To: Massachusetts Residential Program Administrators

From: Ryan Powanda, Presley Batchelor, Brian Barry; Guidehouse

Date: August 14, 2024

Re: Massachusetts Heat Pump Weatherization Usage Analysis (MA24R66-B)

Executive Summary

Guidehouse conducted this study to evaluate the relative usage, cost, and customer comfort for homes that weatherized or did not weatherize in conjunction with installing a heat pump through the Mass Save® heat pump program offerings. This study was conducted to answer research questions posed by the MA Department of Public Utilities (DPU)[1]. This study leverages data collection from the recently completed Heat Pump Metering Study (HPMS), a multi-state study conducted for the Massachusetts Program Administrators (PAs) and for the Sponsors of Energize Connecticut℠ (Energize CT). This study leverages the program data, customer survey, and onsite metering data collected as part of the HPMS to answer these additional research questions.

In the HPMS, heat pump usage data was collected at a total of 185 customer homes across Massachusetts and Connecticut and included metering of central heat pumps (CHPs), mini-split heat pumps (MSHPs), and ground source heat pumps (GSHPs), for both full displacement (FD) and partial displacement (PD) applications. Per the current Massachusetts program guidelines, sites are deemed to be weatherized if the home was built after the year 2000, if the homeowner completes a home energy audit through the Mass Save program offerings and completes recommended weatherization upgrades, or if the total cost of the recommended weatherization upgrades is below $1,000. For the purposes of this weatherization study analysis, homes in the HPMS onsite sample are tagged as having met this weatherization threshold if they were built after the year 2000, or if the customer indicates via their survey response that they had completed weatherization upgrades to their home through the Mass Save or Energize CT home energy audit programs.[2]

[1] DPU Question: "Prior to the end of the 2022-2024 Three-Year Plan term, the Program Administrators shall undertake an evaluation study comparing energy usage, costs, and comfort levels for customers that did and did not weatherize prior to or after heat pump installation. The evaluation study must include a discussion of comparative bill impacts for each case."

[2] Through discussions with the study sponsors, the team determined that the customer survey responses were adequate to tag customers as having completed home weatherization projects. The program data did not provide the weatherization completion status for all of the onsite sampled homes, however, there was a reasonable accuracy (match) between the program reported weatherization status and the customer reported weatherization status for the homes with complete records in both datasets.

This analysis aimed to explore the relationship between heat pump energy usage and home weatherization status and quantify the difference in average energy usage for heat pumps in homes that did and did not meet the weatherization threshold. To facilitate comparison, the study normalized the HPMS metered heat pump usage in two ways – both on a "per ton" basis, and a "per 1,000 square foot"[3] basis.

This HPMS metered usage analysis did not demonstrate statistically significant differences in normalized metered heat pump usage between homes that did and did not meet the weatherization threshold. Variability in site-level usage, combined with the low sample size for the non-weatherized homes, contributed to this uncertainty. Given this finding, the evaluation team recommends further research to quantify differences in average usage between weatherized and non-weatherized homes that install heat pumps. Calibration building simulation scenario analysis, or billing analysis, could be conducted to study these differences.

The team also used the results of the HPMS 2023-2024 end of (heating) season survey to assess customer comfort, cold day comfort, and any other customer feedback that may inform differences in average customer experience for homes that met or did not meet the weatherization threshold. There were no clear comfort trends for weatherized homes and non-weatherized based on the survey.

1. Weatherization Composition of the Onsight Sample

Weatherization can greatly reduce heat loss and save energy in homes and is implemented through adding more insulation to the home and conducting air sealing to reduce drafty air leaks. For the Mass Save program, weatherization modifications encompass the addition of attic insulation, wall insulation, and basement insulation to the home, as well as attic air sealing and exterior door weatherstripping. In 2022, the MA heat pump program offerings require that the home meet a weatherization threshold to be eligible for a Whole Home (full displacement) rebate for heat pumps.

