Water Heater	-1852	-0.12	29.6	0	0
≤55 Gal HPWH Replacing Propane Water Heater	-1198	-0.08	0	16.9	0
>55 Gal HPWH Replacing Propane Water Heater	-1827	-0.12	0	26.3	0
≤55 Gal HPWH Replacing Oil Water Heater	-1379	-0.09	0	0	20.1
>55 Gal HPWH Replacing Oil Water Heater	-2103	-0.14	0	0	31.3

Source: Guidehouse analysis.

[13] Note that it is only appropriate to apply the savings for the larger tank size to cases where a home has a larger hot water load to begin with, and thus program teams should take care to design programs to use the appropriate savings (e.g. based on baseline water heater tank size).

5.3 Heating and Dehumidification Secondary Impacts

During standard operation, a HPWH also removes heat and moisture from the space in which it is installed. These secondary impacts on heating and dehumidification energy consumption are shown in Table 5-3. The savings values shown are a combination of positive savings from reduced dehumidifier use (scaled by the proportion of homes which had dehumidifiers in the same space as the HPWH) and a heating penalty (negative savings) from the increased heating load (scaled by the proportion of HPWHs installed in conditioned space). Heating type proportions were determined based on the survey results, with measures with a fuel-fired baseline water heater having a mix of the baseline fuel and heat pump heat and the electric baseline having a blend of all heating types (and thus having heating penalties for each fuel type).

Table 5-3. Heating and Dehumidification Secondary Impacts[14]

Measure Name	Electricity Savings (kWh)	Peak Demand Savings (kW)	Natural Gas Savings (MMBtu)	Propane Savings (MMBtu)	Fuel Oil Savings (MMBtu)
≤55 Gal HPWH Replacing Electric Water Heater	-8.8	-0.001	-0.06	-0.01	-0.13
>55 Gal HPWH Replacing Electric Water Heater	-37.7	-0.003	-0.10	-0.01	-0.20
≤55 Gal HPWH Replacing Gas Water Heater	-39.2	-0.003	-0.31	0	0
>55 Gal HPWH Replacing Gas Water Heater	-84.0	-0.006	-0.48	0	0
≤55 Gal HPWH Replacing Propane Water Heater	-56.8	-0.004	0	-0.21	0
>55 Gal HPWH Replacing Propane Water Heater	-110.9	-0.008	0	-0.32	0
≤55 Gal HPWH Replacing Oil Water Heater	-77.9	-0.005	0	0	-0.20
>55 Gal HPWH Replacing Oil Water Heater	-143.2	-0.010	0	0	-0.31

Source: Guidehouse analysis

[14] Dehumidification savings was 46 kWh for all measures. The secondary impacts from heating alone can be determined by adding this value to the electricity savings in the table above.

5.4 Total Savings

Table 5-4 shows total savings, including both water heating and secondary impacts.

Table 5-4. Total Savings

Measure Name	Electricity Savings (kWh)	Peak Demand Savings (kW)	Natural Gas Savings (MMBtu)	Propane Savings (MMBtu)	Fuel Oil Savings (MMBtu)
≤55 Gal HPWH Replacing Electric Water Heater	1499	0.12	-0.06	-0.01	-0.13
>55 Gal HPWH Replacing Electric Water Heater	3186	0.25	-0.10	-0.01	-0.20
≤55 Gal HPWH Replacing Gas Water Heater	-1254	-0.08	18.7	0	0
>55 Gal HPWH Replacing Gas Water Heater	-1936	-0.13	29.1	0	0
≤55 Gal HPWH Replacing Propane Water Heater	-1254	-0.08	0	16.7	0
>55 Gal HPWH Replacing Propane Water Heater	-1938	-0.13	0	26.0	0
≤55 Gal HPWH Replacing Oil Water Heater	-1457	-0.10	0	0	19.8
>55 Gal HPWH Replacing Oil Water Heater	-2246	-0.15	0	0	31.0

Source: Guidehouse analysis

6. Overall Conclusions and Considerations

Conclusion: Mode-adjusted HPWH efficiency is lower than rated efficiency due to electric resistance operation.

Metered units showed moderate electric resistance heat usage, which reduced the efficiency by roughly 20% on average from the rated efficiency. Survey responses corroborated this in that HPWHs operate primarily in heat pump mode (54% of the time), but a substantial portion (37%) of operation occurred in hybrid mode, which automatically engages electric resistance heating under certain conditions. This intermittent electric resistance operation—largely driven by automatic system controls rather than sustained use of electric/heater mode (3% of the time)—reduces overall efficiency relative to rating efficiencies that are based primarily on heat pump operation.

> **Consideration:** Adopt the updated savings values from this study, which include an UEF adjustment of 0.81, in TRM calculations.

Conclusion: Tank sizing, temperature set point and operating mode choice all strongly influence HPWH performance and customer satisfaction.

Survey results show that insufficient hot water availability often leads customers to switch to higher-consumption modes, reducing HPWH efficiency. Appropriate tank sizing followed by clear guidance on HPWH modes and temperature settings can help households meet their hot water needs while minimizing electric resistance usage.

> **Considerations:**

- Provide standardized customer education on operational modes. Nearly 20% of customers surveyed were not aware that the HPWH had modes, which may have led to increased electric resistance operation in cases where the initial mode setting allowed for it.
- Encourage customers to try raising the temperature setpoint prior to switching operational modes. Avoid recommending electric resistance-dominant modes as the default solution for hot water shortages.
- When customers increase setpoints to improve hot water availability, advise pairing with installing a mixing valve for safety.
- Guide contractors to assess household hot water load and recommend tank sizes based on actual demand, avoiding blanket upsizing.

Conclusion: Homes with larger HPWHs have significantly higher water heating loads on average, but savings should only apply when larger loads truly exist.

Metering results confirm that homes with >55-gallon HPWHs have substantially higher water heating loads (approximately 56% higher on average) resulting in proportionally higher savings. However, these findings reflect higher household hot water demand rather than an efficiency advantage of larger tanks themselves. Therefore, applying larger-tank savings universally could unintentionally incentivize installations of oversized units in homes that do not need them.

> **Consideration:** Use the tank-size–specific savings values from this study in TRM calculations only when a larger tank is justified by the home's actual hot water load or baseline tank size. Program teams should incorporate guidance for implementers that:
>
> - Larger tank savings are appropriate only in homes with higher demonstrated hot-water demand and larger units should not be installed solely to claim higher program savings, and
> - Program tracking should continue to record baseline tank size and baseline fuel type to support transparent review and accurate application of savings values.
>
> This approach ensures the TRM reflects true performance differences while avoiding unintended incentives for unnecessary upsizing.

Conclusion: Installation location did not significantly impact mode-adjusted performance.

Metering analysis showed no meaningful difference in mode-adjusted efficiency between units installed in conditioned versus unconditioned spaces. Average UEF adjustment factors were statistically indistinguishable across locations, indicating that installation environment was not a driver of performance variation in this study. That said, installation location likely impacts overall in-situ UEF, but it was outside of the scope of this study to quantify this impact.

> **Consideration:** No additional program guidance or eligibility criteria related to conditioned vs. unconditioned spaces is recommended based on this study. Focus should instead remain on sizing and operating practices, which were found to have far greater influence on efficiency and customer experience.

Conclusion: HPWHs reduce dehumidifier usage where units are co-located.

Survey data show 39% of homes have a dehumidifier in the same space; among them, 45% report running it less after HPWH installation. This study estimates an average dehumidification energy savings of about 17% in the homes where the HPWH and dehumidifier are in the same space.

> **Consideration:** Apply the secondary impacts from this study, which include dehumidification energy savings, in TRM calculations.

Conclusion: Overall HPWH satisfaction is high, though opportunities remain to improve satisfaction.

83% of customers surveyed indicated no concerns with the performance of their HPWH. Among those who were less satisfied, common concerns included installation costs, operating costs and hot water availability. The latter two concerns could be addressed by properly sizing units in order to meet the hot water load without using electric resistance mode operation, as discussed above.

Considerations:

- Programs should highlight positive customer experiences in outreach, marketing and contractor training materials to help build customer confidence, support adoption and reinforce the value of HPWH technologies.

- Encourage contractors to size HPWHs based on the hot water load of the home, installing units with larger tanks where appropriate to mitigate issues with hot water availability.

7. Study Limitations and Areas for Future Research

Though the data collected for this study provides valuable insight into the performance and energy savings of heat pump water heaters, further research is still needed to fully understand the real-world operation of HPWHs across a diverse population of customers. The following areas were not covered by this study and merit further research:

- **Mode-Adjusted Performance of Newer Units:** the metered data used in this study spanned from 2017 to 2024, and the metered units were manufactured between 2012 and 2022. The analysis did not show any correlation between year of manufacture and mode-adjusted efficiency, but further research exploring whether newer units have higher mode-adjusted efficiency could be useful.

- **Other Contributors to In-Situ Efficiency:** the UEF adjustment factor developed in this study is based solely on the proportion of operation in the various heating modes, and does not fully capture in-situ efficiency. While electric resistance operation is likely the largest driver of adjusted UEF, a more in-depth metering study which measures hot water load delivered as well as energy consumption would produce a more accurate estimate.