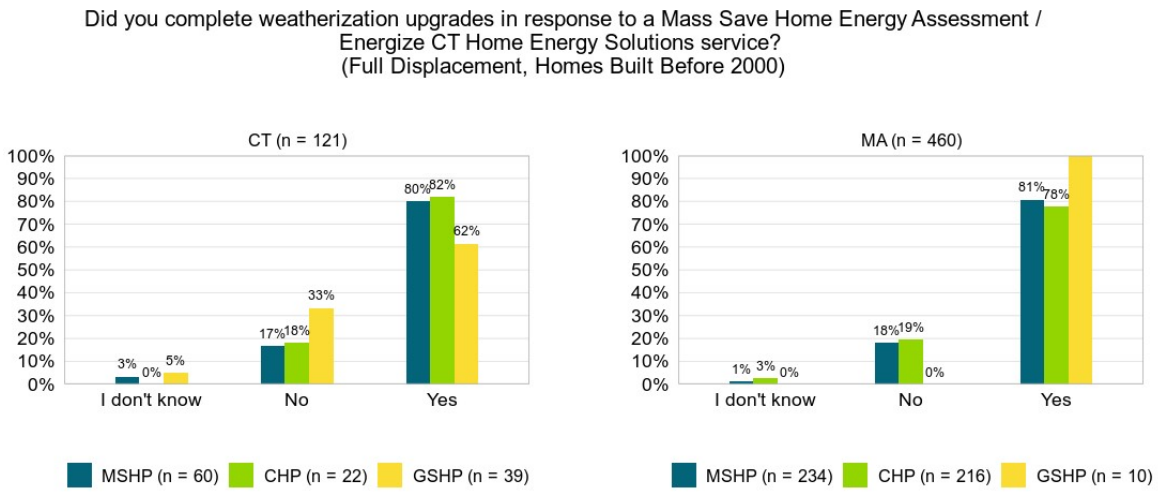
Sufficient weatherization for the program can be demonstrated by satisfying at least one of the following requirements: (A) the home was built during or after 2000, (B) the Home Energy Assessment report indicates less than $1,000 worth of weatherization recommended, or (C) weatherization recommendations made during or after 2013 have been completed. This study examined full displacement and partial displacement heat pump performance across 185 sites in Massachusetts and Connecticut. Sites in this study were flagged as being weatherized if they were either built during or after the year 2000, or if the homeowner indicated that they had completed weatherization upgrades in their response to the customer survey.

In the customer survey, respondents were asked if they completed weatherization upgrades, such as air sealing (i.e., weather stripping) or additional insulation in response to a Mass Save Home Energy Assessment / Energize CT Home Energy Solutions service. The results for homes built prior to 2000 are displayed in Figure 1 for full displacement sites. The

[3] The total home square footage was self-reported by participants.

majority of customers, with homes built prior to 2000, who completed a full displacement installation indicated completing home weatherization upgrades in response to a Mass Save Home Energy Assessment or Energize CT Home Energy Solutions service.

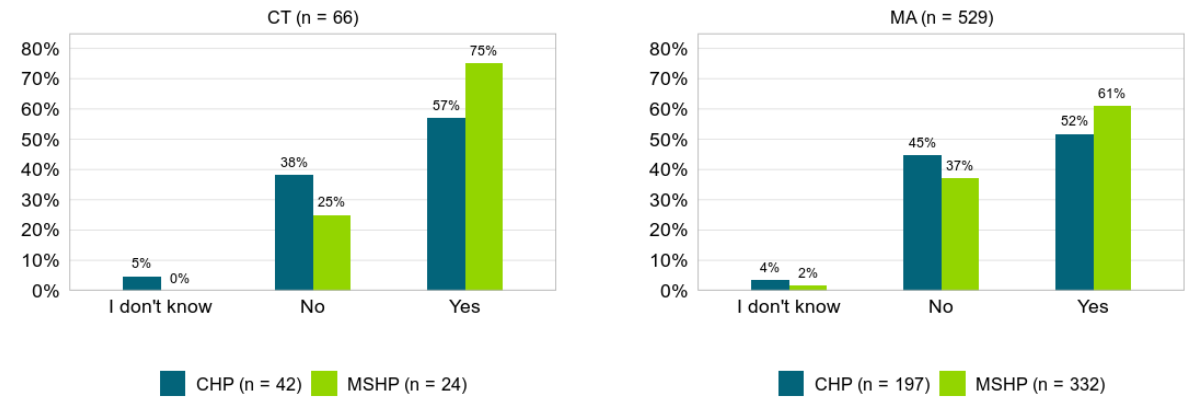
Figure 1: Weatherization Upgrade by Heat Pump Type (FD)*



**Results shown are from survey responses collected through the Wave 1 and Wave 2 survey efforts. Note, only a subset of respondents participated in the metering study.*
Source: Evaluation team analysis

A sizable portion of partial displacement, with homes built prior to 2000, installations also received home weatherization upgrades, as Figure 2 demonstrates.

Figure 2: Weatherization Upgrade by Heat Pump Type (PD)



Source: Evaluation team analysis

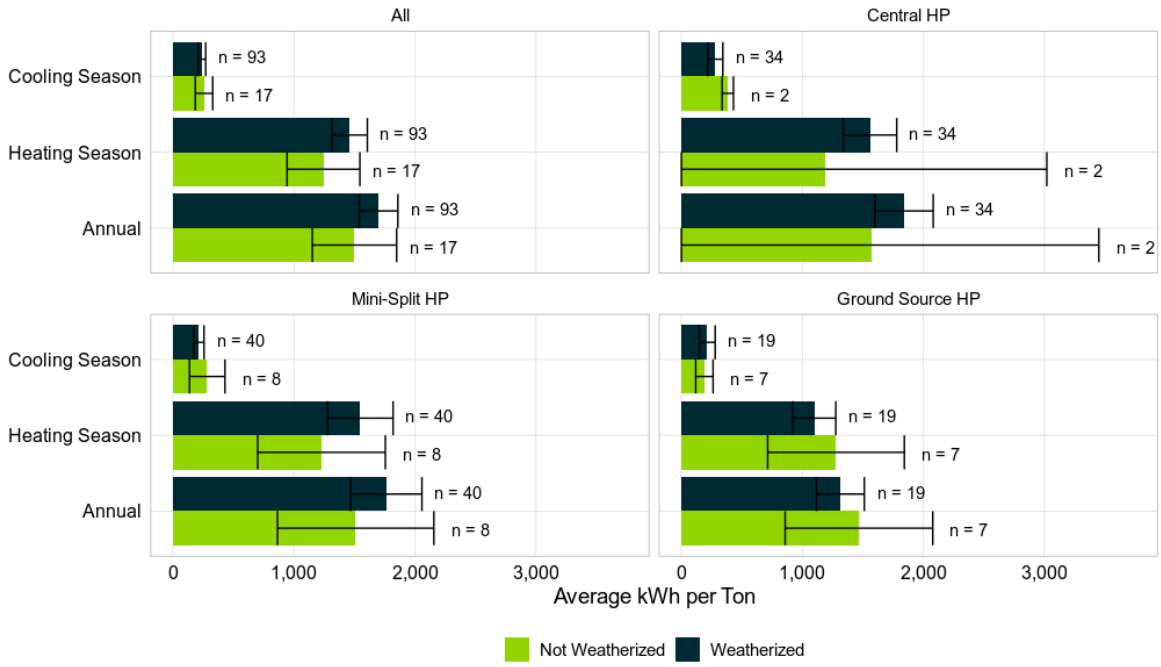
Of the 185 participating sites in the metered study, 176 sites were included in this weatherization analysis, as they had usage data collection for both heating and cooling periods. Across Massachusetts and Connecticut, 140 total sites were deemed to have met the weatherization threshold and 36 sites were deemed to be non-weatherized.

2. Average Usage for Weatherized and Non-Weatherized Sites

Using the metered results from the HPMS, total heat pump heating and cooling season usage were compared by calculating average kWh both “per ton” and “per 1,000 SF” for weatherized and non-weatherized homes. Full displacement and partial displacement sites were considered for comparative usage. The results displayed in Figure 3 and Figure 4 include full displacement weatherized and non-weatherized sites across Massachusetts and Connecticut, encompassing Central Heat Pump, Mini-Split Heat Pump, and Ground Source Heat Pump types. Figure 5 and Figure 6 include partial displacement results for the same sites and heat pump types.