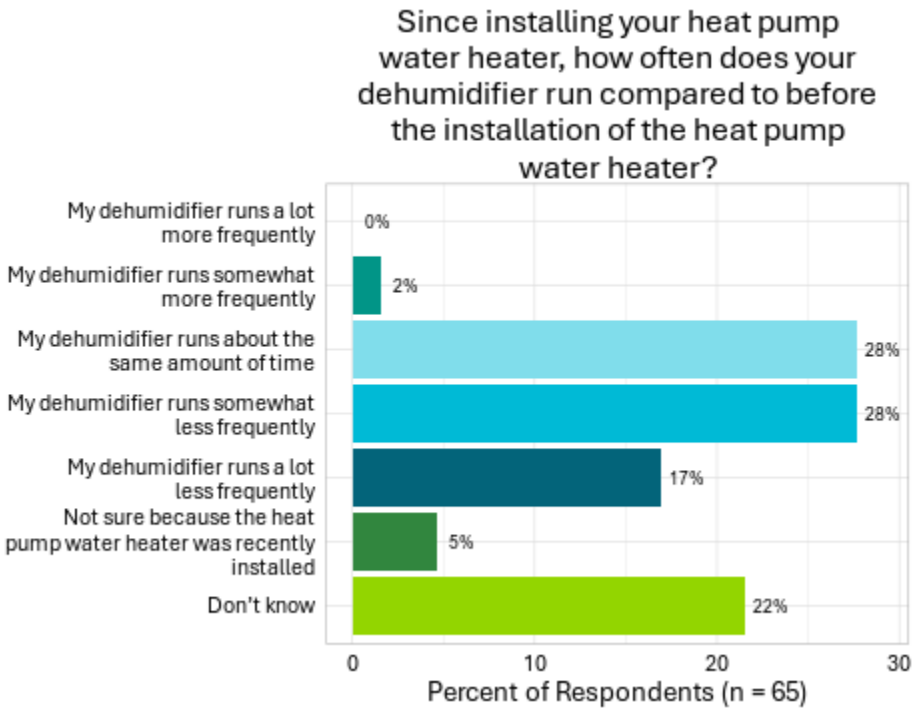
- **Performance of 120V HPWHs:** with the increasing emergence of 120V units in the market, additional monitoring is needed to determine whether these units have significant differences from 240V unit in in-situ performance and annual energy consumption.

- **Performance Across Customer Demographics:** this study did not differentiate results based on customer demographics. Future research could be beneficial in understanding if energy savings and customer experience differ for low-income households, renters, or other demographic groups of interest.

Appendix A.

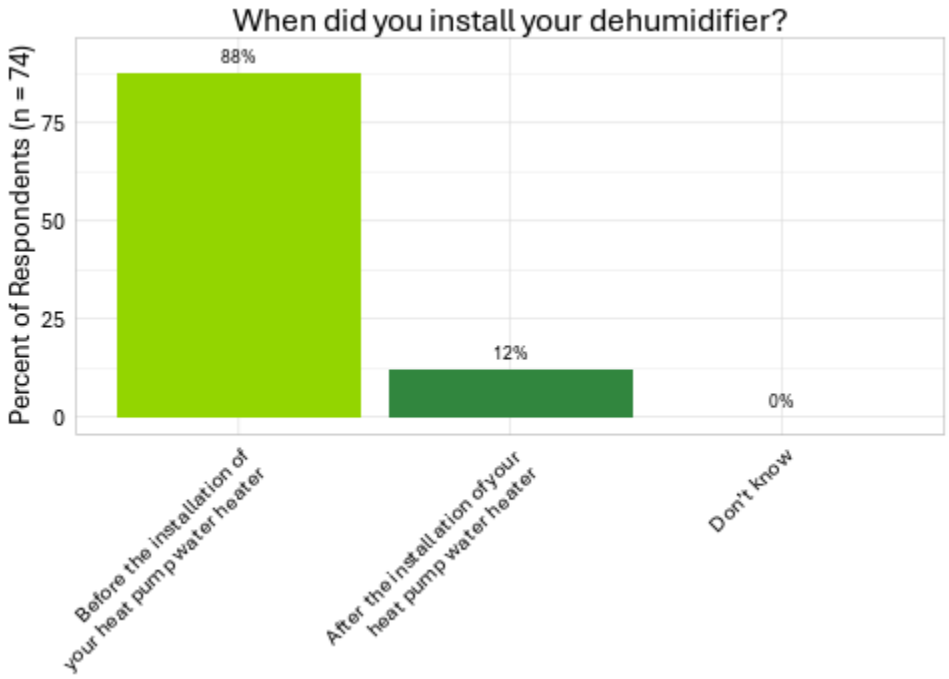
A.1 Additional Survey Analysis Plots

Figure A-1.



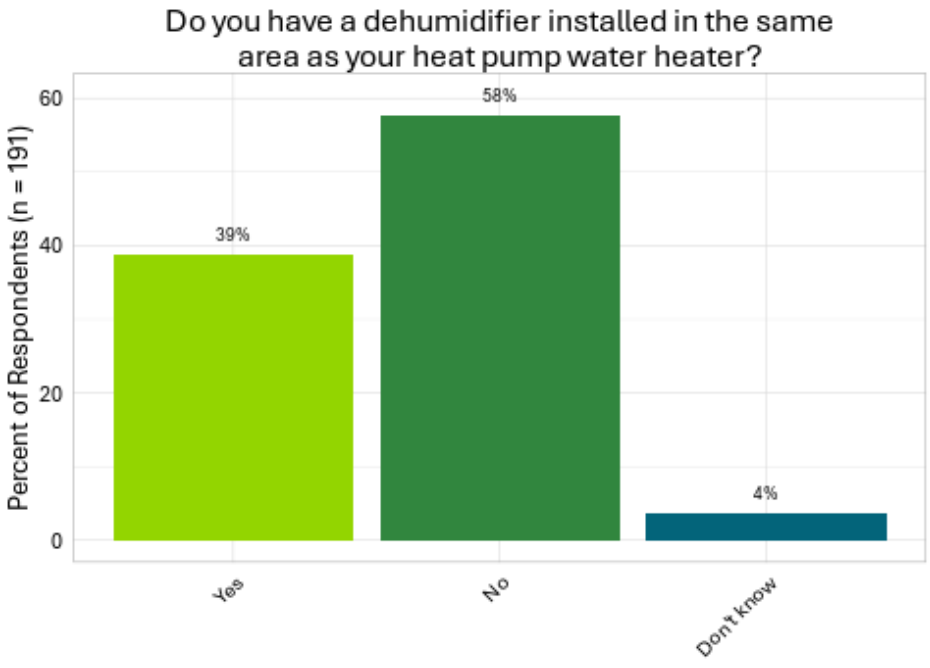
Source: Guidehouse analysis

Figure A-2.



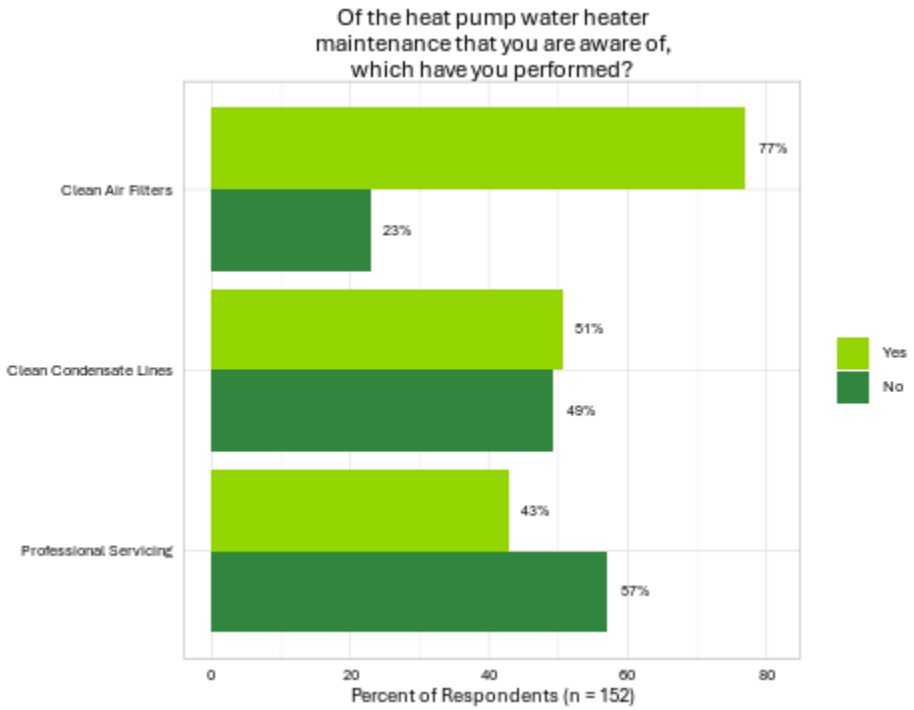
Source: Guidehouse analysis

Figure A-3.



Source: Guidehouse analysis

Figure A-4.



Source: Guidehouse analysis

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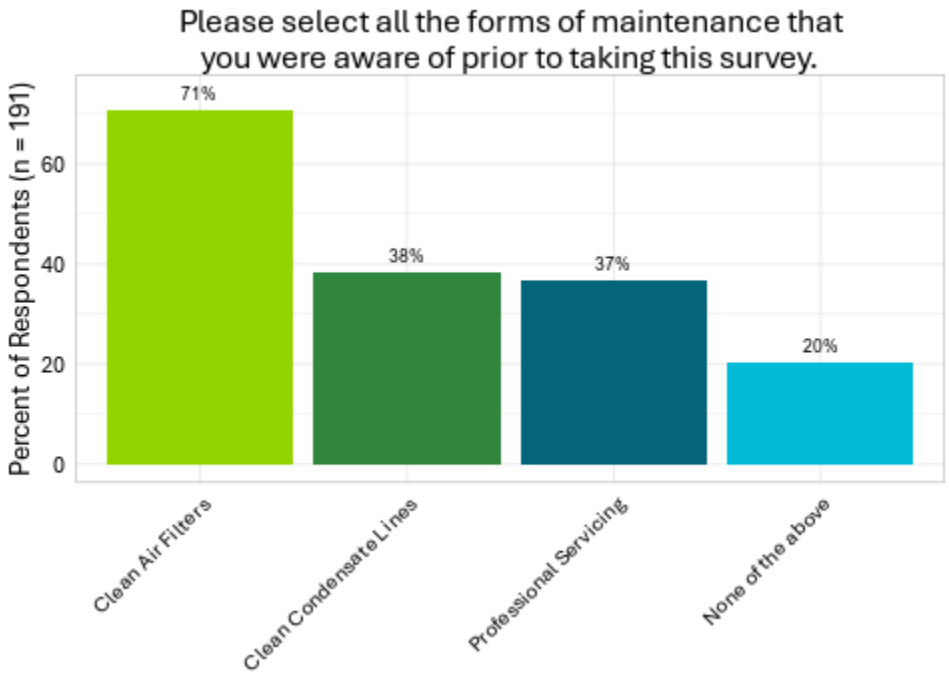