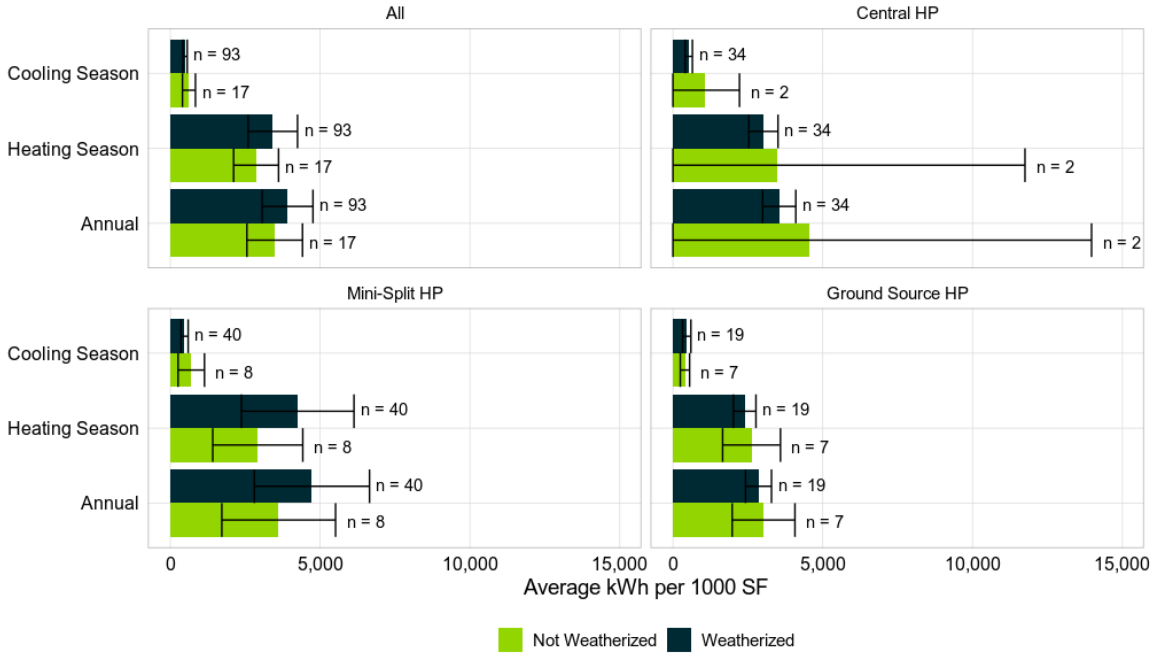
The figures below display the error bars for the heat pump usage estimates; the usage estimates overlap between non-weatherized and weatherized homes for all of the usage summaries. The usage estimates for non-weatherized homes are particularly uncertain given the low sample size of homes that have not met the threshold. There are many factors that influence heat pump usage at sites outside of the weatherization status of a home that contribute to significant variability in usage between homes. Some of these include heat pump operation patterns and occupancy patterns. Given this uncertainty, the team does not recommend using the metered usage estimates to derive overall savings estimates for home weatherization.