Source: Guidehouse analysis

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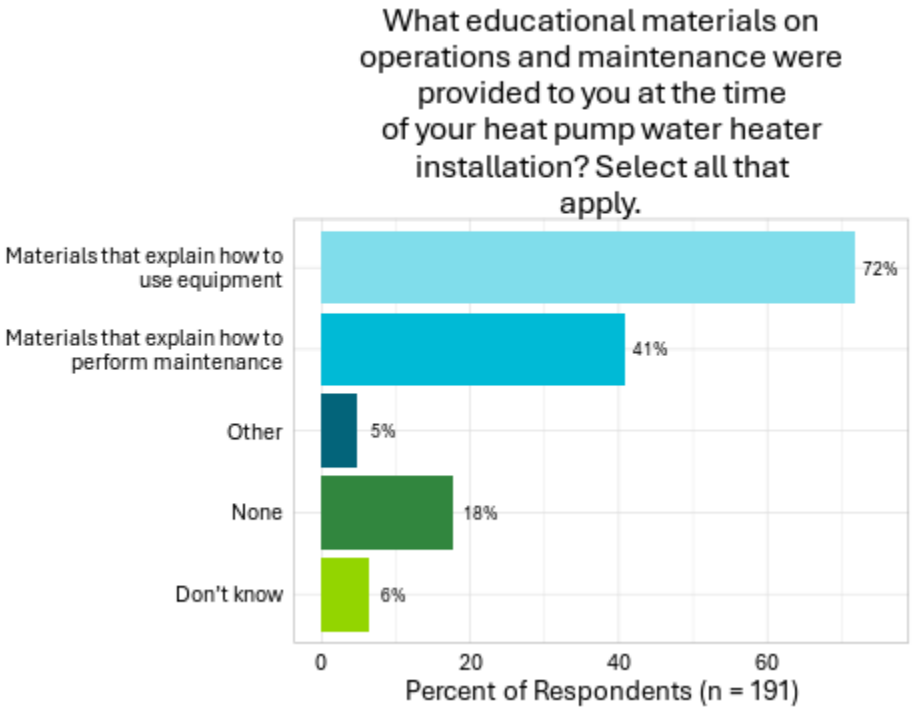

Source: Guidehouse analysis

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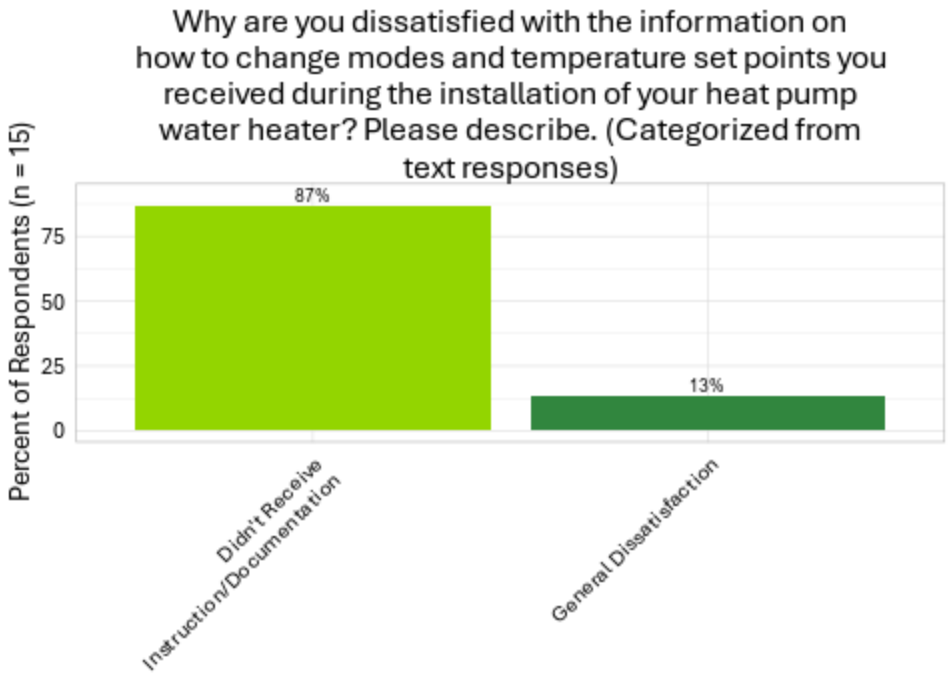

Source: Guidehouse analysis

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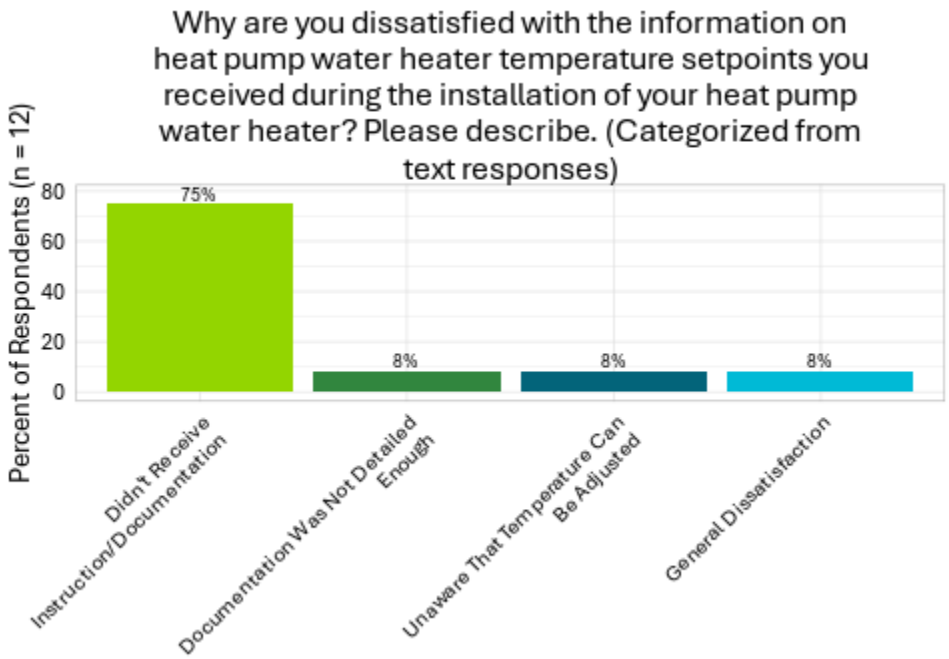

Source: Guidehouse analysis

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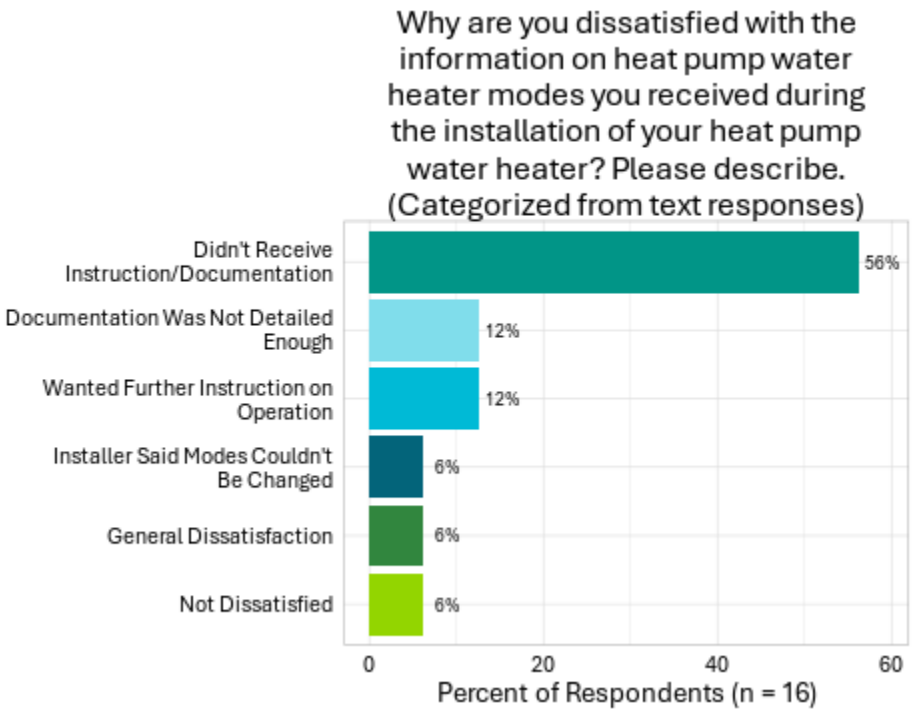