Figure 3: Full Displacement Heat Pump Average Usage Per Ton



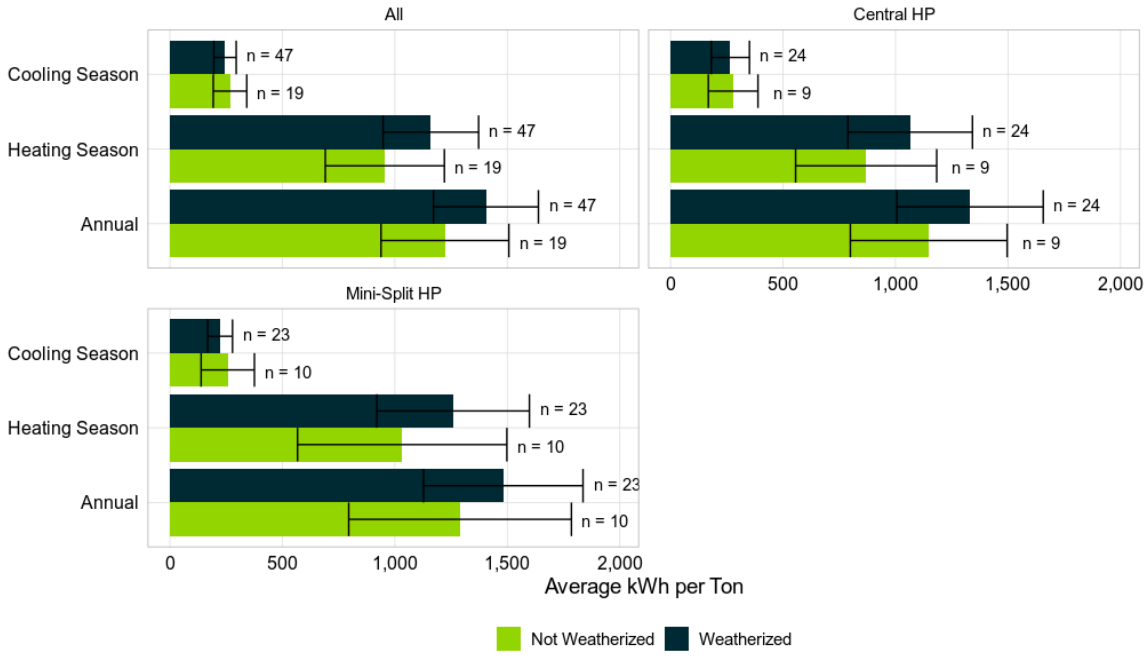
Source: Evaluation team analysis

Figure 4: Full Displacement Heat Pump Average Usage Per 1000 SF



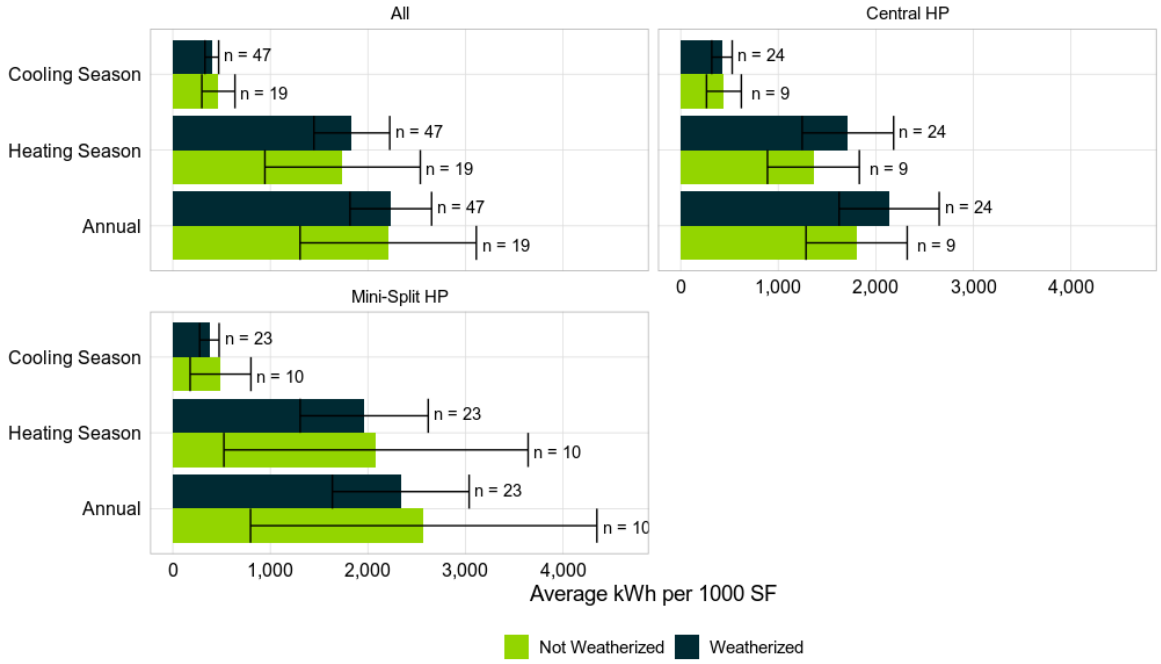
Source: Evaluation team analysis

Figure 5: Partial Displacement Heat Pump Average Usage Per Ton



Source: Evaluation team analysis

Figure 6: Partial Displacement Heat Pump Average Usage Per 1000 SF



Source: Evaluation team analysis

3. Comfort Comparison for Weatherized and Non-Weatherized Homes

In February 2024, Guidehouse fielded an End of Season survey to all participants in the Heat Pump Metering Study. The primary focus of the survey was to understand how participants use their heat pump(s) and any additional heating source(s) during the winter and cold periods. In addition to behavior, the survey also captured comfort and satisfaction. Unfortunately, the weather did not drop below 5°F in Massachusetts during the Winter of 2023-2024, so the survey was launched with questions referring to a cold period at the end of January 2024. The coldest day in the Winter of 2023-2024 had an approximate low of 15°F.

The End of Season survey received a total of 136 response, with 87 responses from full displacement sites. Of these 87 full displacement sites, 74 were identified as having met the weatherization threshold (85%) and 13 were flagged as not weatherized (15%). Guidehouse cross tabbed weatherization status for full displacement sites with the responses across a variety of comfort questions in the End of Season survey. As summarized in Table 1, Source: Evaluation team analysis

In Massachusetts, customers that receive a full displacement (whole home) rebate are currently required to meet the weatherization threshold.

Table 2, Source: Evaluation team analysis

In Massachusetts, current program requirements require that customers who receive a full displacement (whole home) rebate fully remove or disconnect their pre-existing heating system. The proportion of homes that use backup heating systems in 2024 should be lower than the proportion that indicate backup heating system usage from the 2021/2022 participants.