Source: Guidehouse analysis

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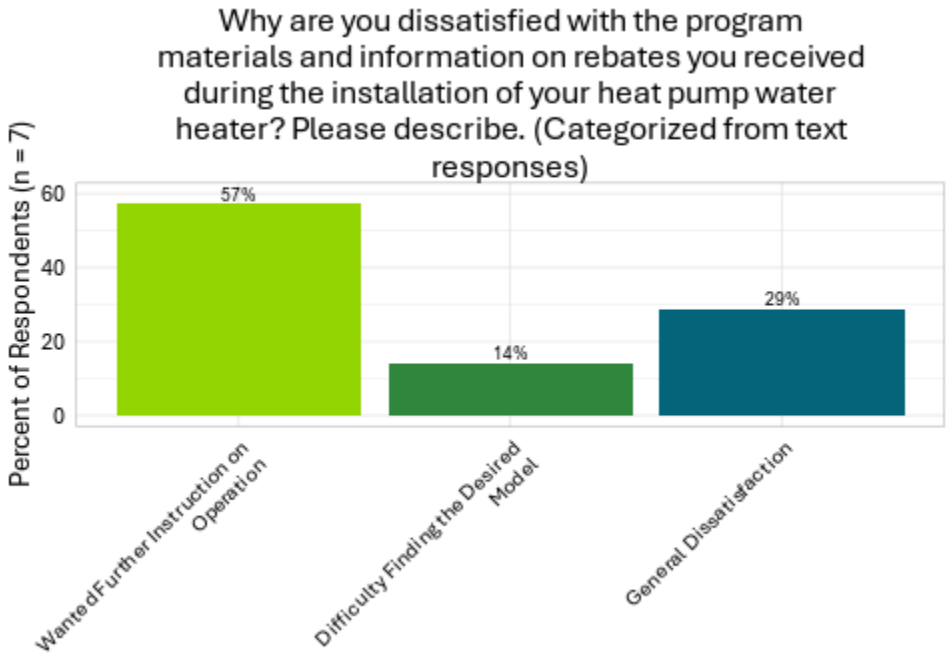

Source: Guidehouse analysis

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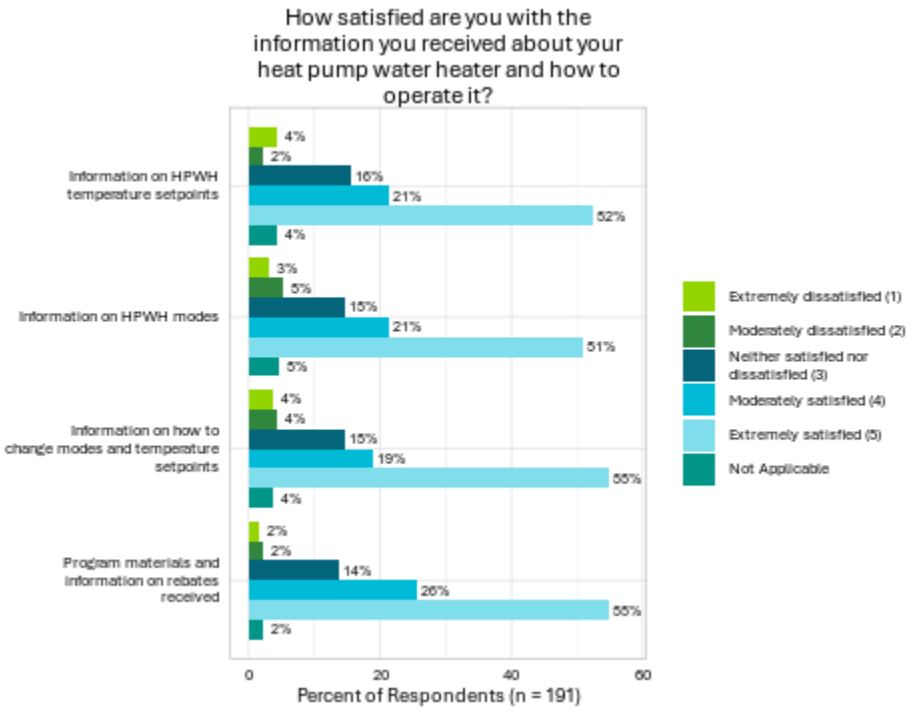

Source: Guidehouse analysis

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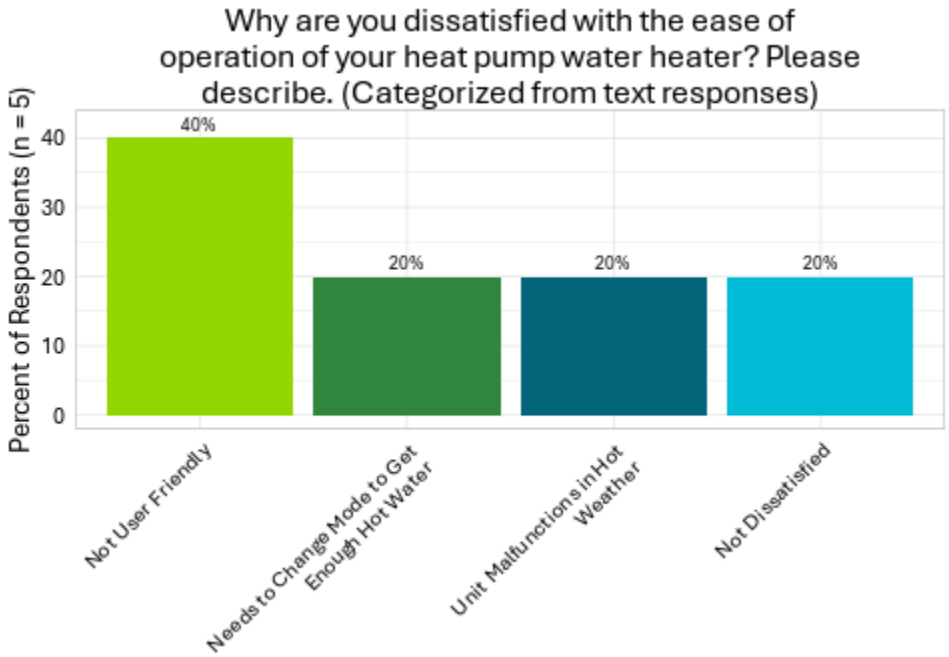

Source: Guidehouse analysis

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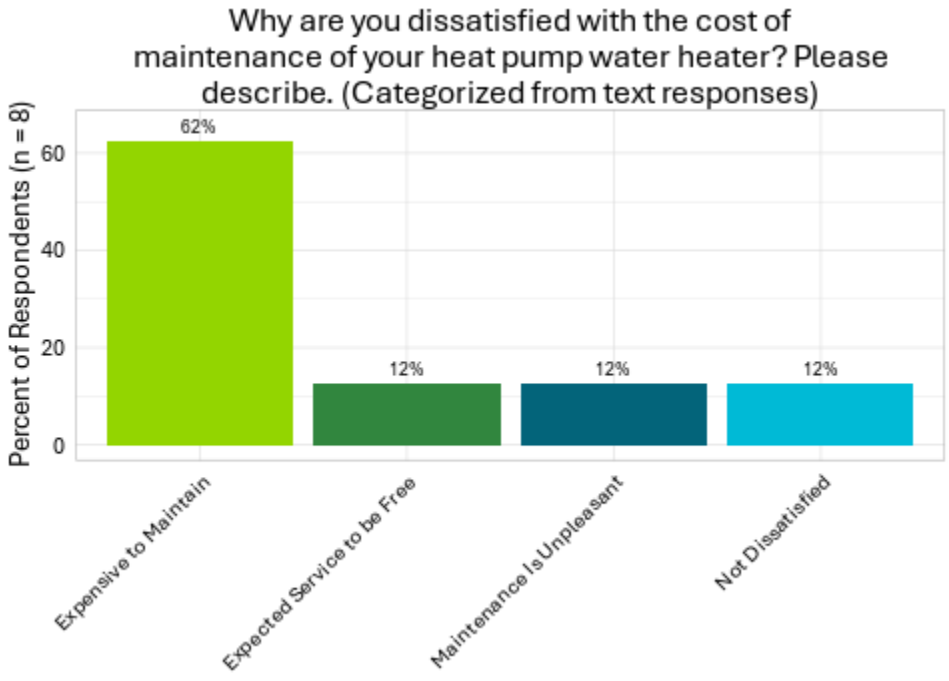

Source: Guidehouse analysis

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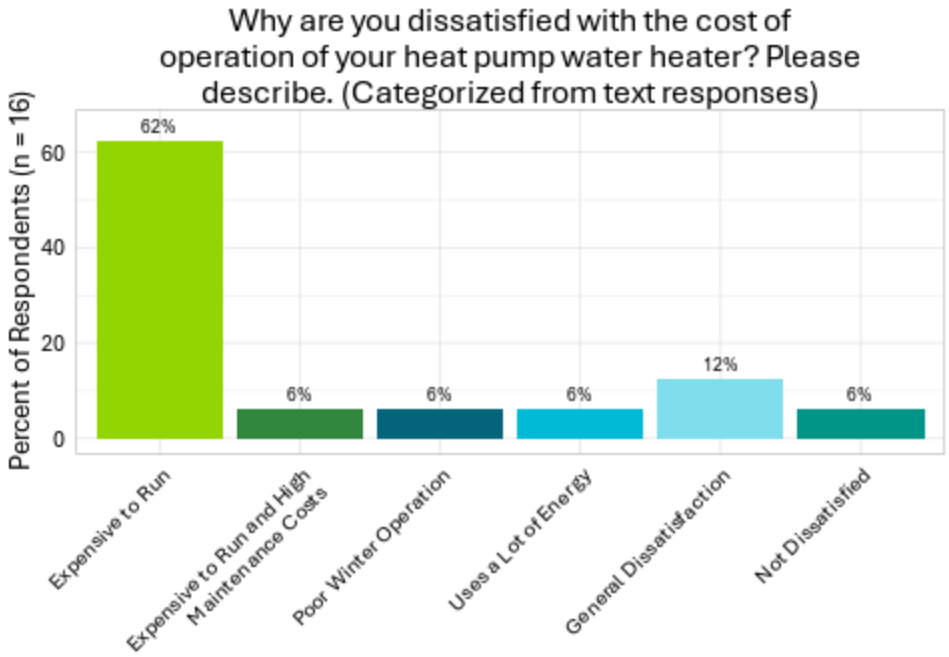

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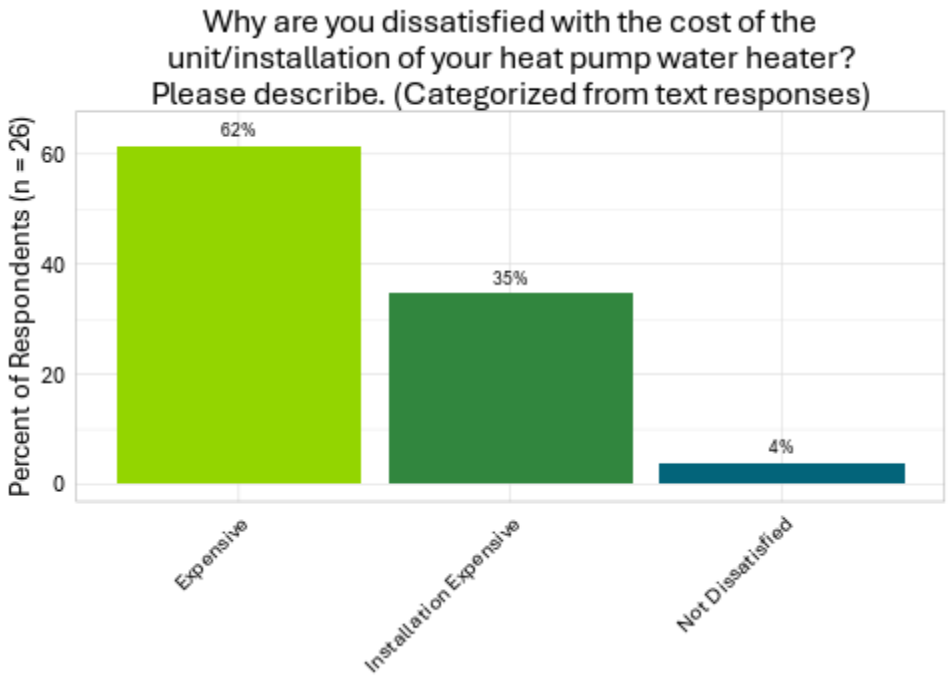

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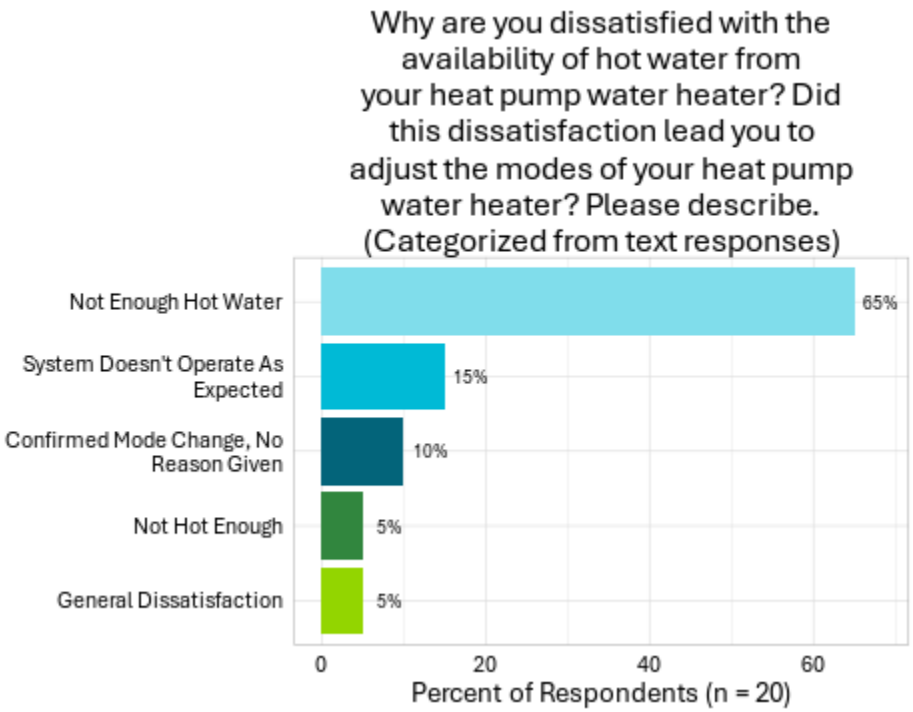

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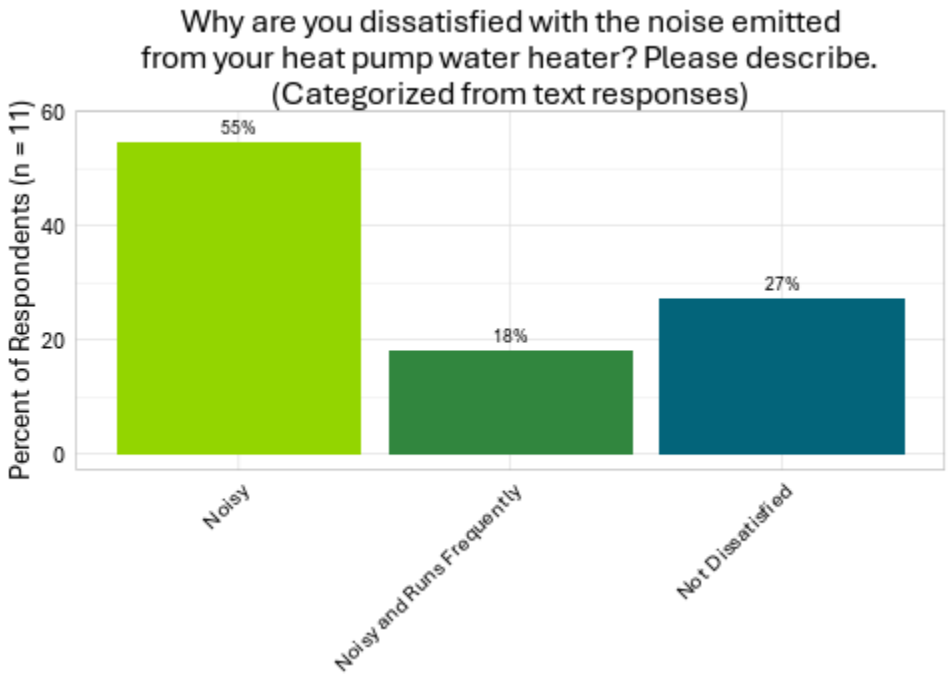

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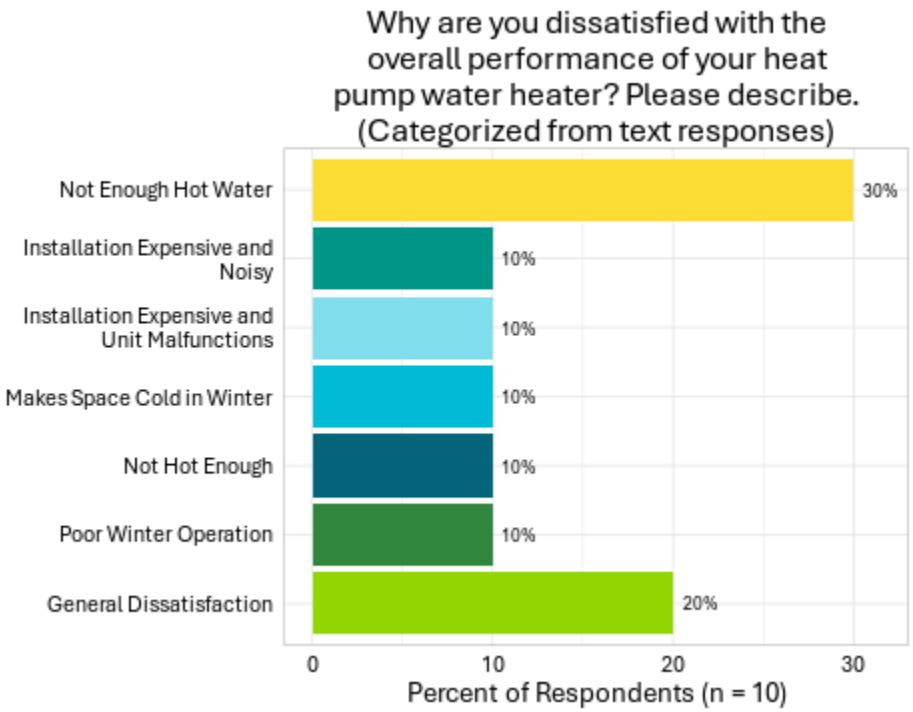

Source: Guidehouse analysis

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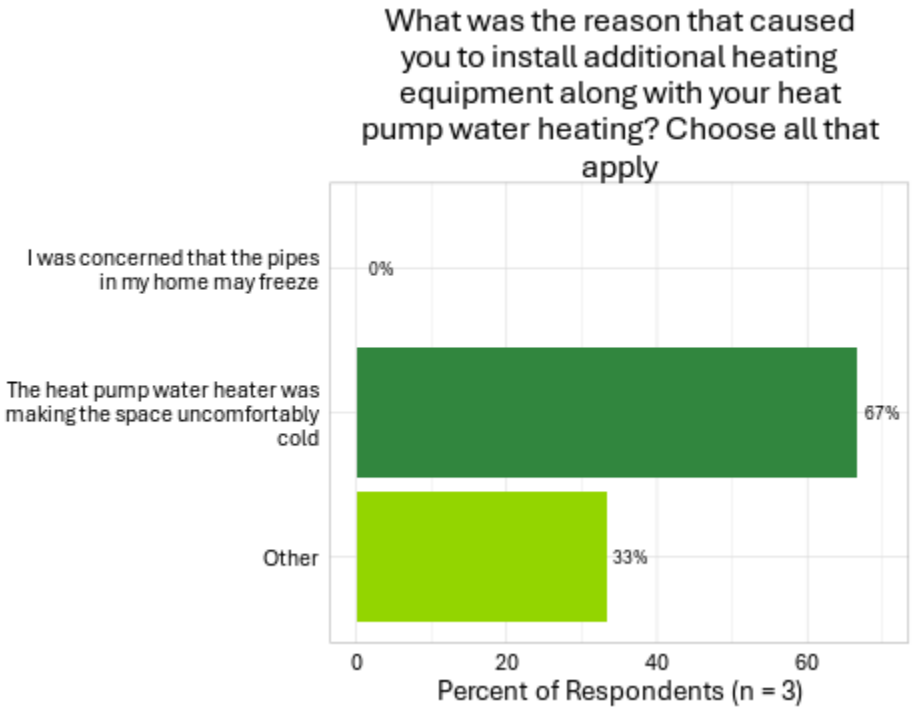