Table 3, and Table 4, the results of key comfort questions did not show any clear trends. Most questions had similar distributions of responses regardless of weatherization status.

Table 1. Question A4: Did you disconnect or remove your existing heat source(s) when you installed your heat pump?

Wx Status	Response	% of Respondents
Wx (n = 74)	Yes	62%
	No	38%
Not Wx (n = 13)	Yes	62%
	No	38%

Source: Evaluation team analysis

In Massachusetts, customers that receive a full displacement (whole home) rebate are currently required to meet the weatherization threshold.

Table 2. Question A8: Did you use your additional heat source(s) (other than the heat pump rebated by the Sponsors of Mass Save / Energize CT) during the most recent cold period (January 20 - 22)?

Wx Status	Response	% of Respondents
Wx (n = 33)	Yes	85%
	No	15%
Not Wx (n = 9)	Yes	56%
	No	44%

Source: Evaluation team analysis

In Massachusetts, current program requirements require that customers who receive a full displacement (whole home) rebate fully remove or disconnect their pre-existing heating system. The proportion of homes that use backup heating systems in 2024 should be lower than the proportion that indicate backup heating system usage from the 2021/2022 participants.

Table 3. Question A20: During the most recent cold period (January 20 - 22), did your home maintain its normal indoor temperature?

Wx Status	Response	% of Respondents
	Yes	89%

Wx Status	Response	% of Respondents
Wx (n = 74)	No	11%
Not Wx (n = 13)	Yes	85%
	No	15%

Source: Evaluation team analysis

Table 4. Question A29: Please rate the effectiveness of your heat pump in meeting the heating needs of the space the heat pump is responsible for keeping heated during regular winter weather and cold periods.

Wx Status	Response	Average Rating*
Wx (n = 73)	Cold Periods	4.2
	Regular Winter Weather	4.7
Not Wx (n = 13)	Cold Periods	4.2
	Regular Winter Weather	4.6

**Rating on a scale from 1 - 5, with 1 being extremely ineffective and 5 being extremely effective*

Source: Evaluation team analysis