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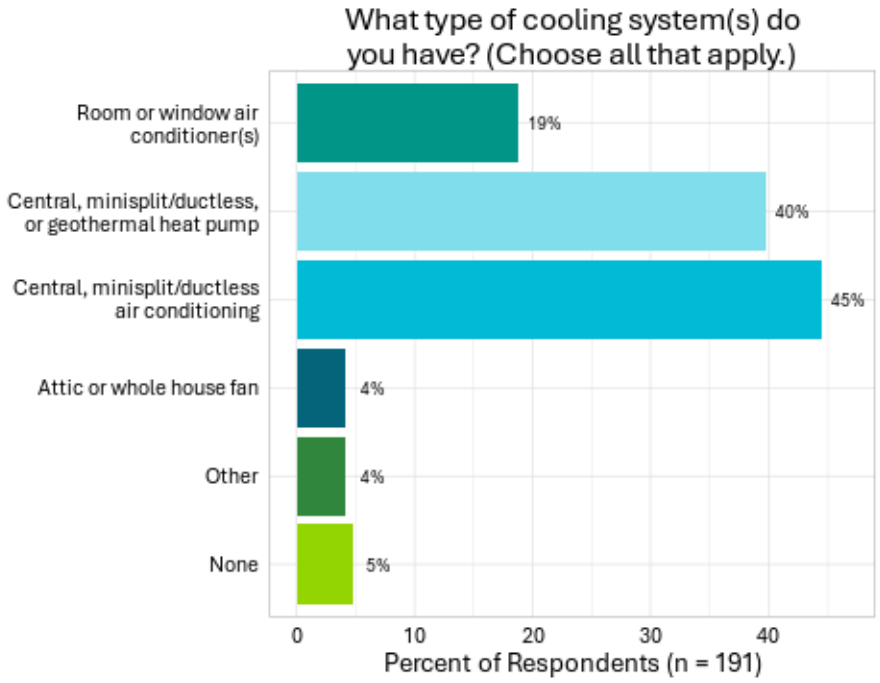

Source: Guidehouse analysis

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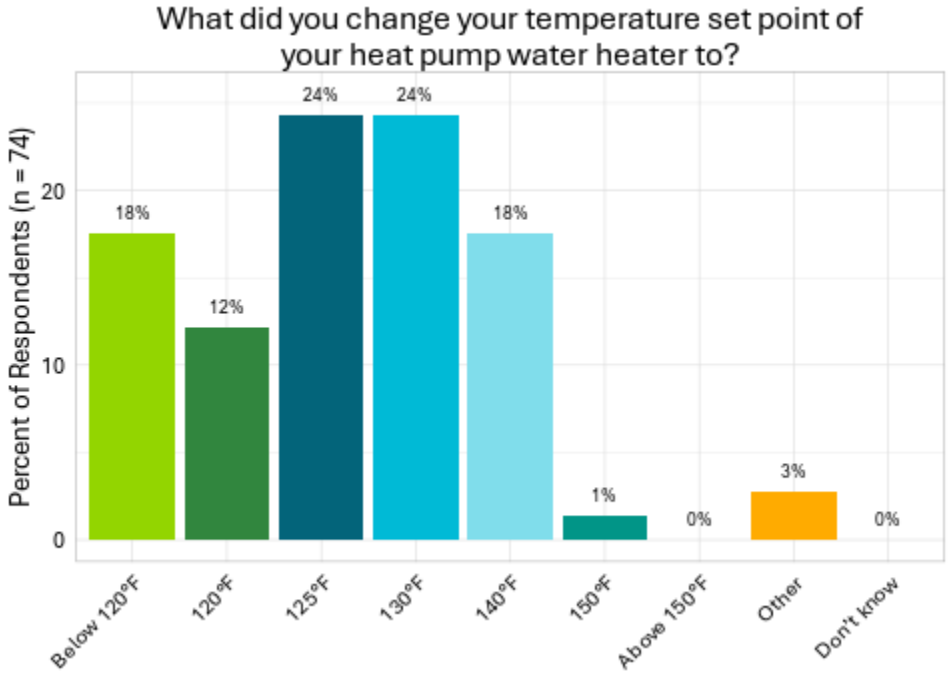

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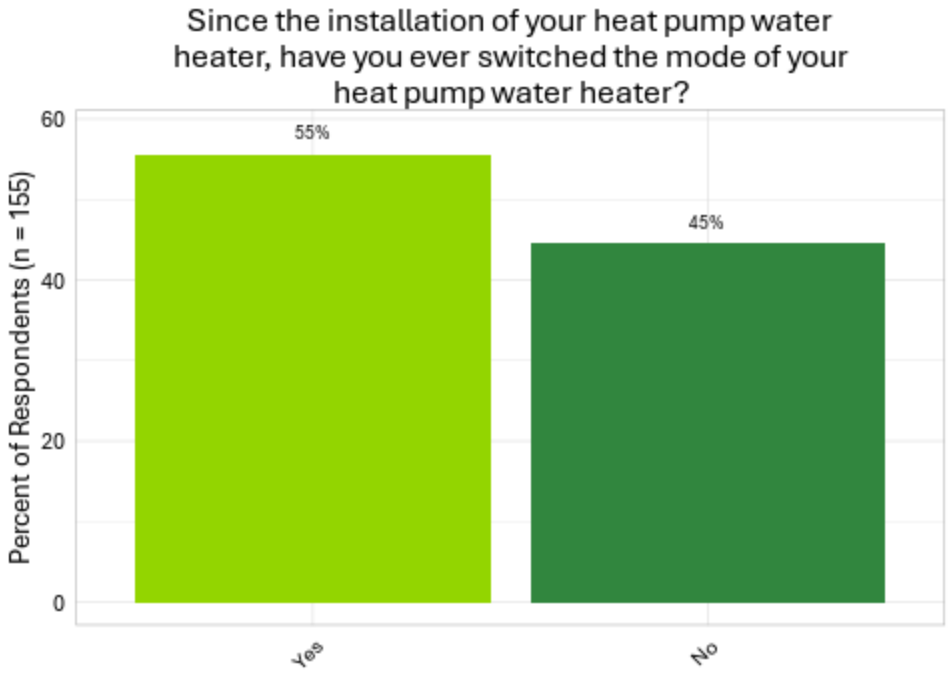

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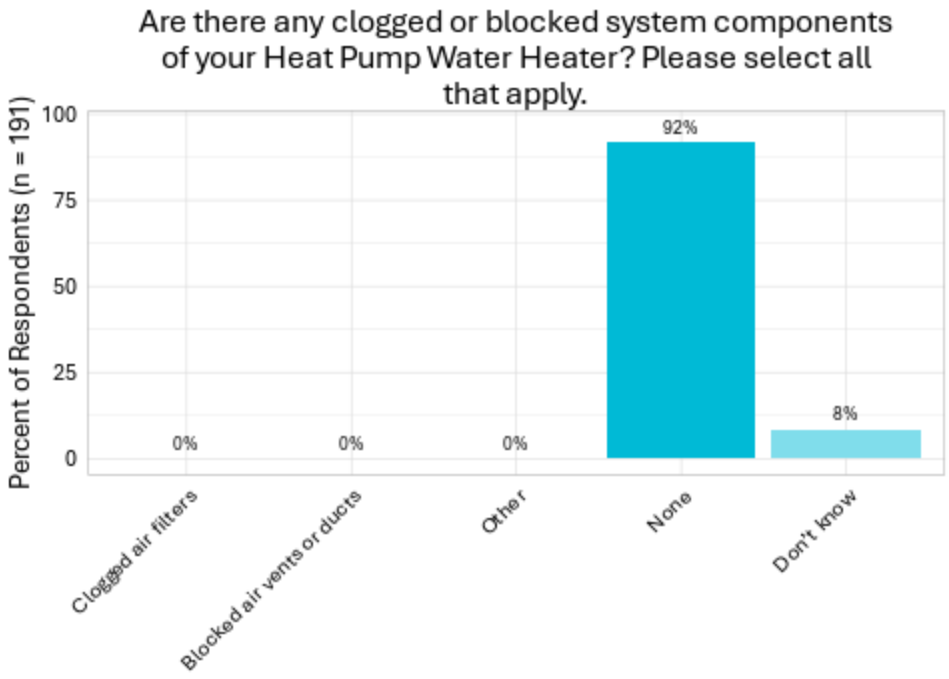

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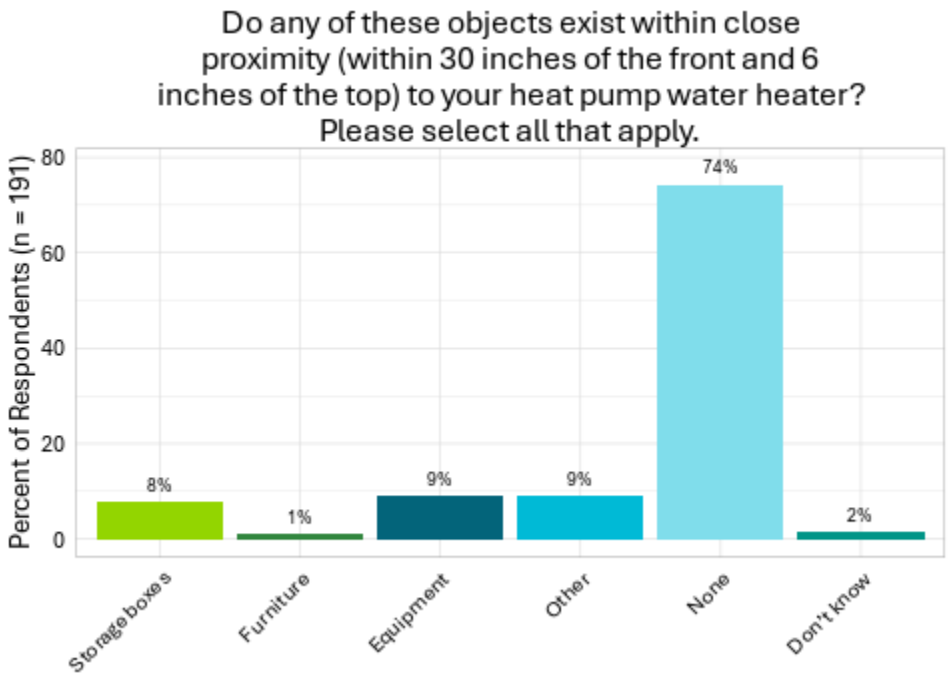

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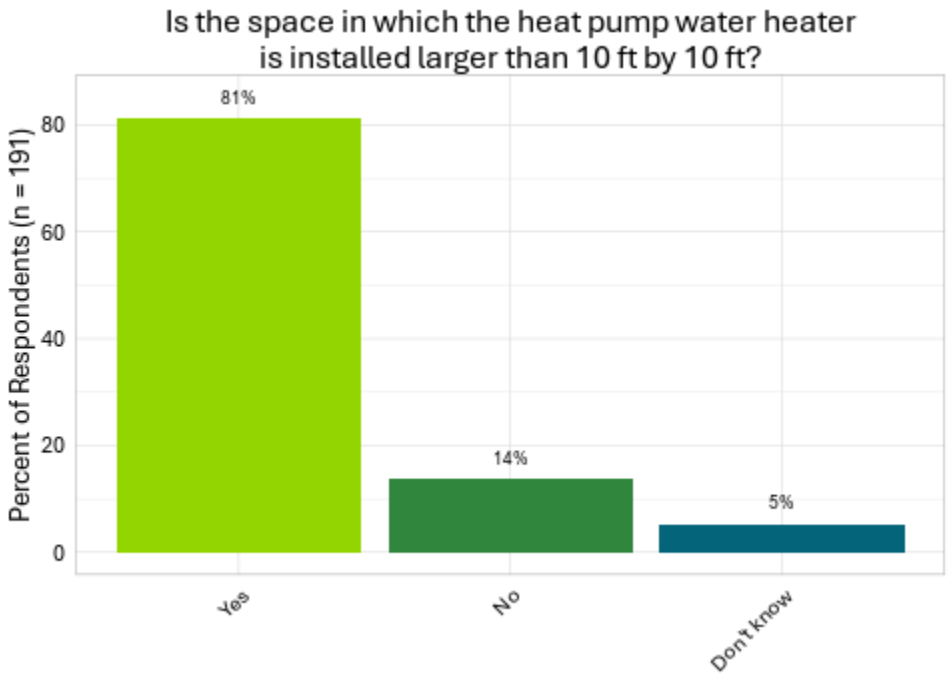

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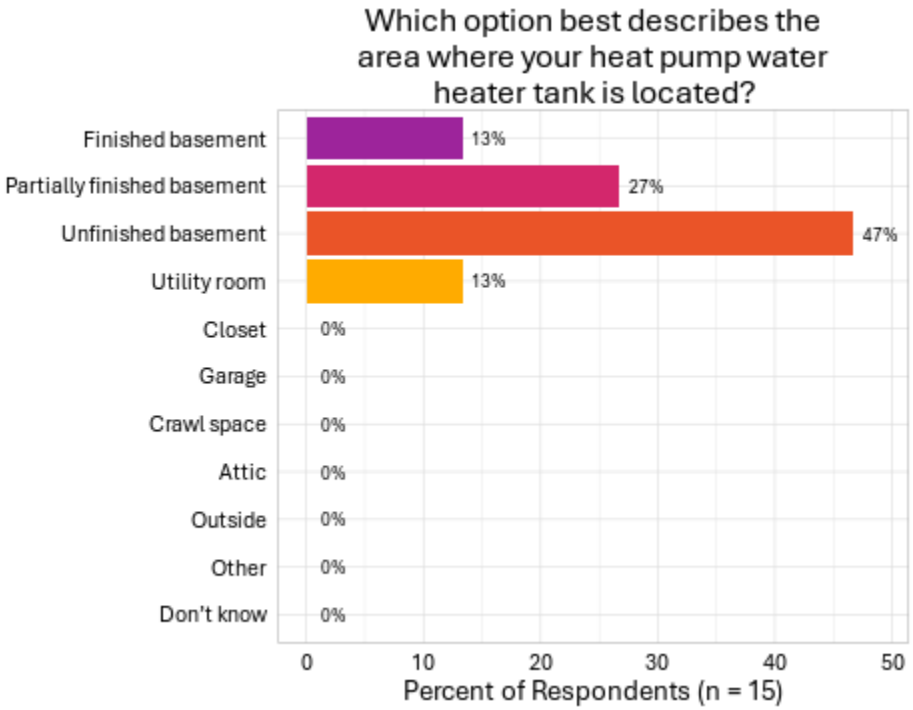

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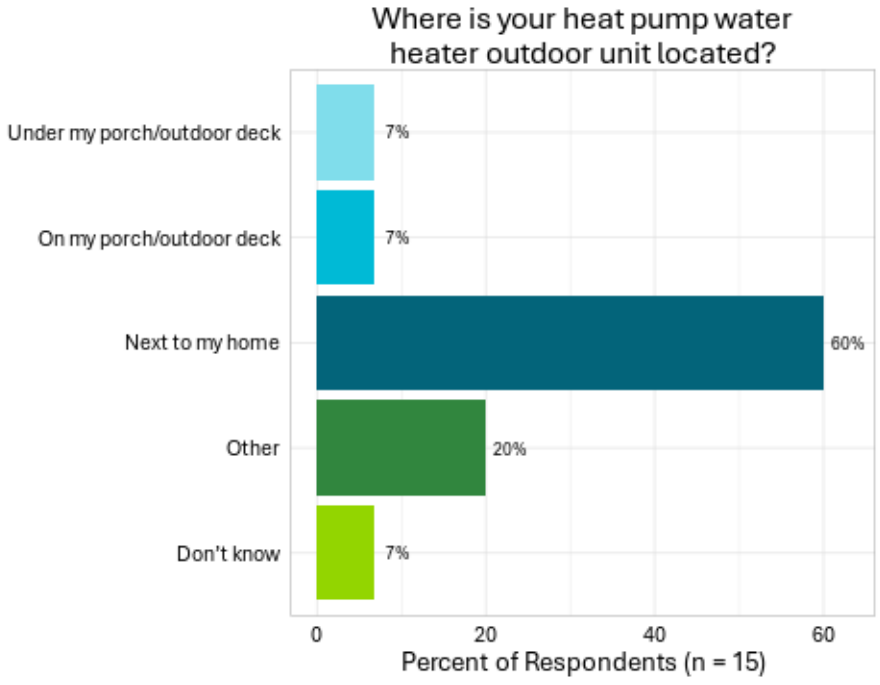

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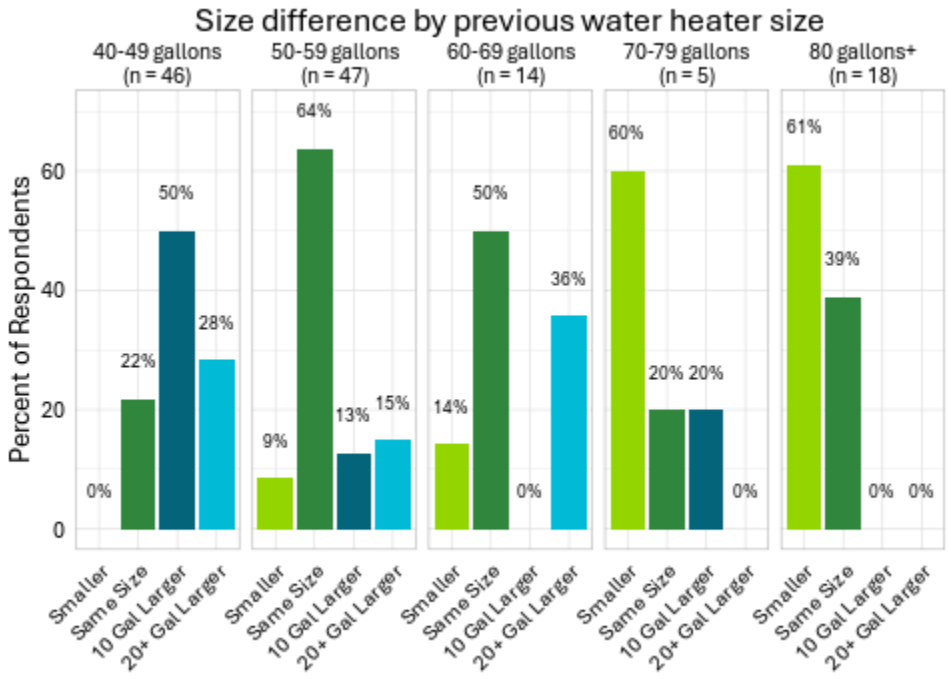

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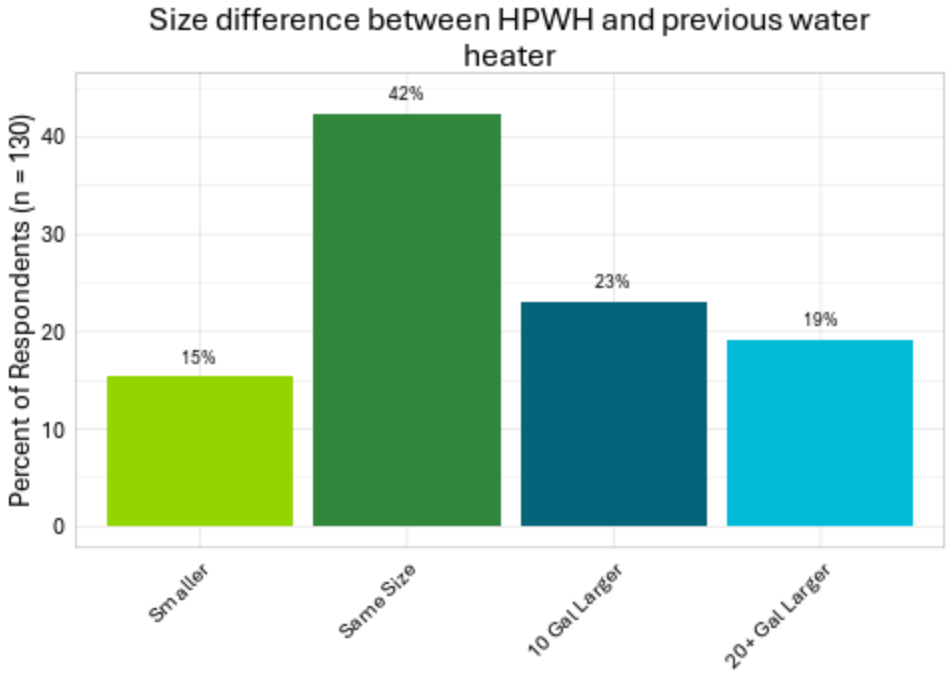

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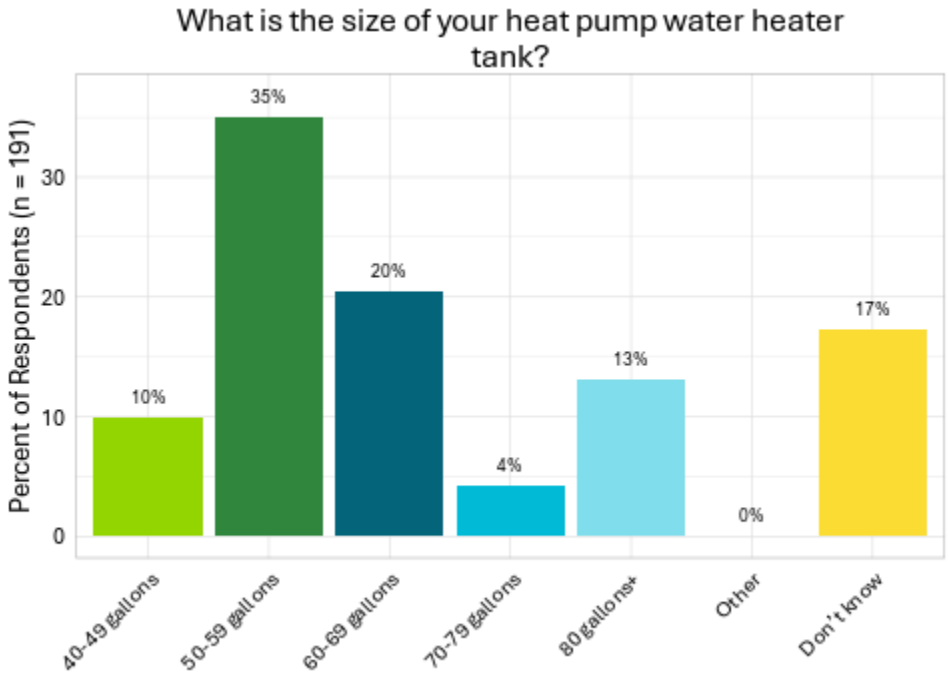

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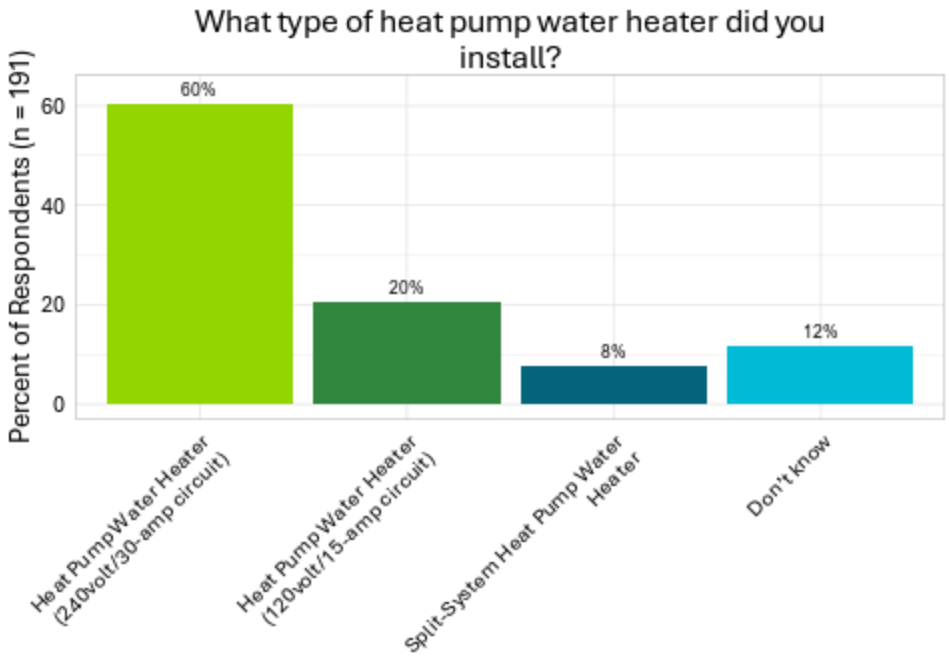

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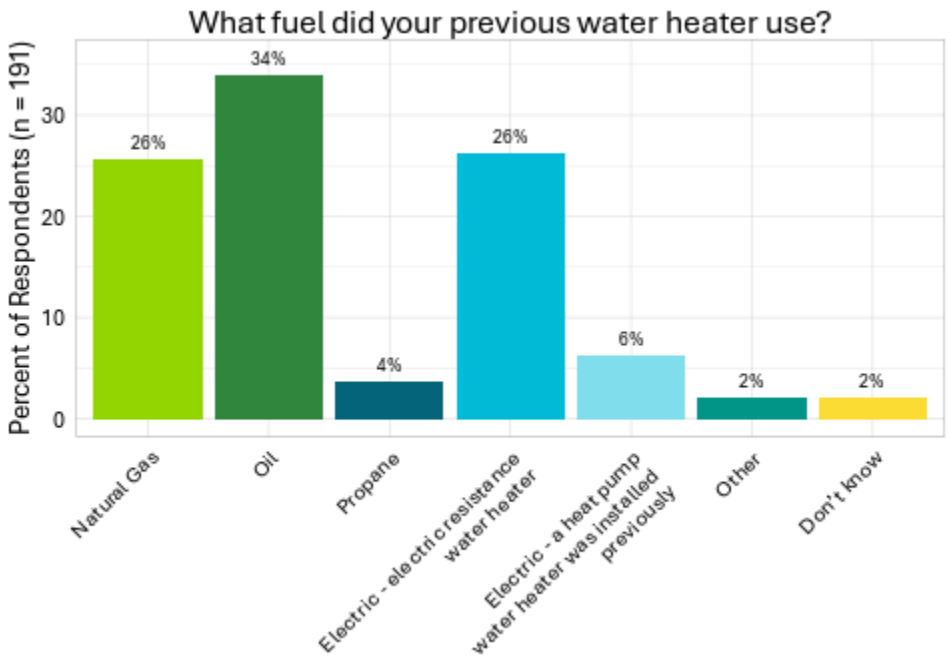

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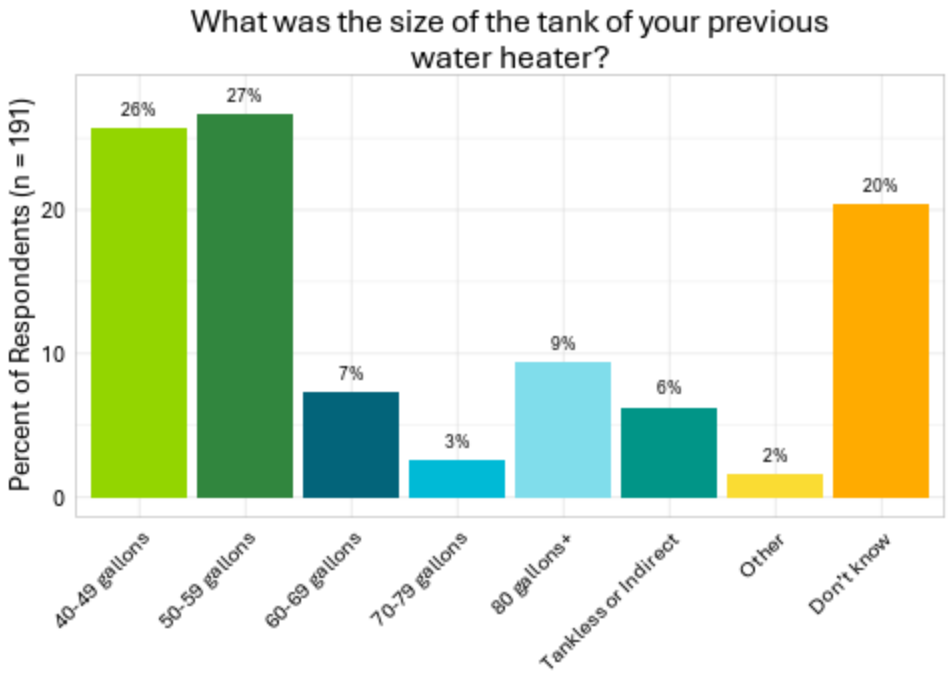

Source: Guidehouse analysis